CONSTRUCTION SITE PLANNING AND LOGISTICAL OPERATIONS

Site-Focused Management for Builders

Second Edition

edited by
Randy R. Rapp
Bradley L. Benhart

PURDUE UNIVERSITY PRESS

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North American Industry Classification System 23 is Construction. The Canadian and Mexican construction industries are comparable to that of the U.S. Federal agencies and use NAICS to classify businesses for statistical purposes. www.census.gov/eos/www/naics.

North American Datum of 1983 (NAD83) is an earth-centered datum based on the Geodetic Reference System of 1980. The size and shape of the earth was determined through measurements made by satellites and other sophisticated electronic equipment; the measurements accurately represent the earth to within two meters. www.towermaps.com/nad.htm.

Impact fees are the costs associated with public utilities and the impact that the project will have on the local services provided by the municipality. These fees can include support for sanitary sewer expansion, electrical services expansion, water services, fire and emergency services, road improvements, public school construction, and so forth. Visit www.impactfees.com to start accessing information on local impact fees broken down by state, county, and city location.

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PREFACE

This book is written to help professionals improve on-site management of construction projects. It should be valuable for aspiring and current superintendents and for upper-tier construction management or construction engineering baccalaureate students who expect to serve professionally on construction jobsites. It also offers much to owners' representatives to such projects.

The editors became convinced that this book is needed, as none currently written seems to cover the subject quite as they wished to teach it in the Building Construction Management courses they teach at Purdue University. Perhaps the book closest to it was the locally published *Construction Site Planning* written by our colleague, Dr. Fredrick "Fritz" Muehlhausen, and later modified by Randy Rapp, who successively combined to teach thousands of students about jobsite logistics in their course of that name. A complementary course synergizing students' site management knowledge was Construction Site Supervision, most recently taught by Brad Benhart. One can find multiple books that cover many of the subjects, but no one book captures enough of what we believe to be essential for good site operational and logistical management. None quite pulls together the predominant topics that we have found must be known to enhance the performance of field professionals.

The content draws from both the technical and the managerial realms. Jobsite supervision often demands integration of many competing concerns in order to plan and direct operations that simultaneously satisfy requirements imposed for schedule, budget, quality, and safety. The book is structured to first provide much of the focused technical knowledge, which informs the jobsite leadership, management, and control processes. All authors are seasoned practitioners and educators, and well versed in what they hope to convey. The book includes some international perspectives provided by James O'Connor of Technological University Dublin. Of course, many of the fundamental planning and supervisory concepts apply globally.

If the book continues to prove as helpful to field professionals and students as some readers have reported, then there are many supervisors, colleagues, clients, and students who share in whatever credit the book merits. Their generous guidance, insights, demands, and questions over the decades have added much that our observations alone would not have offered. We thank Professor Wayne Reynolds, PE, past construction management degree program director at Eastern Kentucky University, and Dr. Michael Emmer, associate professor in the construction management degree program at Roger Williams University, for their valuable critique of the first edition. Any errors in this edition remain the responsibility of the editors and authors.

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SECTION I

THE PROJECT AND SITE PREPLANNING

Many construction veterans say that a successful superintendent is like the conductor of an orchestra:

- Musicians = workers.
- Instruments = tools and equipment.
- Paper music = plans and schedule.
- Resulting music = the completed building.

Each day, the superintendent is planning the work (writing the music) and executing the plan. Without the superintendent, the workers are left to interpret the music without direction. They can make it for a short period of time but will often fall out of time without the superintendent there to keep them together.

While this entire book will explore the processes and skills required to be a great superintendent, this section will examine the preplanning that goes into a successful project from the site perspective. A great builder once said, "You make money in the office; you keep from losing it in the field." While this quote is often unpopular with superintendents, it does bring up a good point. The profitability on a construction project is typically targeted early on, during the bid or negotiations. While all the authors of this book strongly advocate the involvement of the field staff during the bid process, we recognize that this is often unrealistic. Most teams are left with the task of planning after the job has been awarded. Either way, the more preplanning a superintendent does, the more efficient the project will run.

Section I will highlight traditional basics required of planning a project coupled with new technologies that now aid a faster and more accurate plan. The foundation will be set with a look at a typical project site in perspective, including today's economic pressures. Preparing and recognizing for the unknowns will be reviewed in chapter 3—Due Diligence. Lastly, the book will utilize some of the most recent software systems and how they can save the superintendent time and money during the initial project planning.

CHAPTER 1

THE PROJECT AND SITE ENVIRONMENT

Randy R. Rapp, DMgt, PE, CCP

INTRODUCTION

The construction industry offers dynamic, challenging, and rewarding work. The special features of every building project guide and constrain contractors in their goal to fully satisfy their contracts with owner-clients while enabling contractor profitability.

Construction projects are unique, site-specific endeavors that last for definite time periods and employ material, labor, and equipment technologies unlike those in other industries. Project team members are the shareholders formally linked by interlaced contracts and agreements. They include the owner-client, the designer, the general contractor (GC) or construction manager (CM), subcontractors, vendors, craftsmen, and laborers. How the project team members are organized and interact will change with the method of project delivery and the team members' complex desires and needs. Other stakeholders, such as neighbors and interested governmental and nongovernmental special interests, impose still other opportunities and constraints. The work of building construction contractors and way they deliver value to the project owner-client are different from project activities in other industries. The challenge of managing activities on the site is a big part of what makes building construction special.

LEVELS OF MANAGEMENT

Executive or Enterprise Level

The top management team (TMT) of a company determines the strategic objectives and drives the broad decision-making and planning that keeps the firm viable. A TMT generally consists of the company's president and chief executive officer (CEO) as well as all who directly report to them. The best TMTs ingrain strategic thinking—not just strategic planning—throughout their organizations. That kind of thinking looks at enterprises and everything they do in their quest to keep the company economically competitive in the industry. The strategic time horizon of executive managers should be long, looking ahead many years. In theory, looking broadly and many years ahead makes executive management different from project-level supervision, which is the subject of this book.

Operational or General Level

The operational level bridges activity from the executive level to the project level, guiding project activities to attain strategic objectives. It is within this realm that programs of multiple related projects are developed. For example, a general contracting firm in the past might construct buildings only by traditional design-bid-build (DBB) delivery, which is a delivery system whereby an architect first completes a design for which the owner then invites bids in order to select the lowest offer among competing contractors. Later, the firm, while perhaps analyzing the market, might decide that the time is ripe to seek design-build (DB) projects, which is a delivery system whereby one legal entity performs both the design and construction phases, making the post-design contractor bidding time of DBB unnecessary. Saved project time makes DB delivery attractive. The firm then might develop a DB program of indefinite duration, lasting as long as top managers desire to pursue DB projects. Programs can last as long as the company exists or can be of shorter duration. The challenge for general or program managers is to simultaneously juggle the often-competing resource demands of multiple projects.

Project Level

A project is an endeavor to create a unique product with assigned resources and a distinct start and finish. The word *value* often crops up when discussing business ventures such as construction projects. Projects are the value-generating actions of business enterprises. The contractor's profitability commonly correlates positively with the amount of value created by the firm's portfolio or array of projects. Value for both the owner-client and the contractor is measured by the profitability they derive from the project. If the project is not expected to create value exceeding its costs for the owner-client, then the project will not happen. The contractor therefore works to sequence its activities and integrate its assets to develop this value for the owner-client.

The object of a project and any related contracts is performance that safely accomplishes the owner-client's desired work on time, within budget, and with an acceptable quality of materials and workmanship. These broad project objectives usually apply to the production of goods and services in any industry, but achieving them for building construction can be especially challenging because the varying characteristics among constructed projects makes each project unique.

Site location, building design, ongoing owner involvement during the work, productivity factors, and task scheduling all combine to differentiate construction from the work of other industries. The details differ among construction projects. Combinations of the following conditions differentiate a construction project from other industry projects:

1. With few exceptions, the total construction project process involves several organizations that design and build the project. Different organizations design and build the project, except for some projects delivered by design-build (DB), where the same company may do both. Even in the DB case, subcontractors almost always construct some of the building.
2. Within the same firms and depending on their expertise, project team professionals often change in successive projects.
3. The preponderance of direct labor applied to a project typically comprises a wide variety of formally defined trades and closely supervised trade crews.
4. The many tradespeople assigned to the work often change during the project, creating a "day labor" aspect to construction. Worker turnover during a longer project may exceed 100%.
5. Weather can be expected to regularly influence project costs and completion dates.

6. Logistical matters are critical; comparatively large weights and volumes of material must be transported to and remain in the completed project. This underlies much of the subject matter of this textbook.
7. Construction projects may be located far from any other facilities and require almost complete self-sufficiency and independent sustainment of the workforce, such as in construction camps.

Figure 1-1. Highly restricted work sites adjacent to buildings, as shown in this image from Florence, Italy, can require elaborate and costly scaffolding for access. The planning and permitting for such temporary works are seldom trivial.

VALUE CHAIN ACTIVITIES

The value chain activities of figure 1-2 include design, which might be thought to pertain more to DB project delivery. However, the responsibility for many design details on almost any building project lies with the GC, and the subcontractors' design expertise often makes them essential to installing the desired functionality into building systems. The project manager (PM) and the project superintendent commonly have the authority and responsibility to organize the detailed tasks within the value chain to best serve the client and enhance the profit margin. The superintendent's concerns are predominantly with on-site operations planning and execution. The superintendent can improve project performance by working smartly with the PM to leverage the supporting functions of the company to improve the efficiency and effectiveness of site tasks.

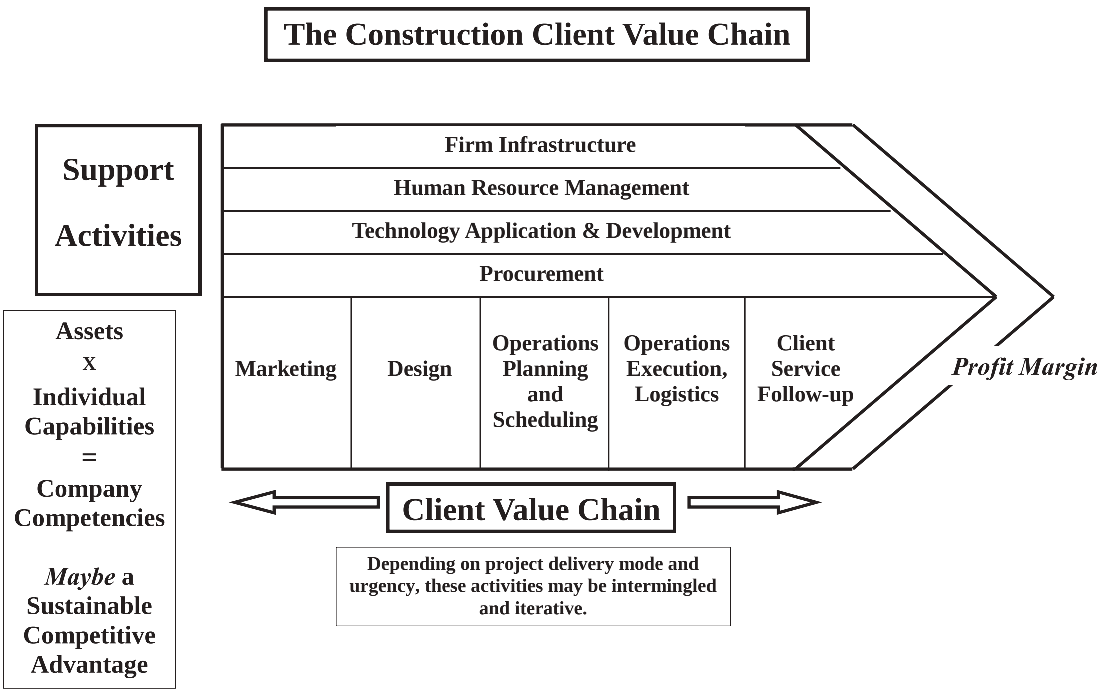

Figure 1-2. A generic construction industry value chain. Value is created for the client by project activities, but business unit or company-wide support functions can assist or hinder its creation. Activities on the jobsite affect and are affected by other people and functions of the firm. Site planning and logistics are links in the chain. Every company or business unit establishes its own value chain, which leverages its competencies in order to seek a sustainable competitive advantage and profitability (modified from Porter 1985, 37).

PROJECT SUPPORT ACTIVITIES

Skilled project professionals learn to leverage the supporting assets of their firms to ensure better performance at the construction site. A firm's support infrastructure comprises functions such as general management decision-making, finance and accounting, and legal expertise.

These all-encompassing functions tend to affect the entire firm and most, if not all, of the value-generating activities of the company or business unit. If they are well done, the advantage accrues to projects of those firms compared to those of the enterprises that are not as administratively reliable. If not, then the enterprise may struggle even to justify their selection by an owner for a project.

Achieving necessary employee motivation and skills derives in great measure from human resources (HR) management. Although it is good organizational leadership that inspires employees to perform well, good HR policies help reduce frustration and discontent, which keeps skilled employees with a firm, thereby reducing turnover and enhancing efficiency.

Technology application and development are more than formal research and development (R&D) and tend to run through many offices and departments in contracting firms. Design divisions in some firms innovatively apply technologies. Other companies might establish automated linkages among cost estimating, field reporting, and cost accounting to administrative advantage. Building information modeling (BIM) is increasingly applied by the best builders. The methods and media by which documentation is prepared and ideas are communicated also are viewed as technological applications. Beyond management and administration, technology improves construction tools and equipment on-site to lend advantage to the contractors seeking higher, safer productivity.

Procurement support comprises all the policies and procedures by which supplies, materials, installed equipment, tools, and crew equipment are purchased for projects and internal purposes. Economic business relationships with vendors are important, but the procurement function is more than the act of ordering items from a supplier. It also includes the procurement of subcontractor and consultant services for the work of a project. Sources of competitive advantage for a contracting firm might include smart communication of procurement information among those with the need to input or know order and delivery status, retaining suppliers and vendors who cater in special ways to the company's needs, and being knowledgeable of the arcane rules and requirements of procurement for federal sector building construction projects subject to the Federal Acquisition Regulation (FAR).

Having the expertise of procurement professionals in a contracting firm can reduce waste and delay from wrong materials and quantities arriving on-site at the wrong time. Planning the packaging of materials to speed their installation and improve safety adds value, too. Of course, procurement can be no better than the timeliness and accuracy of requisitions submitted for materials and equipment. Contracting firms should include other facets of logistics, which are also part of operations execution and value creation in their procurement process. Chapter 7 explains sound site logistical procedures and administration.

THE FOUR PRIMARY PROJECT PERFORMANCE DIMENSIONS

Naturally, profit margin is a primary determinant of project success, but that measure of value is sometimes not known for certain until the project closes out. However, superintendents can more carefully evaluate their ongoing performance on the basis of safety experience, schedule control, budget adherence, and quality achievement. These performance indicators are measurable and essential for adjudging how well the building is being constructed. Section IV, Leadership and Control, provides necessary guidance.

Safety

Disciplined safety practices must permeate all planning for a construction project. The construction superintendent, assisted with the observations and expert advice of a company safety manager, is probably the single most important person to ensure that safe practices are known, implemented, and maintained throughout the project. The contractor's safety record for the previous three years of work determines the company's experience modification rate (EMR), which factors into the contractor's workers' compensation costs of labor and bidding costs. Some owners refuse to offer work to contractors with poor safety experience.

The contractor's supervisors must have safety enforcement authority commensurate with their duties. Wise contractors ensure that the Occupational Safety and Health Administration (OSHA) requirements are stipulated in subcontracts, because it gives contractual authority to site managers to enforce the required safety procedures.

Safety is truly a team effort and must be internalized by all. One sloppy or uninformed person can kill crewmates. In such an environment, dangerous work conditions are identified and communicated to workers and supervisors by anyone who sees them. When workers see that site supervisors never knowingly place people in risky work conditions and immediately remove everyone from such predicaments, if they unexpectedly do occur, their confidence in the leadership of the project to deal with safety issues grows. This devoted attitude of "safety first" is reinforced even by common logistical practices such as having heavy material packages delivered near the work face so they need not be carried far or toted across vehicle paths. Purchase orders (POs) to external sources, prepared from requisitions that cannot be satisfied within the company, can require that materials be bundled in ergonomic packages that reduce physical stress. The particulars of site safety management are summarized in chapter 11.

Schedule

Of time, cost, and quality, finishing the project on time is often the most prominent aspect of performance. While any facet of project performance can lead to dissatisfaction and, in the extreme, to the perception of project failure, one often hears or reads that timely completion is the most critical measure of acceptable construction project delivery. Chapter 12 presents task planning and scheduling techniques that effective superintendents routinely apply for larger and more complex works.

Cost

Strict cost control from the earliest stages of the project is essential to project completion within budget. In 2006 the author was told that of more than 800 U.S. government projects and programs including construction and required to apply a detailed cost-schedule management system, never did a project or program improve its cost status (budgeted vs. actual) after the work was 15% complete. Not one of them had better cost performance upon completion than what was reported at that point. Expecting that substantial early cost overruns can be recouped later in a project without affecting the schedule or quality is unrealistic. Any superintendent who is not extremely attentive to all costs and planning from project inception is asking for a budget overrun. Chapter 13 explains the principles of project cost control that building construction professionals should apply.

Quality

Quality in a construction project originates predominantly from the designer. The specifications and drawings, more than any other part of the building contract, convey the quality that is intended to be built into the work. The project is a team effort, however, and without disciplined contractor adherence to the contract requirements, suitable quality cannot be achieved. The best design and most careful specifications mean little if the contractor fails in its duty to understand the project documents and establish reliable means and methods to build the requisite quality.

Quality management has two aspects: quality control (QC) and quality assurance (QA). QC is the testing and checking of the work and its materials and installations to ensure that the contract specifications are achieved. Concrete cylinder strength breaks are an example of QC work. QA "checks the checker" by reviewing the systems, expertise, and conditions that affect the reliability and validity of the QC testing. Testing apparatus calibration, current laboratory certification, and updated training of the QC staff are QA actions, among others. QA often includes random checks of QC by performing, say, 5-percent extra tests to confirm the QC data, perhaps by employing a different laboratory.

More common in government work but increasingly required by private owners, a formal program of contractor quality control (CQC) contractually delegates responsibility for checking the work of the contractor. In these cases, the owner or its agent retains the duty of providing QA by establishing and recurrently vetting the systems and procedures that enable QC tests and techniques to remain consistent and accurate. Of course, good contractors check their work anyway, regardless of whether there is a formal CQC program. Rework is very costly. Chapter 13 relates techniques by which the contractor can deliver the specified quality to the owner.

LEADERSHIP

This topic rightfully draws much attention in the construction industry. Chapter 10, "Leadership and Communication," offers much more about the subject. But the leadership environment demands attention with other overarching construction site topics, to differentiate the imperative from aspects of the management function elsewhere in this chapter. Leadership and management are different sides of the same coin by which project success is bought and profitability results. *Leadership* deals with motivating and, perhaps, even inspiring people for effectiveness. *Management* deals with coordinating processes and things for efficiency. In practical application successful supervisors satisfy both leadership and management requirements as mutually supporting and intertwined actions. Managerial decision-making is better when the professional knows leadership principles and tries to best serve others' needs.

If the professionals of the project team do not consciously consider leadership imperatives and try to act upon them, then it is less likely the project will be led well. One need not be in a supervisory position to exercise sound leadership within their assigned duties. Thinking about and observing the effect their activities have on others enables junior professionals to begin to gain the wisdom, which provides the skills for good leadership in later advanced roles. The professional's attitude of selflessness in service to the client and the project team has a great deal to do with effective leadership performance. This does not mean one is timid, only that a humble but confident attitude underlies one's behavior.

The legal and social culture in which one operates has much to do with constraining and empowering leadership. For projects run by U.S. companies, it is traditional American values that provide a sound basis for principled project leadership. Leadership principles comprise core values, ethics, and traits. Integrity and trustworthiness in their dealings with others are essential. Open and prompt communication of all aspects affecting or affected by the issue at hand is essential. Project contributors must see evenhandedness, equal opportunity, and denial of cronyism in order to trust supervisors and give their best to the team effort. The project professionals display by personal example the behavior they wish to see in all the project team.

While not the only technique that can facilitate good leadership, putting "eyes on" the many activities of the project—routinely walking around the site at unannounced times to see what transpires and who is doing what—can inform the leaders about the project team and the details of the work at hand. The latter practice enables better information flow, often by informal exchanges, and project team members realize that the leader personally knows and cares about the project and its people.

Looking in greater detail, what generally characterizes the operationally focused actions of professionals of a well-led construction project? Successful, "get it done" behavior and process skills comprise these four proven tenets from an earlier organizational operations manual (HQDA, 1993):

- **Initiative**. A bias to effective action advancing project accomplishment. Willing to take prudent risks by accepting responsibility for essential activities that erupt and for which accountability is not clearly defined. This precept does not excuse being an impulsive, "loose cannon on deck," but it might result in keeping higher authority informed of changed circumstances by advising the boss, "Unless you say no, this is what I intend to do . . ." This shows the professional is situationally aware and has a plan to keep the work moving.
- **Agility**. Quick mental flexibility leading to accurate and timely decision-making. The professional quickly addresses diverse project conditions and problems as they arise, from technical activities being performed by crews on-site to business management issues in the project office. It derives from resourcefulness and adaptability, which result from education, training, and experience in a variety of relevant disciplines and circumstances.
- **Depth**. Decision-making looking beyond immediate to long-term project requirements and actions. The manager recurrently thinks well into the future, anticipating new requirements that surface from inevitable differences between what was expected when the project was first planned and what is encountered when the work is actually done. Procrastination prescribes failure.
- **Synchronization**. All task performance well-coordinated in time and place so that no resources are wasted. A reliable planning process (Chapter 2) is critical to developing such coordination, and a useful project critical path method (CPM) network schedule (Chapter 12) helps implement the plan. Projects encounter many changes; they must be orchestrated to nevertheless yield good outcomes. Details about execution are clearly, concisely, and correctly communicated to those involved, giving them a chance to confirm or express concerns, so the project staff ensures the activities are performed when, where, and how they must be.

The benefits of studying leadership are substantial for any professional who wants to be all they might. The underlying nature of people tends not to change much over time, so what one learns of leadership does not become obsolete. The knowledge gained can be valuable for almost any kind of interactions with people, no matter their formal roles. Many books and articles, recent and historical, provide excellent information. From them one can build a mental leadership framework relating work experiences from which to draw insights, anticipate challenges, and improve. There is little excuse for construction professionals, who routinely deal with people, to not know leadership imperatives and their role for project accomplishment. Better understanding of dilemmas higher authority must contend with enables the professional to contribute better to project success.

DISCIPLINED PLANNING

"Failing to plan is planning to fail!"
—Alan Lakein, time management guru

To deliver success, a project team should plan activities or events with passion. One can find assorted "how-to" lists of planning steps. A simple one from AACE International is PDCA: **p**lan, **d**o, **c**heck, **a**djust . . . and repeat as necessary. Here is a more descriptive series of planning steps (Oglesby, 1989, p. 85):

1. **Plan the planning process**. Smaller efforts might almost be planned intuitively by experienced professionals, but the larger the operation, the greater must be the preliminary work to lay out the necessary steps and allocate the resources for a thorough, accurate, and coordinated plan. The leader of the team assigns specific tasks and deadlines to all who plan the project. The larger the building and the more self-sustaining the site, the more involved the preparation becomes. In their understandable haste to develop and execute a plan, inexperienced managers can overlook this critical step.
2. **Gather information**. Although effective bid development and cost-estimating processes focus attention on project planning, most of the detailed project planning occurs after a bid is won and before the contractor mobilizes assets to the building site on or soon after the notice to proceed (NTP) date. The NTP is a letter that formally gives permission for the contractor to commence work. That time interval is sometimes called the "slump" or "slack" period (also see chapter 12). Project team members might be concurrently involved with work on other projects, but the PM and superintendent normally devote most of their time to planning the newly contracted job in earnest. Planning always seems to involve a judicious trade-off of time and effort against the reduction of risk and uncertainty about the work. Since time is never unlimited, uncertainty and risks may pervade the operational plan. A rule of thumb: 80% of the planning time should be devoted to the 20% of the project activities offering the most opportunity to develop efficiencies or mitigate risks. Selection of those activities hinges on professional judgment, which derives from construction experience.

3. **Prepare the plan**. Staffing decisions are very important to the project plan. Preparing the subcontracting and logistical plans is necessary for any well-managed work. While the logistical plan with its procurement plan section will vary from job to job, the procurement procedures (how requisitions and other recurring matters are processed) will be standardized. The first detailed project schedule is also a critical product of the planning that is frequently required before the owner's representative issues the contractor a NTP to the site or makes the first work progress payment. Well-run projects prepare contingency plans for risky developments. Detailed plans for some operations that occur later in the project, especially if it is fast-tracked, might not be developed until the later design stages; but as more knowledge about the work is gained after some of the on-site work is completed, details must be determined and instructions communicated to the field supervisors. Well-managed companies have standard operating procedures (SOPs) that require routine activities to be done in the same way on all the work they do. This saves decision-making deliberation time so that managers can focus on the planning requirements that are different for their project. SOPs also speed the performance of common tasks because the staff performs them uniformly and repetitively. For example, logistics procedures—not the project-specific logistics plans—are often standardized in a firm.
4. **Communicate the plan to those with a need to know**. Timely and correct implementation of project plans mandates prompt oral and written communication to all with a need to know and act. Even if future requirements are not definitely known, field supervisors should be aware of reasonably possible demands. Regularly planned meetings among field supervisors and staff are a part of good communication for project planning and supervision. Chapter 9 discusses good leadership communication techniques.
5. **Evaluate the results**. It is essential for good project management that measurable objectives be established so that the planned and actual performance can be compared. This enables managers to accurately modify future actions in order to improve results. Good supervisors discipline their decisions and instructions to seek continuous improvement of performance.

Chapter 2 details techniques for operational planning. The following sections discuss some important topics that the construction project planner must address.

Geography

The geographical characteristics of a construction project site include the following:

1. **Topography**: The lay of the land can help or hinder on-site movement of materials. Terrain slopes, for example, can affect surface drainage.
2. **Accessibility, communication, and transportation**: Logistics is a major site-cost element for construction contractors. Some studies estimate that 10-percent of a typical construction project's cost is incurred for logistical operations. A long commute to the site, for example, tends to degrade worker productivity, and in some cases travel to the site may be paid by the project. Sites that are highly restricted in accessibility, movement, and storage space complicate planning and increase project cost (figure 1-1).

3. **Elevation**: Less oxygen at higher elevations can degrade the performance of people and equipment.
4. **Climate**: The general weather patterns at the site, including temperature and precipitation, can affect productivity, materials, equipment, and application techniques. The vegetation, soil types, and drainage patterns of the site may also be influenced by long-term climatic effects.
5. **Natural resources**: Project feasibility and construction methods can hinge on the proximity of necessary construction resources, such as suitable soils and water.
6. **Nearby business and residential development**: Nearby development can be a constraint or resource for the project. For example, if earthwork hauling operations are slowed by congested traffic, the project may become costlier. Conversely, having many nearby suppliers can ease logistical planning and responsiveness.
7. **Laws, regulations, and work rules**: These can vary widely from region to region. They affect administrative procedures, inspections, site overhead costs, and crew productivity.

Analysis of these matters underlies broad planning concerns. Many of the details that building professionals must know or do before working on-site, as a matter of due diligence, are reviewed in chapter 3.

Geology

Mother Nature is fickle. The geological features among construction sites can vary a great deal. The foundation and drainage conditions are very important geological characteristics that derive from the geological history of the site and occasionally are impacted by the historical activities of people. Although the specifics of every site will vary, knowledge of the area's geology can give the contractor a fair idea of the array of soil types and drainage challenges that might be confronted (Leggett & Karrow, 1983, p. 18-3).

Geological studies describe the underlying composition and structure of the earth throughout a region. They can show the contractor information that the site-specific soils report probably does not fully display. A series of two-inch diameter investigation boreholes sunk, perhaps, only at the corners and center of a large building footprint often misses some of the underlying materials or obstructions that can affect the work (see figure 1-3). As an example of subsurface risks, despite a competent site investigation, the excavation for a building foundation at an urban site uncovered asbestos containing materials (ACM), which delayed the work while the refuse was removed at added cost. Some cities maintain a public record of the past use of land, and this can offer good information about possible hazardous materials on sites.

Knowledge of the geology often enables better appreciation of the effects of construction operations on the soil and groundwater as well as their effects on the construction project. Usually, a soils report and, perhaps, a geological survey will accompany the bidding documents, which can provide the contractor the detailed information it needs for thorough planning. Owners have a duty to inform bidders of hidden ground conditions of which they are aware and which can be expected to affect the contractor's means and methods of work. Owner-provided information is often accompanied by a contractual disclaimer that the contractor should use the information at its own risk. To further distance themselves from changed conditions claims,

Figure 1-3. A geotechnical investigation rig. The investigation is usually performed before the contractor is hired, as part of owner due diligence, and the results are published in a geotechnical or soils report, which could be part of the bidding documents. Soil samples can be extracted in driven sampler tubes for analysis. The results are displayed by boring logs, which commonly give the soil classifications, soil moisture contents, and penetration test blow counts at various depths. The log also shows the groundwater level, which might fluctuate over time to affect construction operations.

owners might make the site soils or geology report available but withhold it from formal inclusion in the bidding package and contract documents. Then, a contractor's application of the reported information is more a matter of contractor responsibility than of owner endorsement, and more contractor risk attends its use. Chapter 5 examines soils, geotechnical construction, and drainage in more detail.

CONSTRUCTABILITY, LIFE-CYCLE COSTS, AND VALUE MANAGEMENT

These three factors interrelate, as shown in figure 1-4. The team members for larger building construction projects commonly look closely at the aspects of these related terms or tasks in order to secure better performance and reduced cost. The field professional should be conversant with these terms and how they might affect decision-making when managing the construction of a building. Of course, these processes are particularly significant when the project delivery mechanisms closely involve contractors in the earlier project development stages, as for CM and DB work. However, even for lump-sum work, contractors might give advice and make decisions that improve these matters.

Constructability

This concept for analyzing project planning, design, and operations has been formally addressed by the best managers of the industry, at least since the 1970s. Constructability is defined as follows: "The optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives" (CII, 2011).

In other words, the delivered project is better when the expertise of the contractor is wrapped into all the processes of the work, and that occurs only when the contractor is brought into project development when the design is being developed. This does not fully occur in the case of DBB delivery, but the principles of constructability can and should be applied during the construction phase for any project.

The Construction Industry Institute delineates 13 concepts for effective implementation of constructability (CII, 2013). Some that might be most useful are paraphrased here:

1. Contractors should be immersed in the project early, especially to develop the contracting strategy.
2. Designers must consider major, common construction methods.
3. Construction site layouts must be efficient, with materials quickly and safely available to the installing crews. In many cases, this will be the predominant means by which a superintendent contributes to constructability. Construction management students who have been tasked to analyze many building sites over the years continue to report substantial variation in the apparent efficiency of site layouts.
4. Design and procurement schedules are critical to construction.
5. Design elements should be standardized, specified, and configured to enable efficient construction, even during bad weather.
6. Designs must promote accessibility of construction and maintenance personnel, materials, and equipment.

Prefabrication, preassembly, and modularization technologies offer substantial constructability improvements. Whenever the method offers assembly-line conditions and moves activity away from the work face, productivity and quality improvements tend to result. Costs are reduced when less-skilled, lower-paid labor can install the same quality work, and fewer trades on the job make management simpler. High-rise buildings demand that the time allocation of lifting and loading equipment be very carefully planned and controlled for good construction efficiency. Constructability especially benefits or suffers from how field supervisors perform two of their responsibilities: site layout (mentioned earlier) and work methods for major crew activities.

Constructability reviews by the project team should be scheduled for all phases: planning, design, procurement, mobilization, and construction operations. For DBB delivery, the GC applies construction savvy for procurement, mobilization, and construction since it is too late in the project to substantially affect the design (Douglas et al., 2009, p. 6).

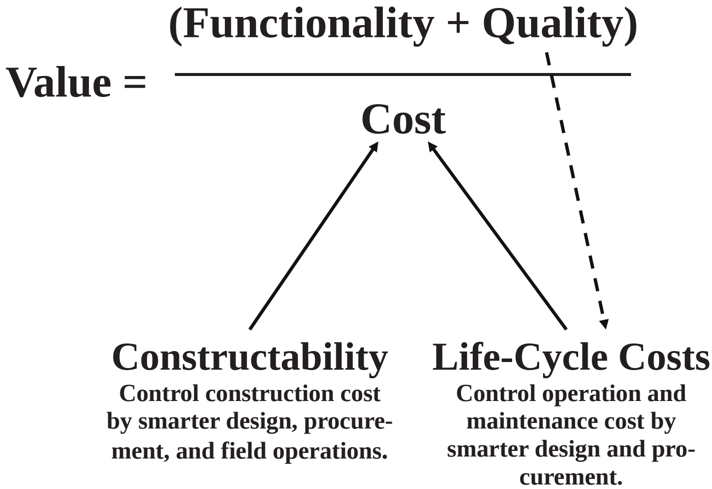

Figure 1-4. The impact of constructability and life-cycle costs (LCC) on project value. Although designers have the primary impact, field personnel can also contribute.

Life-Cycle Costs

Life-cycle costs (LCCs) extend analysis beyond only the design and construction phases of a building project. A building program LCC captures all costs incurred from conception to disposal. Ongoing operation and maintenance (O&M) and conversion of use costs also are considered in LCC analysis. Sound design allows good functionality, longer life, ease of maintenance, and reduction of utility costs and should include environmentally friendly components, but the eventual demolition of the building or reprogramming of its usage should be factored into its design as well. LCC analysis generally requires that long-term costs be compared among competing alternatives. The time-value of costs over the specified period of analysis for the building, considering the planned replacement of the building or its components, enables selection of the appropriate alternative relative to value. Of course, when it comes to the overall value embedded in the building or its features, factors other than cost also weigh on the final decision.

Value Management

Value management is the combination of value engineering (VE) and value analysis (VA). VE is the review *during the design phase* of factors that affect project value creation. VA is the review and examination of such factors *after the design phase*, when the work is being done.

Value Management =
Value Engineering (design phase) + Value Analysis (construction phase)

Value management is commonly applied to reduce costs, but this perspective alone can be myopic. The client should be informed of ways to increase value that the project will offer them, even if the proposed change does not reduce cost. Occasionally a change that slightly increases cost may be worthwhile, if the functionality or quality is improved. A change that increases the cost for one element often requires that the cost of another project element decrease to maintain the overall budget. There might be times when the improved value from a proposed change can be enough that the client will increase the project budget in order to capture the value of the proposed change. Both VE and VA should consider LCC beyond the initial design and construction costs.

The contractor can play a significant VA role. When opportunities to improve value appear, it can be the site professionals who see the prospects. Valuable modifications can sometimes be implemented during execution. The contractor should tactfully propose recommendations for changes because owners and designers can be somewhat defensive about changing design decisions they have already made. Contractual incentives sometimes pay the contractor a stipulated fraction of the achieved cost reductions from any contractor-recommended VA changes.

NEWER PROJECT TECHNOLOGIES

Building construction industry contractors that wish to remain competitive adapt to new technologies to improve work efficiencies. Some firms are more innovative than others, but companies that are unwilling or unable to stay at the technological frontier will fall behind their competitors. The competitive advantage for contractors depends on how well they integrate technology into their work management techniques in ways that are not easily replicated by competitors. At a basic level, if anyone's time is consumed entering the same data more than once for separate but related reports, then smart managers know that the recording process can be improved.

Technology should permit professionals to devote their time to improved decision-making and accuracy for effectiveness and quicker response for efficiency. Real-time status reports (e.g., actual crew costs or material deliveries) and immediate, complex, relevant spatial comparisons (e.g., clash of utilities in building designs) that would be nearly impossible for a person to create without technology can reduce risks and lead to better management. Without time-consuming meetings or formal reorganizations, information can be shared collaboratively so that all the project team members with a need-to-know can promptly communicate and solve problems. Internet-accessing tablets and digital images are replacing paper notebooks and traditional documentation for those who embrace technology.

Building project owners often lead in technology application and demand that their contractors interface with the newer technologies upon which the owners already rely. The owner's demands must be served, of course, but a critical focus for the contractor is that technological advances need to be economical as well. Besides cutting the costs of routine tasks during all project phases, whether in the home office or the project trailer, technology should improve the quality and timeliness of work on the site or reduce its cost, or maybe all three. As constructors note new technologies, their use should be innovatively applied within the project plan.

Building Information Modeling (BIM)

BIM is arguably the most important application of technology to building construction during the past decade. BIM offers more than a repository of needed information; it compels building construction project management processes to change, drawing more time and attention to preplanning that speeds construction, improves safety, and cuts waste. Incurring greater cost with more planning and analysis during preconstruction can be more than compensated by reduced installation costs. BIM draws input from the contractor, subcontractors, and vendors to virtually erect the structure in space and time, to reduce potential conflicts and organize essential documentation. Even if it is not applied by owners or designers, some contractors build their own models to enhance their management of the work. "What-if drills" examine alternative installation procedures that permit managers to rapidly choose the best construction approach.

Unmanned Aircraft Systems (UAS)

The past decade brought the proliferation of applications of unmanned aerial systems or drones to the construction job site. Assorted educational and commercial videos of their fixed wing or rotary capabilities can be observed on the web.

While the underlying flight technology is interesting in itself, the main purpose of the devices when applied to construction has been to transport appropriate sensors to locations where their visual, electromagnetic, gravitational, or other capabilities can function. Indoors or out, tracking material locations, measuring installed work, and inspecting safety and work quality are just a few of the construction applications provided. One also finds increasing use of drones to carry repair parts, tools, and materials to remote crews needing items promptly, when conditions make it economical. Depending on the task, an unmanned aerial vehicle (UAV) enables the constructor to obtain more accurate and timely data, safer and more economically than other means of observation and inspection have previously offered. The drones can be flown manually by a pilot, or they can be programmed to fly autonomously at necessary times and along useful paths.

Some of the default rules for flying a UAV include the following, which leave ample room for useful application to construction project operations (FAA, 2023, see reference website):

- The height of the flight path above ground level must be 400 feet or less.
- The weight of the drone must be 55 pounds or less.
- The flight must be continually observable, visual line-of-sight (VLOS), unless the pilot obtains a formal waiver.
- The flight path is restricted near airports, stadiums and sporting events, special use airspace, and Washington, D.C.

When used for commercial purposes, as for construction, the drone pilot must obtain a commercial license from the Federal Aviation Agency (FAA) under Part 107. Doing so is not especially costly or time-consuming, but companies wisely question the economics of devoting a full-time pilot to assorted project needs. Also, ever-improving technologies are costly to frequently upgrade, if purchasing a drone for the firm. Insurance premiums add to ownership costs. Thus, leasing drone services for purposes by which the company best applies UAS functions might be wise. There can be a tendency to try to apply novel UAS functions, when traditional processes would be better. Not every inspection or logistics challenge demands a drone. In any case, integrating UAS capabilities into the construction project plan can be smart.

PROJECT EXECUTION PLANNING

A project execution plan addresses concerns for planning construction work. The principal sections of the project execution plan template of a major construction contracting firm are summarized below (KBR, 2005).

1. **Overview and owner's strategies**: What is the owner trying to achieve? The contractor is hired to enable the owner to best achieve some of their business goals. The chance for repeat business and better-paying negotiated work improves when the owner sees that the contractor understands and responds to their needs.
2. **Project execution strategy**: What is the firm's "elevator pitch," which is a short summary highlighting how the work and the major project objectives will be achieved within resourcing and other constraints? All the project professionals assigned to the work ought to know and support this, if they are to work harmoniously and successfully. The execution strategy synchronizes resources with project objectives.
3. **Project major milestones and master schedule**: Although the details are unknown until the project scope is examined and the work is broken down, an order-of-magnitude schedule is usually developed when the contractor bids the work: start date, completion date, and major intermediate milestones, which are tentatively established from the invitation to bid (ITB) or the request for proposal (RFP) and advised by prior experience for similar project scopes.
4. **Project organization**: Which staff members will be assigned to the work? What functions will be performed? Will staff members such as procurement and safety people be shared among projects, *matrixed*, or assigned full time to a project? Where will staff members "hang their hats"—at the home office or the project trailer?
5. **Key issues and risk mitigation**: What aspects of the project are especially important for the contractor? How should the contractor reduce any risks associated with them? As an example, the progressively more intense regulatory environment of the United States creates risks for contractors that hardly existed a generation ago.
6. **Health, safety, and the environment (HSE) and security**: Besides government penalties for unsafe work practices or environmental harm, responsible leader stewardship of people and natural resources makes these concerns at least as important as any others. The possible sources of requirements for contractors are many. For example, just one series of possible compliance issues for construction contractors, NAICS 23,[1] is listed by the U.S. Environmental Protection Agency (EPA) on their website at http://www2.epa.gov/regulatory-information-sector/construction-sector-naics-23.
7. **Project success factors**: What performance must be achieved along various dimensions in order for the project to be successful? How will performance objectively be measured in order for the contractor to readily gauge success or its lack? Project profitability is critical but is seldom sufficient for the best contractor performance.
8. **Customer satisfaction**: What should be done, and how should those requirements be accomplished to fully satisfy the client? Customer satisfaction reaches beyond contractual sufficiency. Extra attention, planning, and disciplined execution can lead to repeat business, which is more profitable for the contractor.

9. **Project controls**: Cost estimating, work scheduling, cost control, and contract modification management are common functions within the realm of project controls. Their effective implementation gives project supervisors the capability of knowing the current budget and schedule status in order to determine operational changes that should be made and accurately forecast the completion cost and date.
10. **Project quality assurance (QA) and quality control (QC)**: Although the designer is the entity that primarily determines the level of construction quality through the drawings and specifications of the project manual, the contractor is obligated to deliver work that complies with those contract documents. Are shop drawings and other submittals affecting the quality of installed work identified and scheduled? What systemic checks will assure that the project specifications are achieved?
11. **Design**: Design might not be of the same level of concern to contractors for DBB work as it would be when the work is performed under DB contracts. However, the fast-tracking of projects, the contractor fabrication of installed components, and the increased demand placed on contractors and their subcontractors to detail the architect's contract drawings all compel contractors to be smarter about design processes and controls. Contractor familiarity with design principles aids communication with architects and engineers.
12. **Subcontracting and procurement plan**: "Buying out" the job refers to submitting purchase orders and writing subcontracts to obtain the labor, materials, and equipment that the GC does not already have and which are necessary to construct the building. A project that is judiciously "bought out" ensures that costs and schedule are suitably controlled and that only reliable subcontractors and vendors join the project team.
13. **Project administration and document management**: The complex, litigious, and regulated circumstances surrounding modern building construction in the United States makes thorough, timely, and accurate documentation preparation and distribution essential. Although almost all of this can be accomplished digitally, paper remains a default mode of communication for many who work in the construction industry.
14. **Project closeout**: In a practical and wise sense, planning for project closeout starts well before the final stages of the work—especially during the "slump" or "slack" period between contract award and mobilization onto the site, and even during the bidding phase. The contractor's team examines the closeout requirements associated with the project to help determine the schedule and general requirement costs incurred to close out the job, which sometimes affects the bid price. Among the many other aspects of the work that the superintendent analyzes in order to contribute to an accurate bid, closeout matters such as commissioning and special documentation packages should addressed. Even if these processes are routine or subcontracted, the effort devoted to them should not be haphazardly decided as their deadlines approach but considered before the bid is tendered.

Rogers found that a majority of 32 surveyed CMs believed that their firms did not "spend an appropriate amount of time and effort planning for project closeout in the early stages of each project," although the respondents thought their firms emphasized closeout (2012, p. 28). In the respondents' experience, sooner or later firms seem to devote significant attention to closeout, but they might not carefully plan closeout from the early project stages. It would appear that more planning up front could reduce closeout delays later. It follows, then, that smart managers formally schedule the closeout requirements to ensure that those tasks are accomplished earlier in the project, whenever possible, to reduce the end-of-project time demands. Scheduled tasks are seldom overlooked. See chapter 16 for a detailed discussion of this project phase.

Activity Planning

A construction project is delivered in phases, such as design, construction, and operation. The DBB contractor is predominantly concerned with construction, and building construction work is commonly divided into building systems for detailed management. The Construction Specifications Institute (CSI) UniFormat offers a useful scheme that categorizes the site work, foundation, substructure, superstructure, interior, electrical, mechanical, and other systems. The UniFormat is primarily applied to organizing the building design work, where it provides a proven configuration for conceptual estimating and major phase scheduling. It can also help organize the contractor's planning efforts.

Assorted work packages lie within each building system, and contractors apply their experience to discern specific work tasks or activities for installing each work package. Activities are the most detailed breakdown with which superintendents commonly deal. The productivity data for work performed by a contractor is usually recorded by task, and the CSI MasterFormat by which specifications are organized may offer a useful scheme for those data. Each activity is performed by one crew, using a given array of labor, tools, and construction equipment during a finite period of time to install materials and equipment or to accomplish other work. The crew's activities provide the breakdown for detailed cost estimates and work durations. The work tasks include all that must be done to erect the building fully in compliance with the contract, which must not overlap to include any work within other planned tasks. The contractor establishes the detailed project cost estimate and work schedule by combining these characteristics of each activity. The detailed cost estimate, not including the markup for general overhead and profit, normally becomes the project budget for financial control of the work.

The time after bidding and before the NTP and mobilization to the site, referred to as the "slump" period, is very limited for construction professionals assigned to a project. Although they should plan each task, a smaller fraction of the work will draw their greatest attention. They concentrate their planning on work that carries the most risk or offers the most opportunity for better cost and schedule performance than estimated for the bid. Detailed planning of work activities includes the following considerations in order for the superintendent to prepare the appropriate requisitions:

1. **Crews**. What labor skills should the crew possess? Does the layout of the work imply that the number of helpers should be increased relative to the journeymen? Should multiple crews be used to speed the work? Will project manpower be as level over time as possible?

2. **Tools and equipment**. Which specialized individual tools will be needed? What crew equipment is appropriate? If a crane is already on-site for erecting steel or other tasks, should a bucket be ordered to place floor slabs, or is it better to pump the concrete?
3. **Materials and supplies**. Materials are installed into the building, while supplies are consumed during the project. What quantities are needed, and with what specifications?

Many companies establish rigorous content and format for their activity planning documents, while others leave such procedures entirely to the judgment of the PM. Standard procedures reduce the chance of overlooking essential planning factors and speed information communication.

Logistics

Logistics is a system of people, equipment, and procedures that optimizes the delivery of materials to their location of use: the right stuff in the right amount to the right place at the right time.

> Logistics incorporates physical facilities at various locations, transportation, inventories, handling, and storage. These have been necessary functions since the beginning of time. What is new about logistics is that it is now considered to be a formalized support element (Green, 1999, p. 4).

Chapters of this book are devoted to important aspects of logistics, and success for almost any physical activity on the project site is affected in some way by logistical concerns and management. Construction materials management is especially important, and its most important aspects are explained in chapter 7. The superintendent who does not understand the significance of logistics and plan accordingly from project start may face problems later.

An earlier section emphasized the criticality of procurement activities for generating customer value. In its broadest sense, logistics comprises procurement. However, there is more to logistical operations than only procurement and materials handling (Stukhart, 1995, p. 139). A logistics plan relates the needs and constraints for the planned sequence of construction with site safety and security and the movement of labor and materials. The logistics plan should be project-specific, while logistics procedures are performed in much the same way for all projects. The plan might include (Muehlhausen, 1998):

1. Protection of adjacent property, roads, and utilities.
2. Location of construction fences, gates, and project trailers.
3. Crane locations and erection paths.
4. Locations and types of protection for pedestrians near the work.
5. Utility connections or sources.
6. Temporary storage of materials and equipment.
7. Temporary roads, staging areas, parking, and locations of temporary offices and storage trailers.

A comprehensive construction site logistical plan might also deal with hazardous materials, surface drainage, impacts on neighboring businesses, noise and vibration reduction, dust control, and restrictions on times of deliveries or waste removal. Other matters will often be addressed in the plan as well. Very large projects place a logistics manager on the construction site to ensure the plan is executed properly.

One part of a complete logistics plan is the Stormwater Pollution Prevention Plan (SWPPP). If the project both (1) disturbs at least one acre of land by clearing, excavating, or stockpiling and (2) drains any precipitation beyond its boundaries, then a National Pollutant Discharge Elimination System (NPDES) permit is required (EPA, 2004). Currently, failure to have the required permit can result in a daily fine up to $32,500. If the contractor has operational control over construction planning and execution on the site, then its duties include submitting a notice of intent (NOI) for its new pollution source 14 days before moving earth and a notice of termination (NOT) within 30 days after completion of site work. Chapter 6 further explains SWPPPs, but the reader should beware changes by the EPA.

Subcontracting

As previously explained, the contracting strategy is a major factor for good constructability. Subcontractors work on almost every commercial project, and their specialized skills are absolutely essential for modern building construction. Probably no GC in the United States employs all of the trades and specialties demanded for building projects of substantial complexity, and in many cases, it is subcontractors who bring the scarcest and most valuable technical construction skills to the site.

The subcontracting plan is an important element of the project plan. The bought-out fraction is usually most of the value of larger projects. Owners might require that the GC self-perform a significant part of the work so that the GC remains firmly committed to the project. Project subcontracts are usually firm, fixed prices. If the subcontract stipulates *pay when paid*, then the subcontractor must be paid in a reasonable time for work accepted, whether or not the GC has yet drawn a progress payment from the owner for the work. A less desirable and sometimes illegal method for compensating subcontractors, *pay if paid*, is a provision that allows the contractor to withhold payment unless and until the owner pays the contractor for the work.

Justification for subcontracting the work may involve any or all of the following (KBR, 2006):

1. Specialized work that is not within the GC's capability.
2. Inadequate resources, quantity or quality, for the projected workload.
3. Requirements to subcontract portions of the work to particular entities designated by the client, such as Minority and Women-Owned Business Enterprises (MWBE).
4. Union considerations.
5. Cost-effectiveness of subcontracting versus direct hiring.
6. Geographic location.
7. Risk sharing.

Capable subcontractors, appropriate risk sharing, and working relationships that maintain a sense of shared benefits and risks inspire the best work. Carefully coordinated subcontractor efforts to preclude interference among the trades are critical for productivity and maintaining a sense of partnership among the contractor's team. This will result in large measure from the superintendent's management and leadership skills.

Building Commissioning

Individual building system complexities and the interrelationships among the systems sometimes degrade overall building performance, especially with regard to their environmental effects on the occupants and their energy demands. As a result, a formal building commissioning protocol is sometimes included in the contract. A commissioning program moves beyond only the heating, ventilating, and air conditioning (HVAC) installation to include all the building's systems. Its requirements must be carefully considered when bidding the job. In addition to system installation, testing and training activities also should be scheduled. Documentation preparation should be planned from the project start and routinely accomplished as the work progresses to preclude hectic, last-minute preparation.

A number of common circumstances support the need for a commissioning program. There can be conflicts between building codes and contract specifications. Additionally, increasing designer and subcontractor specialization is not routinely fully integrated, and functional performance testing can be overlooked. The owner's O&M staff is often initially unprepared to keep unfamiliar systems operating within specifications. Certain provisions must be made to deliver the best combined system performance. The commissioning procedures confirm that all the installed systems meet the owner's demands and the design intent. All stakeholders communicate better about shared concerns with such a process, and, ultimately, better occupant productivity and owner value result from optimized system operations.

Construction phase actions involve coordination and preparation of record drawings, product and key operating data, systems manuals, and training programs. Recommended checklists include delivery, storage, and installation requirements. Testing records document all conditions and outcomes of the system evaluations. The commissioning team includes specialized contractors hired to perform all of the protocols, and the project superintendent is expected to schedule meetings about the commissioning process coordination. Most training events are scheduled before substantial completion (discussed in chapter 16) to ensure that the building's O&M personnel know how to keep all systems at peak performance from the moment they are accepted. Only after all of these matters are documented should systems be turned over to the owner (GSA, 2005, pp. 34–45).

Demolition and Restoration

New building construction sometimes occurs with disposal or restoration of existing structures. Demolition activities precede new construction, while restoration of existing structures might be planned concurrent with new work. Specialty contractors commonly perform that work, even if the GC reconstructs parts of demolished or restored buildings. If the contractor must coordinate with or control the specialists, then knowing their techniques and concerns might be useful. The National Demolition Association represents many of the leading specialty firms that demolish buildings safely and efficiently. Many restoration contractors are represented by the Restoration Industry Association (RIA) and the Institute for Inspection, Cleaning, and Restoration Certification (IICRC). All of these industry specialization organizations, which can be readily located on the Internet, publish some of the most pertinent and current references for their work (www.restorationindustry.org; www.iicrc.org; www.demolitionassociation.com).

Mobilization

The movement of the contractor's people and equipment to the jobsite is commonly called mobilization. The contractor must accomplish an array of initial tasks that will enable the project to begin in a timely manner and with all the necessary site resources at the ready. Project office space, utilities, permits, fencing, and site construction equipment are just a few of the many requirements for work to be managed well, and their timing and location should be determined case by case. Many companies prepare generic plans and checklists to facilitate complete and timely mobilization. Some aspects of mobilization planning are detailed in chapter 3.

Not only is planning and execution time required for these preliminary assets, but contractors must finance their costs from earlier projects or lines of credit since no progress payments have been earned yet. There can be exceptions to this rule. Some owners may establish an allowance for mobilization, whereby the owner-estimated costs are promptly reimbursed to that estimated amount upon completion of stipulated mobilization tasks. This practice helps the contractor with early cash flow, and it diminishes the tendency for contractors to front-load a cost-loaded schedule with high values to compensate for the contractor's mobilization costs. It makes for a more timely relationship between contractor costs incurred and revenues received.

CONCLUSION

Every construction project is unique even though some contractor assets and tasks associated with the work change little from project to project. The topics of this chapter present many, but not all, of the requirements that may affect site planning and logistical operations for building construction projects. Being aware of them enables the project site team to apply its assets when, where, and how they best perform the work. Later chapters will examine many of the subjects in greater detail.

QUESTIONS, PROBLEMS, AND EXERCISES

1. Prepare a list of information sources that you should consult when planning a common building project, whether before or after you have won the bid.
2. At a building construction firm where you have worked or would like to be employed, request permission to speak with a general or executive manager (someone above the project level) about the company's (1) firm infrastructure, (2) human resource management, (3) technology application and development, or (4) procurement function and how it is managed to contribute to the competitive success of the firm's projects. To what factors must the mid- or upper-level managers pay close attention in order to keep the services efficient and effective in order to best serve their projects? Write a 300–400 word summary of the interview.
3. Explain the relationship between constructability and the four primary project performance dimensions. What are the most important principles by which good building constructability can be achieved?
4. Explain the difference between a project logistics plan and logistics procedures, and give three examples of what each might include.

5. What challenges might building commissioning create for a superintendent's planning?
6. In what ways does knowledge of geology and soils assist a superintendent's planning?
7. What can a construction superintendent do to improve the constructability of a building? How can building information modeling help the superintendent in that effort?
8. What procedures should a construction superintendent implement in order to improve the work of building subcontractors?
9. Considering your past observations on a construction site or at your school, identify a situation where the person in charge was (a) effective in leading a group to accomplish a shared task and (b) ineffective in trying to do so. The leader need not be the same in both cases. What made the leader successful or not? How could either have improved their performance? In a paper of 500 words or fewer, compare and contrast the leader's traits and actions, and explain how you think the successful leader may have developed the necessary skills.

NOTE

1. North American Industry Classification System 23 is Construction. The Canadian and Mexican construction industries are comparable to that of the U.S. Federal agencies and use NAICS to classify businesses for statistical purposes. https://www.census.gov/eos/www/naics/.

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CHAPTER 2

PROJECT OPERATIONAL PLANNING

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(Parts are drawn from the author's earlier publications. Thanks to Bradley Benhart for his many recommendations improving the chapter.)

INTRODUCTION

Dwight Eisenhower cautioned that, "Plans are nothing, but planning is everything." As the leader for the June 1944 D-Day invasion, arguably one of the biggest projects in history, he must have known of what he spoke. One plans for what the process reveals and what can be learned, not just for the formal document and specific instructions that initially result. The interactive relationships among project resources and necessary activities to enable objectives to be attained are difficult to know without a reliable planning process. Even when actual circumstances of project execution differ from what is planned, one better understands the likely ramifications of the differences, of what is most critical. The project manager can prepare better and react quicker and smarter when changes must occur, as they commonly do. Moreover, every day matters: U.S. government studies years ago showed that for more than 800 of its projects and programs including many for construction, never did the cost performance, the ratio of budgeted to actual costs, improve by project end beyond its status at 15-percent complete. A project typically does not recover, if poor planning leads to difficulties at the start. Execution matters greatly from the moment of mobilization, so effective prior planning is imperative.

THE PLANNING ENVIRONMENT

Recall Alan Lakein's caution in Chapter 1 that failing to plan is planning to fail. Some managers think planning is not very useful, since it takes time, and at least some changes from original plans almost always result. This misses the point. Changes are routinely expected in almost any operations, but thorough prior planning enables project professionals to understand possible impacts of those changes more quickly and thoroughly, so that reaction to the changes is more appropriate and swifter. Readers also learned in Chapter 1 that constructability is especially improved by careful site logistical layout and optimal selection of major crew activities, as well as by a coordinated sequence for lifting loads to height in tall projects—all of which mandate careful planning. Investment in extra planning, an indirect cost, can reap savings later in much-reduced crew direct costs for installing the work. Investigation decades ago showed a financial return on planning from 4:1 to 8:1, where direct work cost savings from preventing crew errors or improving their productivity far exceeded the added costs of more early project planning (Oglesby, 1989). More recently, the early project planning compelled by BIM offers similar benefit. Additionally, for movement to remote, logistically restricted regions, inadequate planning will almost certainly result in delayed work or outright failure. Yet more challenging, international construction demands all the planning of similar domestic projects but with an extra layer of complexity.

Even seasoned professionals sometimes have a jaded view of the planning function. A university construction course may be titled “Planning and Scheduling,” leading some to think that planning is only for job site operations, perhaps with a few critical procurement actions also scheduled for good measure. This view is too limited for necessary project planning. Some of the greatest challenges to the PM can come from project support actions that fail to happen in a timely manner. Planning that underlies a network activity schedule is very important, and project professionals rightfully key on those efforts. However, the overall operational plan for the project extends beyond what happens at the workface. Background activity, such as a special concern of the owner, can be taken for granted or assumed to happen “as it always does.” It also demands specific attention to ensure success.

Project planning includes contingency plans for undesirable but possible events. Not every possibility can be addressed, but the PM should identify those offering the greatest risk. One may think of risk as the product of an undesired event’s potential cost to the project, times its probability of occurrence. However, everyone views risk from their personal perspective, with some being risk-averse and others risk-seeking. After determining which risks can be accepted as they are, the project manager eliminates, transfers, or mitigates those remaining. These include alternative actions, say, in the event of delayed critical materials or a labor strike. For example, risk of delayed delivery of materials might be reduced by scheduling early delivery and on-site storage of those items.

Risky Contingencies

Risk = Cost of Event if Occurs x Probability of Occurrence

Accept. Assume it will not happen, or if it does, live with it.

Mitigate. Reduce the likelihood of occurrence or its harmful effect.

Transfer. Shift responsibility for the risk to another, by contract or insurance.

Eliminate. Cease the risky activity.

Figure 2-1. Risk is in the eye of the beholder. However, the planner can apply this more objective point of view for prioritizing attention to and planning for contingencies.

Properly determining and adjusting these activities in time, place, and scope to satisfy variable project circumstances hinge mainly on the creativity of the project leadership. Many activities are similar to what has been done on earlier jobs, but most of the time, new conditions require tailored approaches. Necessary professional creativity results from capability gained by prior work experience and education, as well as the willingness to try new things. CM creativity needs as much inspiration and dedicated thought and is every bit as valuable as any architectural or engineered design. The project team plans with passion and commits to making operations as productive as possible. The underlying planning principles and techniques remain much the same from project to project, even when decisions vary. Planning the planning process is critical, just as emphasized in Chapter 1.

An effective project planning process will especially leverage time available during the slump period, that period between being awarded the project contract and beginning the work on site. The detailed project operational planning that makes for success commences in earnest after getting the contract. Of course, some operational planning is performed even as one compiles a bid or proposal. Time is of the essence. One begins work on site shortly after the owner gives the notice to proceed (NTP). That permission is granted after such documents as permits, insurance certificates, and bonding are secured; and some owners demand a detailed CPM network schedule before offering the NTP.

To plan operations, the team collaborates to conceive the best array of activities at the workface and elsewhere, which accomplishes the goals and objectives of the project. The operational master plan satisfies all requirements associated with the schedule, cost, quality, and safety of the work. The details of work for traditional design-bid-build (DBB) projects can be known well ahead of time, but some project delivery schemes, e.g., guaranteed-maximum price (GMP), leave some of the project undefined at time of bid or proposal. Estimating for a bid or proposal price is a form of planning, since one envisions future conditions and how project personnel shall accomplish tasks. Lack of all details complicates but does not preclude planning. It may make planning even more critical than in situations for which all significant aspects of the scope of work are known. The robustness of planning determines the capacity of the project team to rapidly and accurately adjust their activities to cope with progressively better-defined circumstances.

Project support activities may be some of the most challenging to plan. Some may not be rigorously scheduled in the sense of a crew activity critical path network (Chapter 12), but even if not, they must nevertheless be accomplished for project success. For example, traffic control of oversize deliveries may expand effort to municipal law enforcement and must be coordinated. Synchronizing actions of the project team to ensure desired results and not unintentionally working at odds, say, by mistakenly planning to simultaneously use the same storage or assembly areas demands attention. Every project is different, so every project plan differs.

The planning sequence is typically iterative, either within progressive steps or after multiple steps of the process have been performed. For example, as one phase of the work is planned, it might become obvious that storage requirements for some materials on a small site for a later phase of work will require an off-site warehouse or secure yard. For sites with storage limitations, timing of material delivery and sizing of equipment grow more important. Besides space and time, the operational planner thinks in terms of the people who need to know and use the plan. A decision-making maxim is, "Influence the action two levels down, and influence the thinking two levels up." That range also applies to considerations for the plan capturing such decisions. Two levels above the project might be a VP Operations, while two levels down are the work crews. In most companies, then, project planners should consider the effect of what they prescribe throughout the organizational levels from workface to executive offices. This does not, for example, mean the project planner tells the foreman and crew members how to do their jobs, only that she considers their needs in formulating project management actions. This planning view helps ensure that actions are more coherent and organizationally sensible. The reader sees why the planning process requires a comprehensive and integrated perspective.

The construction project planner should also understand where their effort should be focused. Company standard operating procedures, SOPs, are performed as published. Their routine nature normally requires no special thought, unless it is obvious something about them must be changed after coordination with higher supervisors and staff. Planning effort during bidding or proposal and from contract award to notice to proceed, NTP, is commonly time-constrained, so the team exploits that preconstruction or "slump" period to analyze and decide what matters most to reduce project risk or develop opportunity. It is wise to devote 80-percent of available effort to the most important 20-percent of the project plan. Delegation to team members is judicious. Prior experience is usually the best guide to enable integration and synthesis of project actions. Earlier decisions must be checked and, sometimes, changed. Also, as the CM devotes more time to detailed planning, the particulars of the project become well-embedded in thought. As a planner "lives the project," the mind subconsciously connects elements to enable discovery of new project relationships and requirements. There are no shortcuts to good planning of challenging construction projects, although technologies such as BIM and CPM scheduling software feed into the project plan.

SUPERINTENDENT INVOLVEMENT WHILE PLANNING

The site superintendent should be immediately involved in all planning beyond elemental and routine considerations, since more than any others, that person is directly responsible for executing work on the job site. Particularly complex or unusual tasks may require special preparation that draws extra attention from the superintendent, whose inputs are essential for overall project operations. The superintendent's sequencing of the crew activities, for example, falls within the operational planning realm as defined here. The "super's" plan of action has much to do with the choice of equipment to be employed and its duration on the site. Simply stated, effective scheduling and cost estimating can be highly problematic without a "sense check" by the superintendent. Because every project is unique in its demands, even experienced PMs assume unnecessary risk by not getting input from involved field operators before preparing a work plan.

WHAT PROJECT OPERATIONAL PLANNING IS NOT

Often when we read of planning, the writers refer to the strategic or executive level, or they might describe the work of a construction crew. The operational planning to which this chapter refers lies *between* those levels of thought and action. It is useful for clarity and reduction of complexity to think this way when planning operations.

The thought a crew foreman gives to activities is vitally important but usually not significantly different from job to job. There can be exceptions for truly unique work installations, but the application of tools, materials, and labor techniques normally fall into replicated patterns with which the foreman and crew are well familiar. Materials delivery to site storage and manning of the crew is assured by other parties. Thus, for our purposes the foreman is not considered to be a project-level planner, who looks across multiple functions and requirements to create the project plan and integrate actions of the entire project team. Except for special coordination, the project planner does not prescribe detailed foreman or crew actions, even when aware of the foreman's needs.

At the other end of the planning spectrum, strategic planning is broad and applies expected resources in time and place to achieve major company objectives for the indeterminate future. The scope of such planning comprises more than what any one project accomplishes and orchestrates all of the company's resources. Each project and the company activities supporting it fall within broader long-term action to contribute to higher level program or company purposes. Project planning is arguably more constrained.

THE PROJECT DECISION-MAKING ENVIRONMENT

(Modified from Rapp, 2002, pp. 6–8)

Construction project professionals are concerned with jobsite management, and it is at the project level that client value is generated. It seems appropriate, then, to examine project decision-making to better understand the process and discern how it can be improved. Good decision-making is obviously essential for profitable outcomes. However, even with wonderful decision-making, a subsequent lack of thorough planning and supervision for thorough execution leads to site mismanagement.

Is decision-making under uncertainty less important for project-level professionals directly generating value for clients than for executives looking further ahead in time and leading the company to best support value-making projects? It should be simpler to determine possible outcomes of decisions for the project duration than for the indeterminate future of a company. All levels of management are constrained by laws and resources, and projects may be further restricted by policies established by their organizations' executives. By limiting some options, organization policies tend to focus project decision-making on fewer permissible alternatives. That reduces the uncertainty that project professionals confront when they make decisions. Still, one wonders whether or not the PMs fully appreciate all of the uncertainty and risk with which they contend, and how their decision-making and resulting planning might be improved.

PMs can be shielded from undesirable results of their decisions by any number of chosen or chance conditions. A good project team can often make their leader's poor decisions more palatable by selective implementation, figuratively whittling "square peg" decisions enough to fit "round hole" conditions. Also, the time between making a decision and acting on it can permit circumstances to change, so that what would be a poor or mediocre decision nevertheless yields a good outcome. Changing situations can make the outcome of the decision worse, too.

Since even highly experienced PMs with a capable project team, extensive information management systems, and automated data analysis capability sometimes find themselves blindsided by unexpected events, one sees project management certainly embraces uncertainty. Mere data offer little to the PM, unless it is sorted, integrated, and synthesized to yield useful information, and the management system for information—e.g., hardware, software, communication procedures—must be tailored to how and why the project team members interact as they do. Despite possible education or training in methods of decision analysis, managers often fail to gather available information and use all tools reasonably available to analyze it objectively. Many merely "satisfice"—sacrifice an optimal decision in order to quickly satisfy the immediate need to move ahead. And it is true that a timely 70-percent solution is almost always better than a 95-percent solution that is late. Although satisficing might derive from simple indiscipline, such failure often results from the lack of time to carefully dissect and weigh alternatives. In this regard, one of the greatest services a PM can render themself is to make sure that decision-making authority is properly delegated to others with adequate information and capability, also giving them the authority to make decisions. (The responsibility for the decision remains with the PM.)

"Suffer all the decisions to come unto me" is a prescription for wasteful use of the PM's time. Those who have seldom operated extensively in an environment of trust, confidence, and open information flow may have little concept of how wonderfully effective such management can be. It requires a teaching and coaching approach to team leadership, which demands time invested in the near term to save even more time in the future. Part of a PM's effectiveness is reflected in the development of the other team members in his or her charge—a PM performance goal that well-run organizations require. The more that project decisions can be judiciously delegated to free the PM for higher-level decision-making, the more time the PM will have for deeper analysis by which to make better plans about the issues that matter most.

Even if time is not extremely critical, immediate PM acts of omission or commission may lead to suboptimal decisions. People are overly active at recognizing and basing decisions on patterns that do not really exist. Good data analysis can help remedy this tendency. Is there really a trend or not? Human intuition can be reliable—especially when making big-picture creative leaps while planning the project—but when coupled with hard data from reliable processes and good analysis, it can lead to better decisions and planning.

Follow-on reactions may come from other stakeholders affected by the decision. Mechanistic analysis alone and without consideration of the interests and motivations of others affected by the decision often leads to difficulties. The most significant decision-making fault that the author recalls in himself and others as junior PMs was a failure to appreciate reasonable courses of reaction adopted by those affected by their decisions. The responses of the other parties may be outright conflict or, at least, lackluster implementation. By considering second- and third-order outcomes, the PM can make more robust decisions, so that likely responses by other stakeholders will reinforce or, at least, not stall implementation. A small investment of time to hear and consider the views of others and act upon them can go a long way to gaining support for decisions. One may categorize decision-making as an activity separate from implementation, but the decision-making process rightfully considers how a desired outcome will be achieved. If the PM does not secure vigorous implementation of decisions, then the process is hardly more than a futile academic exercise.

Managers often fail to appreciate the value of future options created or curtailed by their decisions. "Keep your options open," is a prudent exhortation that should lead to robust decision-making in any situation. Decisiveness is a trait rightfully admired, but if a professional does not need to commit to a course of action at an earlier point in time, then delay may become a virtue. Similarly, the "optimum" alternative may not be the best, when hedging the bet and eliminating the worst downside risks will serve the project better. Can a final and better decision about a significant installed item not be delayed until the project is further developed, instead of deciding now, simply to be done with it, so as to move on to other work? Can the final dimensions of part of the facility not be designed later, to allow alternative equipment to be installed, if the currently preferred items may not be timely available or optimal in performance? Obviously, there are trade-offs to be made, but mechanistic decision-making is questionable in these circumstances.

In conjunction with an open and trusting communication environment, after-action reviews (AARs) offer an exceptional opportunity to improve future project planning. Although discussions with assorted PMs and other project professionals in a number of construction firms may be anecdotal, this author's impression is that thorough and well-orchestrated after-action reviews of project outcomes are few and far between in many organizations. AARs are not just to find out in detail why a project soured, but to focus on future improvement. In no sense should an AAR be conducted to assign blame. The well-run projects offer opportunity to understand why events turned out favorably. This improves future decision-making by spreading the seeds of success among all of a company's project teams. For some firms, it may be that defensiveness about possibly finding poor performance exceeds desire to cultivate trust and honesty leading to better decisions.

This is unfortunate, since the sharp professional judgment characteristic of competent PMs probably develops more from recognizing and correcting prior poor decision-making than from any other single mechanism. While the direction in which managers move projects to remedy earlier errors is usually correct, the magnitude of the corrections tends to be too conservative. When a change is made, it should be distinct. This will offer a chance to clearly see the effect the changed resource input has on the performance output. Better judgment about adjusting the resource for future decisions then results.

Project-level decision-making obviously has its share of challenges. There are always new circumstances to confront, and recognizing the differences between the current and earlier projects is more critical than seeing their similarities. Since some uncertainty prevails, careful judgment remains necessary. Since that is true, a project professional's experience and analytic capacity, coupled with the self-discipline to apply them skillfully, remain in high demand for project decision-making and planning.

THE OPERATIONAL PLANNING FRAMEWORK

Contractors heading to small, somewhat routine projects near their home office might not need to plan all parts of their projects as comprehensively as those who intend to work much larger jobs many hours or days from home. However, the principles and many details discussed in this chapter apply to both work situations. Even smaller projects require careful planning.

The general guide to project planning provided in Chapter 1 must be detailed, so that an efficient process can satisfy any unique project requirements (Oglesby, 1989). Individuals of the project team must be provided sufficient detail to know what they are expected to do. The plan is prepared to help the project leaders communicate necessary action, not to be an end in itself. One invests the time needed to compile a helpful plan but does not become "handcuffed" to the document's preparation.

The later outline is adapted from an operational planning format, which has been successfully used for more than a century (HQDA 1993). The operational plan does not supersede contents of the project manual or contract, but it supplements these by clarifying or emphasizing important points decided about how the work shall be done. While some may question the details, unless the CM knows of something better for the purpose, this format serves well for planning construction operations. The planner can vary the amount of detail with the stage of planning and needs of the users. Users would normally be all of the project professionals associated with executing the work, plus subcontractors and vendors, so nothing sensitive is included. The more fully the plan is completed, actions are coordinated, and the information is circulated, the smoother will be the project execution. No two people will compile identical plans for the same project. Like all communication, even when trying to be objective, the published document reflects the writer's personality and sense of what will matter most. Even if a PM does not choose to prepare a document quite like this, the underlying planning and coordination that it captures must nevertheless be accomplished and communicated for success.

Brevity is good. Redundant comments are undesirable. Repetition seldom makes anything clearer but probably increases the chance of conflicting interpretations of instructions. State the matter once—clearly, succinctly, sufficiently—and be done. Contents of company standard operating procedures, SOPs, are not restated in the project plan. The plan is for specific needs and actions of the unique project, while SOPs address what is encountered for many or all company projects. Just refer to the SOP without restating its content when occasionally essential for emphasis. Neither does the project plan restate what is obvious from the CPM network schedule. However, the plan might emphasize the critical nature of this or that crew task and any unusual coordination for its smooth execution. The plan determines exceptions, actions performed somewhat differently from what is normally done or encountered.

A reader may think that stating presumably obvious procedures and information (to them) in a plan is needless. What seems apparent to those who have been through many projects can be new, different, and unknown to some employees and subcontractors. Some construction project requirements might not be so obvious or routine. Professionals need a source of information for independent decision-making, when supervisors might not be immediately available to answer questions. Therefore, beyond the detailed procedures, effective action requires that employees remain informed of broader purposes and objectives. The operational plan document can aid that communication, and its use can be tailored to the PM's and superintendent's needs.

Responsibility and Authority

Recall that an important principle of good management is that each critical task is assigned to a specific person and given a deadline: Someone is responsible *and given enough authority* to plan, resource, and supervise each task. Parties with responsibility to execute elements of the plan must have full authority to complete their duties, or frustration erupts. Professionals work through the conflicts, but the seasoned planner anticipates and precludes such concerns by ensuring complementary authority-responsibility. Subordinate elements need time to do their planning, so the one-third, two-thirds rule is common: Project level planning consumes no more than one-third of the available planning time before handing all necessary information to subordinate elements for their planning. When the project plan is communicated, not only do team members learn what they must do; they also know if tasks otherwise expected to be theirs shall instead be done by others.

The project operational plan format:

I. Situation

- A. Related organizations.
    1. Within the company. Projects of other company sections or departments, which are not formally on the project team, but which might affect the project accomplishing its work, say, by using company assets that the project sometimes needs.
    2. Outside stakeholders. Organizations and groups affected by the project, and their concerns. These might include government agencies, community organizations, or other associations with special concerns that should be addressed. Nonstandard coordination with municipal regulatory and law enforcement offices. Subcontractors and vendors of the project are addressed within.

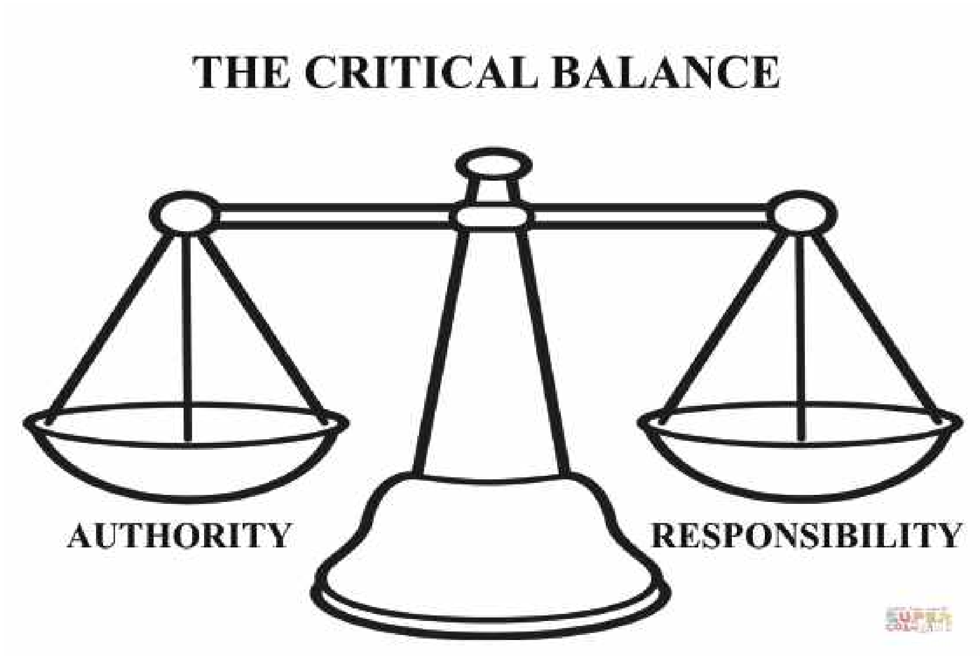

Figure 2-2. Plans must ensure anyone assigned tasks has adequate authority for the responsibilities they carry. Delegating authority to reliable subordinates nevertheless leaves responsibility for the task with the supervisor. (Open access from Paint the World.)

B. Special assets for this project, which shall be assigned to or withdrawn from the typical project organization. Contracts or pre-agreements with entities providing resources for the project are briefly stated here. Special constraints about labor skills and equipment, their numbers, and their time-phased availability or departure are stipulated.

C. Assumptions. Although there are many possibilities, the primary assumptions detail availability of resources (staff and labor, materials, equipment, subcontractors, funding). Upon publishing and implementing the plan, these assumptions are no longer needed as a separate section, since known conditions apply to the operations. If the team finds any assumptions are wrong, then it is likely the plan must be revised.

II. Overall Requirement. Who shall do the work (the contractor); what shall be done; by when; site location; the owner's purpose for the work. (Who, what, when, where, and why.) Relentlessly focus thought and action by the team on achieving this objective.

III. Execution

A. Project manager's general concept of the operations with regard to schedule, budget, quality, and safety.

1. Broad statement for entire project: an "elevator pitch" succinctly capturing special concerns and actions by which the PM intends to set the tone for the work.
2. Major requirements of special interest to this project.

B. Special detailed actions or concerns of the project team and company support professionals and subcontractors. What subordinate organizations or offices should do, but not so comprehensive or restrictive as to restrict their initiative. Requirements for company functional offices serving the project, subcontractors, and primary vendors.

C. Coordinating instructions. Emphasize actions demanding integration, for overlapping time, space, and other resources affecting multiple parties. Examples: lifting equipment; owner-installed equipment; mobilization and demobilization dates of subcontractors. Some constraints might be captured in the CPM network schedule.

IV. Administration and Logistics

A. Administration. Special project concerns about people, times and places for routine meetings. Submittal formats, frequencies, deadlines, and offices for reports. Prescribed management software.

B. Logistics. Special procurement, transportation, inspection, and storage concerns and actions. May state quantities, sources, and planned delivery dates for special supplies, materials, and equipment. Info about items that hold high risk of delay. Especially risky constraints, such as route and delivery restrictions, materials with special tolerances, security. Include special materials handling equipment (MHE) needs.

C. Safety. Special job hazards, equipment, and PPE. On-site medical and evacuation routes to hospital.

D. Primary administrative and logistical staff: names, positions or functions, contact info (telephone, email).

V. Supervision and Communications (In addition to or for modifications of any SOPs)

A. Communication media, addresses of project leaders (postal and e-mail), and office telephone and mobile numbers. Beyond internal contact, stipulate communication devices and media that serve for all organizations with whom the project team routinely needs to be in touch.

B. Planned face-to-face meeting and conference call times and locations.

C. Supervisory staff, their locations, and when routinely on site. Everyone who might need to communicate with decision-makers must know where and when they can find them.

A way of looking at the project operational plan is that if, suddenly, all who had planned the project were no longer available, then a new project team would be able to step in, read the plan, and quickly pick up on all special concerns and actions that would ensure project success. Formal preparation of a document of this type is uncommon for smaller jobs and companies, but other firms will plan and document these kinds of details—perhaps in a different format.

If the PM or superintendent want much detail for any above category, then they can have staff prepare an appendix for inclusion as an attachment to expand instructions. Whatever the project leaders think will enhance communication and effective management of the project has a place in the plan. If in doubt about the format section in which any information should be placed, the planner must simply be consistent about where the info is published; the main concern is to communicate what is critical.

Notional Operations Plan

A notional project operational plan in the recommended format follows in order that the student familiarizes with some things that such a plan might state, and how they might be stated:

I. Situation

A. Related organizations.

1. All other Acme project teams fully committed to work in the Indianapolis-Lafayette region. All projects have equal priority and attention from Acme staff.
2. All normal vendors available with typical demands for their products and services, except that Downing Brick and Block has unusually heavy demand for product until May 30, 2025.

B. Assets. Normal Acme Constructors project organization shall be provided. Pre-agreement with Buster rentals to lease materials handling equipment (MHE) and other general personally-operated equipment remains in force. Electra Contracting and Johnston Mechanical are primary subcontractors. All delivery to and availability on site shall be not less than two workdays prior to scheduled installation, so that their specifications can be verified. Union halls shall be notified of programmed labor requirements two weeks before crew mobilization to site.

C. Assumptions.

1. Full staffing available.
2. Labor market normal.
3. Equipment available.
4. Subcontractors normally committed and reasonably available.
5. Lessee's Delight and Acme Constructors fully funded.
6. Acme Construction Project Site Standard Operating Procedures (SOPs) apply, except as modified in this plan.

II. Requirement. Acme Constructors mobilizes by March 1, 2025 to deliver 40,000-sf office complex in Lafayette, IN, by September 30, 2026, to Lessee's Delight for multiple business leases.

III. Execution

A. Project manager's general concept of project operations:

1. Deliver with extra on-site observation and coordination throughout finishes and furnishings stage, aggressive attention to requirements for prompt closeout, and with floor-by-floor beneficial occupancy after freight and personnel elevators certified.
2. Requirements for subordinate offices, professionals, and subcontractors.
   a. Superintendent pays special attention to subcontractor punch lists to prevent closeout delays.
   b. MEP coordinator pays special attention to Greene Fire Defense, new subcontractor, to ensure good integration with electrical and mechanical work.
   c. Project controls include detailed closeout activities, especially building

commissioning, in schedule. Create BIM by January 31, 2025. Progress payments monthly per cost-loaded activity schedule, no schedule of values. Be cautious of cold weather construction issues in budget and schedule. Budget and schedule status reported weekly via Lessee's Delight Procore web site.

B. Details for project team elements.

1. Acme crew foremen attend weekly operations meetings in project office on last workday of week at 1:00 PM.
    a. Concrete crews.
    b. Masons.
    c. Carpenters.
2. City Earthworks. Performs all equipment excavation. Confirm SWPPP NOI with Acme Field Engineer before any disturbance.
3. Green Thumb Landscaping. Complete landscaping in remote site areas by June 30, 2025, and remainder by July 31, 2026.
4. Electra Contracting. Install site power and emergency generators as sited by superintendent within five working days after NTP.
5. Johnston Mechanical. Install all mechanical and plumbing. Coordinate with city for planned sanitary sewer installation.
6. Greene Fire Defense. Install all sprinklers and alarms as scheduled.

C. Coordinating instructions.

1. Acme Field Engineer ensures EPA NPDES NOI application to EPA 14 days before mobilization. Submit EPA NPDES NOT only when final date of demobilization is designated by superintendent.
2. Off-site vehicle washing discount obtained at Bubba's Car Wash, 0.6-mi south of site.
3. Obtain detailed specifications for owner-purchased equipment by April 30, 2025, and schedule installation with Electra and Johnston.
4. Electra, Johnston, and Greene conduct trade coordination meetings at project office upon mobilization and weekly on Tuesdays thereafter. Superintendent or MEP coordinator always in attendance.

IV. Administration and Logistics

A. Administration.

1. Daily Construction Report prepared by Superintendent that day with PM approval; copy to home office by noon next workday.
2. Subcontractor progress payments within two weeks of work inspection acceptance. Superintendent may designate field engineer to accept work, case-by-case.
3. Manifests to Acme procurement office within 36 hours. Accurate invoices processed and paid within one week of receipt.

B. Logistics.

1. Procurement. All materials and supplies purchased ASAP to lock prices. All purchase orders specify that deliveries shall be by vendor. All manhandled packages 40-lbs or less, if possible.

2. Transportation and storage. Initial materials storage at designated site laydown areas to north of building, or in subcontractor containers to be placed at west side of building. Special owner-purchased equipment to be delivered to Building #2 upon completion of second floor, tentatively end-October 2025.
3. Inspection. Field engineer responsible for reconciling manifest with delivered items.

C. Safety. Nearest medical facility is Good Samaritan Hospital (see attached route map). Upon cut to grade, compacted gravel on personnel and vehicle paths for safe travel and good trafficability. Weekly safety meetings for all site foremen conducted Mondays 7:00 AM at project office by superintendent; safety briefings about ongoing tasks daily by foremen before work begins for all personnel.

D. Administrative and logistical staff

1. One Acme procurement staffer on site throughout mobilization and every Tuesday until mid-point of project.
2. One Acme logistical staffer on site every Tuesday and Thursday until project demobilization. Perform weekly inventories of bulks and prepare control documentation; schedule and oversee final demobilization activities.

V. Supervision and Communications

A. Media and devices.

1. Normal project communication media and devices applied. Project adapts to Lessee's Delight e-Builder system.
2. Postal mail address: 209 North Fair Oaks Drive, Lafayette, IN 47904. Project office phone #765-123-4567. Individual emails already published. Project administrative technician uploads all emails to owner's Procore web site.

B. Meetings

1. Daily on-site operations meetings among Acme field staff and on-site subcontractor representatives in Acme trailer at 4:00PM.
2. Project status meetings and inspections every second Friday among PM, project controls manager, architect, and owner in Acme trailer at 9:00 AM. Meeting minutes and schedule-budget status published to eBuilder secure web site every Friday by 3:00PM.

C. Supervisory staff and their locations.

1. PM spends mornings on site.
2. Field Engineer and superintendent full-time on site.

The reader notes how adaptable to needs this format can be: enough detail without becoming unduly burdensome.

PROJECT MANAGER'S CHECKLIST

The PM will find the following planning checklist useful, especially for larger, more complicated or international projects (KBR, 2005, pp. 2–8). The list comprises some concerns for design-build (DB) and Engineer-Procure-Construct (EPC) projects. The list is broad, and some items will not be required for every project. It likely triggers ideas for still other concerns. The further the work is from home, especially if overseas, the more critical is careful planning. Information for some of the following is presented in detail in other chapters. Depending on the scope of each item that follows and how project leaders wish to assign unique tasks, the topics might be included in different parts of the planning document. Note that some of these items may require detailed planning to ensure essential actions are timely and accurate.

I. General

A. Site visit.
B. Visa and work permit requirements.
C. Other host country requirements.
D. Customs regulations and duties.
E. Travel authorization.
F. Personnel assignment conditions away from home office.
G. Taxes.
H. Royalties.
I. Client final acceptance procedures.
J. Closeout requirements.
K. Personnel, equipment, and documented emergency evacuation procedures.

II. Precontract

A. Pre-agreements or advanced contracts.
B. Record of related negotiations.
C. Insurance.
D. Bonding.
E. Retainage.
F. Penalties and bonuses.
G. Legal review of drafted contract.

III. At Award

A. Contractor's bid or proposal documents.
B. Contract (general and special conditions, technical specifications, and drawings).
C. Proposed budget.
D. Proposed schedule.
E. License and permit requirements.
F. Project financial forecast.

IV. Initiation of Work

A. Design plan, if fast-track design-build.
B. Project partnering and teambuilding.
C. Project team organization and space planning.
D. Preconstruction meeting.
E. Risk management plan.
F. Proprietary materials, classified devices and documents, and security requirements, if any.
G. Project execution plan.
H. Project controls plan.

I. Logistics and materials management plan.
J. Project quality control and assurance plan.
K. Roster of personnel and staffing plan (including planned replacement policy). Plans for years-long projects should include provisions to replace staff between one and two years on the job.[1]
L. Information technology (IT) and communication hardware plan. Among many possible items, this includes computers, office printers, copiers, and faxes, radios, as well as landline and cellular telephones. This hinges on how the PM prefers to operate, contractual requirements, and owner preferences. Details may not be known until the work begins, which shows why planning is often an iterative process.
M. Export requirements.
N. Cultural issues. Work schedules must allow for holidays celebrated by the workforce, but which those preparing the schedule do not commonly celebrate. Schedulers recognize the degraded productivity when some workers consume nothing between sunup and sundown, as they observe religious strictures. Other more subtle cultural concerns arise, as with the meaning of words and responses. If the work involves many owners or workers of a distinctly different culture, then the PM should be sure to understand the nuances in word and deed that can lead to misunderstandings and ill feelings, or the PM should depend on a staff member whose understanding of the culture is reliable.
O. Customer satisfaction and loyalty system.
P. Project health, safety, and environment (HSE) plan.
Q. Implementation of best practices.
R. Critical issues management. These can comprise any aspect of the entire project. Client sensitivities and special needs are included, since these often influence future work. Issue satisfaction and control are required; they may be on the PM's "personal critical path schedule." This refers to actions the PM must accomplish for project success, but which are inappropriate (sensitive?) to formally publish or schedule. It may result by special instructions from company supervisors or the client.
S. Procurement plan.
T. Subcontracting plan.
U. Crew equipment repair parts plan.
V. Construction plan.
W. Regulatory and permitting plan.
X. Project performance objectives for performance evaluation.
Y. Final project report templates.

V. Drawings and Data

A. Professional architect or engineer sealing requirements.
B. Distribution of vendor documents.
C. Distribution schedule of contractor documents.
D. Equipment list.
E. Design specifications.
F. Operating and maintenance manuals.
G. Governmental laws, rules and regulations.
H. Installed item spare parts list.

I. Mechanical equipment service schedule.
J. Customer approval definition and schedule.

VI. Project Control

A. Initial approved cost.
B. Customer change notices.
C. Planning check estimate.
D. Cost deviation estimate-to-actual.
E. Estimate-to-complete.
F. Customer services.
G. WBS codes and schedule.
H. Project mobilization.
I. Level I and II conceptual project schedules. The Level II is more detailed and “rolls up” or consolidates into the Level I version. Level I comprises only major project dates and milestones.
J. Level III detailed project schedule. This offers detail enough to supervise the work and “rolls up” into the Level II schedule. It might include these schedules and more in its overall scheme: factory acceptance test (FAT); commissioning and startup; subcontracting; phased ordering of bulk materials; and phased turnover.

VII. Internal and Client Meetings

A. Project award, both internal and with client.
B. Project execution strategy.
C. Controls estimate.
D. Project quality and technical review.
E. Project schedule and estimate review.
F. Monthly project review with company management.
G. Monthly progress with customer.
H. Design progress.
I. Project health, safety, and environment.
J. Procurement review.
K. Mechanical-electrical review.
L. Subcontract coordination.
M. Construction mobilization.

VIII. Reports

The following might be required by the client or desired by the PM for internal management. People tend to do consistently well only those things the boss checks. Yet compilation of reports takes time and ultimately costs the owner. The reports and their content must be judiciously determined. Mostly, they should capture trends to enable timely action for improved project performance. Any required documentation that appears to be required by rote and whose information seems hardly ever used should be cancelled.

A. Design status.
B. Project health, safety, and environment (HSE) review.
C. Submittal log.

D. Daily production.
E. Weekly construction.
F. Monthly project financials to customer.
G. Monthly project progress to customer.
H. Monthly project internal review to top managers.
I. Monthly activity and status.
J. Quarterly activity and status.
K. Procurement status.
L. Material delivery and expediting status.
M. Construction status.
N. Quality audit.
O. Project closeout.
P. Labor and equipment work-hours.

IX. Financial

These are more common for large projects, but the underlying financials for the project are strong project status indicators for top managers. PMs pay close attention to actions and decisions that affect these. Cash flow is the life blood of a project.

A. Local purchases can be necessary. Besides credit and debit cards, sufficient currency on hand is sometimes essential. The currency must be acceptable to the vendor, and denominations must be practical. Bringing much extra cash adds to security and accounting concerns, but the risks may be necessary.
B. Another critical aspect of planning is cash value added (CVA) by project cash flows. CVA is the difference between cash inflows and outflows. Projects initially consume more cash than they bring in, especially when substantial amounts of construction materials and installed equipment are procured. The PM ensures there is access to enough cash, and that it can be obtained when needed for payments. The fact that one expects the project to generate more cash inflow than cash outflow by project completion is not sufficient for planning.
C. Customer billing administrative procedures should be detailed in contractual general requirements. The general conditions or supplementary general conditions stipulate underlying conditions for payment. Billing and payment details must be clearly established at the first meeting among the project parties, and the terms should be written and signed by promisors.
D. Billings to customer.
E. Business forecast.
F. Contingency management.
G. Bank guarantees include but are not limited to any project bonds. They are risk reduction mechanisms, whereby a financial institution secures some promised action for another party against nonperformance or nonpayment by the applicant. Other parties may require such guarantees to enter into agreements with the bond applicant. The bank does not transfer funds unless the applicant fails to do what it promised another party. The applicant commonly must establish an account at the guaranteeing bank. That bank, in turn, may work through another bank to guarantee the funds.

H. Letters of credit are common for international work and ensure certain payment for goods or services. The applicant arranges the irrevocable credit through an issuing bank, which then works through an advising bank in the second nation to deliver the letter to the beneficiary. The beneficiary is commonly an exporter and, along with the financial institutions, must decide to cancel the letter if the deal does not go through.

X. Closeout

A common admonition is to prepare for closeout of the project from the earliest stages of planning (see Chapter 16), even during the proposal or bidding phase. Intermediate activities and deadlines, say, for building commissioning, should be geared to efficient project closeout.

A. Substantial completion.
B. Performance tests and system commissioning, if unable to be performed sooner.
C. Customer final acceptance.
D. Customer satisfaction survey.
E. Closeout requirements.
F. Demobilization plan.
G. Warranties.
H. Personnel performance evaluations.
I. Final project report including Lessons Learned and Best Practices.
J. Claims.
K. Remaining risks and liabilities.

The preceding list is extensive but hardly exhaustive. Still, it provides a starting point for a closer look at items that should perhaps be synchronized, amplified, clarified, and coordinated in the project operations plan, but which are not immediately obvious.

CONCLUSION

Deliberate and detailed planning is a function that professionals can perform well, if only they commit to doing so. Construction project leaders can plan with passion to distinctly improve project outcomes. The advent of artificial intelligence (AI) included in software for decision-making processes may soon prove to be a routinely useful tool tailored for construction planners. Meanwhile, the planning process remains more traditional, and the recommendations and cautions provided in this chapter continue to be useful, even as they will offer a sense-check and refinement of future AI solutions.

QUESTIONS, PROBLEMS, AND EXERCISES

1. You are a recently hired project engineer for a building construction GC in your region. The PM and superintendent want to see what you know and can do, so the PM tells you to draft the project operational plan in the format recommended in this chapter. You recall that the project operational plan:
    - Informs the project team of critical concerns, events, and procedures that will need their attention to make the project successful.

- Focuses on actions that pertain to whatever the project team should uniquely plan to do for this project.
- Does not restate what would likely be in company standard operating procedures (SOPs).
- Does not state what is already shown in the project CPM schedule. If work of different crews might clash, or if a crew activity or a trade requires special attention to its performance which is not obvious from the published schedule, then the action required for the installation activity might be stated in the plan.

This exercise encourages students to think about construction project planning in a comprehensive way and effectively communicate special actions supporting the project requirement—the construction of the building to meet or exceed all contractual requirements. The ability to mentally picture likely situations and their activities is essential for a planner or manager.

The instructor might provide project documents, but if not, the student is free to think of projects or combinations of projects on which they have worked, or which they find on line. Then, imagine likely project operational needs to address in the notional project plan. **The submission will capture imaginary concerns, tasks, and underlying requirements that are unique to the project, *as the student envisions it*.** That will be guided by any project information given the student and drawn from their own construction experiences and previous education—what they know and can logically visualize about the project. The exercise is deliberately open-ended to simulate the common planning environment and develop student capacity to picture typical project conditions. The instructor may assign the plan to a team of students.

2. State five rules you would always abide by or requirements you would always include when preparing a project operations plan.
3. Explain in your words what is meant by project operational planning, as opposed to strategic or crew activity planning.
4. Referring to #1, above, review the Project Manager's checklist and select those items which certainly apply to your project.

NOTE

1. Projects of long duration at remote locations must include regular rest and recuperation (R&R) leaves for all staff. The project time before replacement depends on the availability of others with needed skills and the manpower that the job requires. This helps keep people from becoming stale and thinking that their knowledge of the work makes them irreplaceable. Further, it helps reduce cronyism and the risk of collusion to report falsely or commit crimes. Replacements should be staggered, so that the project never loses too many people simultaneously. The most critical managers might not be replaced, but they should have assistants or deputies who can keep the work on track while the supervisor takes vacation or gets called away. The PM will want staff who exhibit personality traits conducive to the demands of the work, especially if remote. There is little room for an undisciplined employee or a professional with limited adaptability.]

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CHAPTER 3

DUE DILIGENCE

Robert F. Cox, PhD

INTRODUCTION

Proper preparation of site management requires a good understanding of the due diligence necessary to protect a construction project, its workforce, its physical property, and the adjacent property. This chapter will provide information on various aspects of site due diligence that can have a direct impact on the construction process.

Many site due diligence tasks are undertaken long before the construction project designs are completed (zoning, location, demographics, applicable codes, etc.). All of them have a direct influence on site use and site feasibility from the perspectives of the developer or owner and are vital to the overall success of the finished project with respect to potential uses, markets, lease rates, occupancy levels, capitalization rates, and other parameters surrounding the financial well-being of a completed project.

Knowing that site location and design are typically finalized long before any construction operations begin, the focus of this chapter will be on those areas of due diligence that can influence the successful execution of a construction project. When project management fully understands the construction site and its surrounding properties, they will be prepared to address and mitigate any attributes that can affect construction project execution. The more comprehensive the site due diligence process is by the contractor, the greater the potential for the successful completion of the project.

DUE DILIGENCE AND THE PROJECT ESTIMATING PHASE

How Cost Estimates Are Impacted Through Proper Site Due Diligence

Every construction project is a truly unique, one-of-a-kind project. This statement is true in all aspects of the construction profession no matter how many times similar structures are repeated, such as houses, pharmacies, restaurants, coffee shops, retail stores, and so forth. The actual building product may be the same design across town, but where it is built makes it different. The location and site conditions are what ensure the fact that every construction project is unique.

Capturing the unique nature of the site impacts on the construction cost estimate is critical to the overall project's successful completion. Given the numerous range of unique aspects for any location, the intent here is to provide a summary of some typically identified site-specific characteristics, which are shown in figure 3-1. Each of the items listed are described further in the following sections as to how they can be incorporated into the management and execution of a construction project through proper due diligence.

Estimate Item	**Potential Cost Impacts**	**Sources of Information**
Soil conditions	Cost of earthwork operations • undercut conditions • expansive materials • compaction (bearing capacity) • suitable for fill • water table depth • special stabilization requirements • dust control	Geotechnical report
Sediment control measures	Soil stabilization efforts Sediment control maintenance	Site plan, specifications, Site visit, geotechnical report, EPA report
Utilities	Location of tie-in Logistics of project execution Site utilization plan Crane and hoist selection Impact fees Tap fees	Site plan Site plan Site visit Local utility providers
Existing structures	Demolition/disposal Hazardous material handling Use as a temporary office Use as secured storage	Site plan Site visit
Site access • ingress/egress • parking • deliveries	Crane selection Material handling Delivery of materials Material security/storage Construction means and methods	Site plan Site visit Site utilization plan
Adjacent properties • hospitals • schools • airports • railway • highway • military operations • government offices	Work hour restrictions Delivery restrictions Noise limitations Workforce screening Height restrictions Site limits/boundaries Easements	Site plan Site visit
Special site conditions • EPA/wetlands • Environmental impacts • Protected species (animals and plants) • Corps of Engineers Section 404 permit • Clean Water Act	Fencing/barricades Equipment selection Plant protection Sediment control measures	Site plan Site visit Environmental impact statement

Figure 3-1. Site due diligence impacts on estimates and sources of information.

Accurate and complete estimating of construction project costs is directly dependent upon:

1. Site conditions
2. Identification of constraints and other parameters
3. Selections of means and methods for construction
4. Special construction techniques required
5. Proper levels of allowances or contingencies

PREPARING TO MANAGE THE CONSTRUCTION PROJECT

Review of the Project Site Plans

The most common practice a construction professional undertakes in order to gain an understanding of the project's site conditions is a detailed review of the construction documents. Reviewing the site plans provides the construction team with specific information that has direct impacts on the project execution plan. As the design documents and related engineering reports are reviewed, it is recommended that a standard procedure be followed that will create an inventory of site-specific issues that will be addressed in the overall completion of the construction project.

The first item to determine in the site plan review is the *construction limits*. The construction limits comprise the outermost boundary area within the actual property lines that can be disturbed during the construction operations. Often, these limits even exclude *any* activities, storage of material, parking of equipment, staging, and so forth. The construction limits should not be confused with *setbacks or easements*. *Setbacks* are the local municipal code requirements for the minimum distances that construction improvements must be situated from the property lines (or highways, nature preserves, bodies of water, etc.). These setback dimensions are taken into design consideration when making the final decisions on building locations, parking lots, and site utilities. *Easements* are those lands that are designated for ingress and egress by such parties as adjacent property owners, public utilities, public schools, emergency services, highway, and navigable waterways.

All of these items place limitations on the amount of land area in which the project is to be completed. The smaller the site, the more difficult it is to efficiently handle all the materials and equipment needed in the construction process. It is important to understand that breaching easements, setbacks, or established construction limits can result in severe fines, loss of permits, and even shutting down the entire construction operation.

It is also wise to identify the adjacent property uses and operations that may have an impact on your location. The safety of the general public must be taken into consideration during the detailed site plan review in order to determine all necessary actions that must be undertaken by the construction management team to ensure the safety and welfare of all persons, property, and equipment that passes through or by the construction site. The site plan review will identify those locations where it will be necessary for such standard construction practices as perimeter fencing and pedestrian barricades. Later in this chapter, we will discuss adjacent property impacts in more detail.

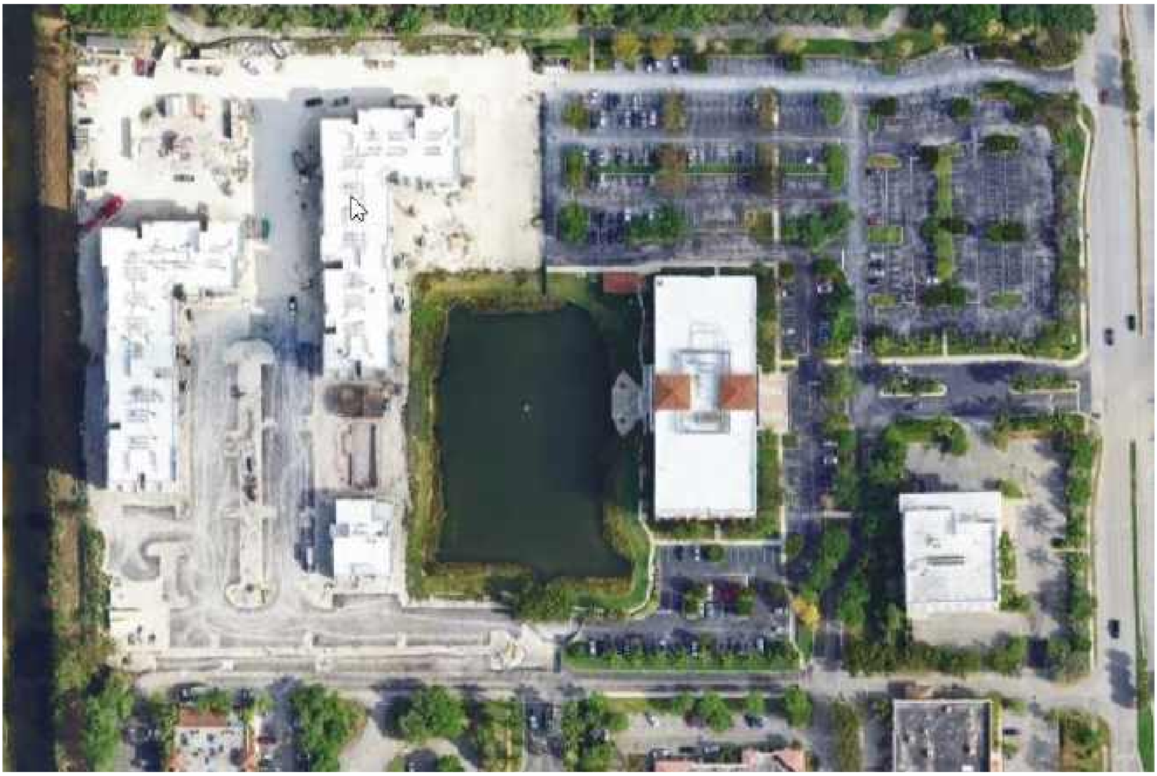


Figure 3-2. Site plan of Liberty Center project, provided by Current Builders.

During the site plan review, a location for the jobsite trailer and employee parking must be identified. The ideal location for the trailer and parking is in an area that is accessible and provides a vantage point from where site supervision personnel can monitor the movement of subcontractors and suppliers in and out of the site. These locations also should be established in areas on the site where there are minimal earthwork operations and utility installations so that the location is not disturbed once it is located.

The site plan in figure 3-2 shows the building location and the surrounding parking layout, roadways, future out-parcels, and the project phasing plans. On the left side of the site plan, you will notice that the parking lot is shown as a faded section with a dark hashed line through the middle of the plan. This demarcation indicates that the current project will include only the site improvements shown on the right side of the plan. For the sake of comparison, figure 3-3 is an aerial photograph of the site prior to any construction operations. An aerial photo can be an effective communications tool in conjunction with the site plan. In addition, the aerial photo should provide the contractor with a better benchmark with respect to access to the jobsite and the potential impacts on adjacent properties. Adjacent property issues are discussed in detail later in this chapter.

Site plans provide the topographical characteristics of a site that should be considered when developing the construction methods for stabilization and erosion/sediment control measures as a part of the ongoing project activities. Steep inclines on the project can provide a major challenge with erosion control and create a maintenance nightmare for the perimeter sediment control required to be in place throughout the construction of the project. Steep inclines

Figure 3-3. Aerial photo of Liberty Center project location. Source: Google Earth.

also provide safety challenges for equipment use and material handling, which can impact the construction methods and overall project costs. For more details on site safety, please refer to chapter 11 of this textbook.

Review of Geotechnical Reports

Geotechnical engineering reports are typically provided by the owner as part of the construction contract documents. These reports provide contractors with vital information about the subsurface conditions. Each soil-boring sample taken on a site adds costs, but each boring also adds more clarity to the virtually unknown conditions below the surface. It is highly recommended to encourage project owners to conduct extra borings to eliminate uncertainties and help reduce the overall risk contingencies taken by subcontractors on earthwork and subsurface utilities bids. A cost-benefit analysis could be done to prove the effectiveness of reducing large amounts of uncertainty and high risk when working on larger sites without an adequate number of soil borings.

The geotechnical report provides information on the various soil classifications and the depth at which each soil stratum is found. The types of soil encountered will have a major impact on the earthwork and excavation operations for the project. Soil classifications affect the shrink and swell conditions of the soil, which directly relate to choosing compaction techniques and its suitability for fill operations. Utilizing the geotechnical report in conjunction with the site plan and mapping the variation of soil types on the site plan can be completed, and effective cut-and-fill operations can be established.

The depth of bedrock and the water table location can have a major negative impact on foundation and underground utility installation. Using the soil borings, it can be determined in advance of construction activities whether or not rock removal or dewatering systems (well points) will be required, and potential methods can be explored prior to commencing work. This is especially true for deep excavation along utility lines or for below-grade structural components such as piles. Water table references and depths are further detailed in the next section.

Water Tables: USGS Groundwater Data

The U.S. Geological Survey National Groundwater Monitoring Network provides access to current water table conditions at selected locations at https://cida.usgs.gov/ngwmn/index.jsp. The USGS database is searchable, and the graphical reports provided are based on the most recent data from on-site automated recording equipment. Measurements are commonly recorded at fixed intervals and transmitted to the USGS on a regular basis.

The USGS groundwater database consists of more than 850,000 records of wells, springs, test holes, tunnels, drains, and excavations in the United States. The available site descriptive information includes well location information such as latitude and longitude, well depth, and aquifer.

Figure 3-5 shows the smaller scaled location near Gainesville, Florida. By clicking on the map the website zooms in to find relevant wells close to our site proximity. Then further details are provided after selecting any of the relevant well locations identified on the map in figure 3-5. After selecting the well location, the website provides the information shown in figure 3-6, which is a summary of the data from May 2014 to June of 2023, in Gilchrist County, Florida. The numbers along the top indicate the well being monitored. The most useful information for the contractor is the depth of the water table below land as indicated on the left axis of the chart. Figure 3-6 shows that the water table depth at this location in Gilchrist County has increased slightly, from approximately 44.00 feet below the surface in April of 2022 to 47.26 feet in June 2023, representing a delta of only 3.00 feet over the that 14-month period.

Figure 3-4. U.S. Geological Survey National Groundwater Monitoring Network (2024).

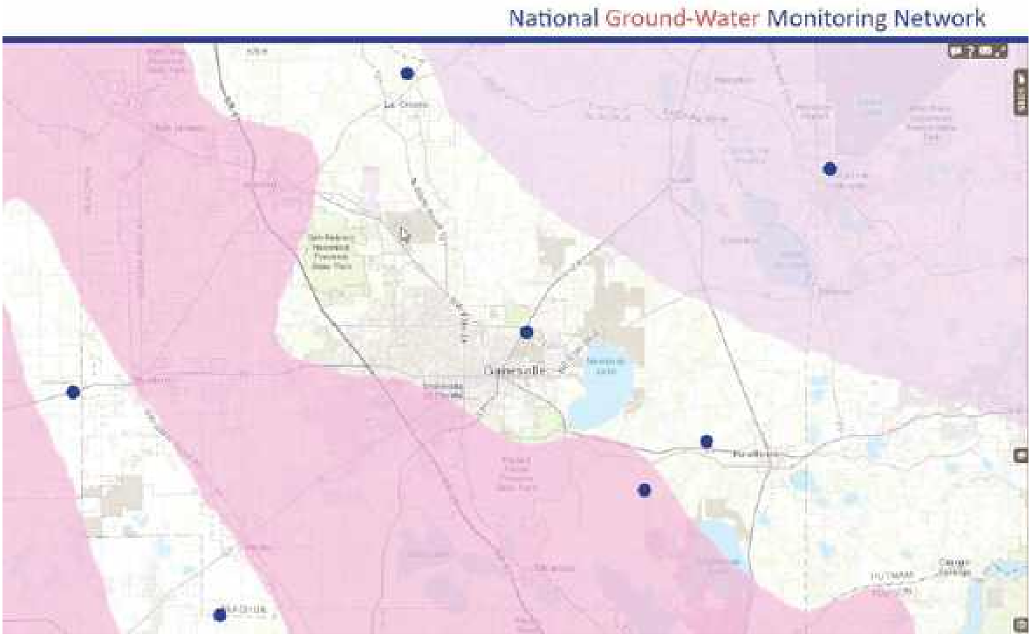


Figure 3-5. U.S. Geological Survey National Groundwater Monitoring Network (2024).

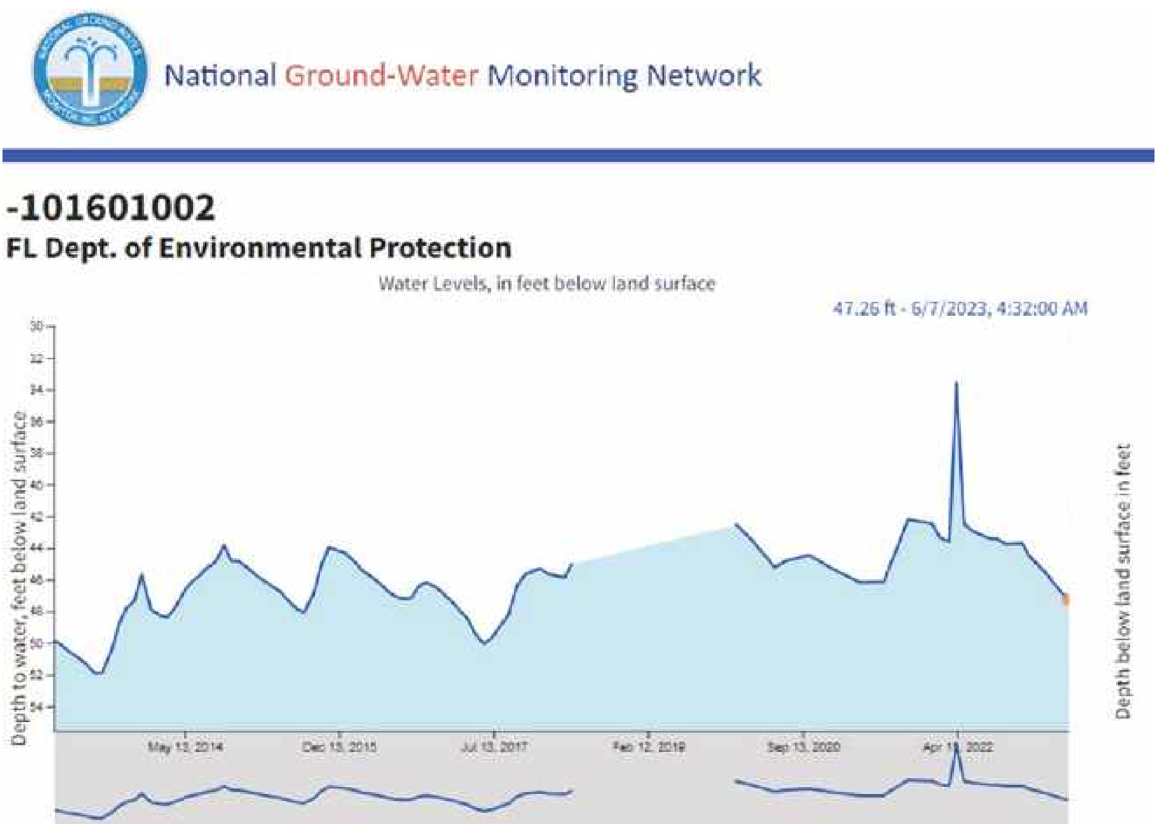


Figure 3-6. Water table information in Gilchrist County, Florida (USGS, 2024).

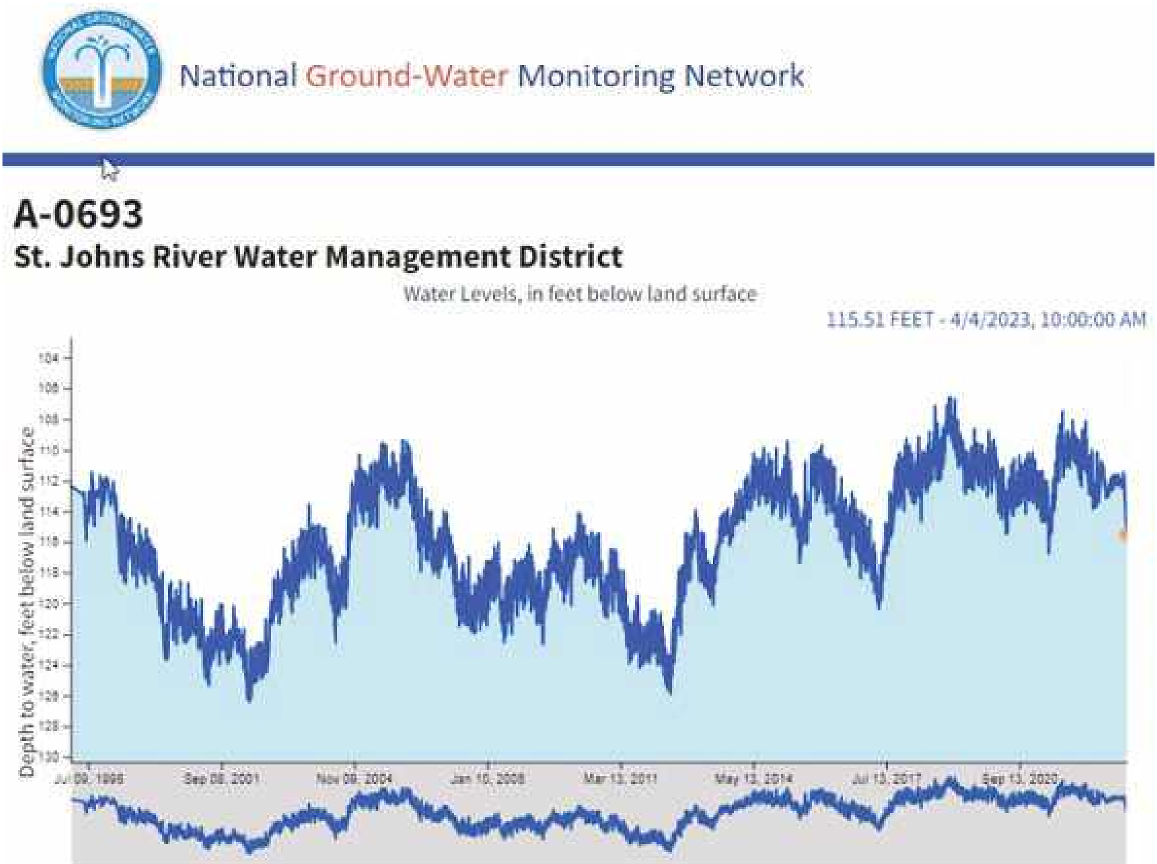


Figure 3-7. Water table information in Gainesville, Alachua County, Florida (USGS, 2024).

Figure 3-7 shows a summary of the data from June 1998 to April of 2023, found by clicking the well location in northeast Gainesville, Florida. This monitoring well location is approximately 18-20 miles east of the well shown in figure 3-6 in Gilchrist County. Please note that this well's data covers almost 5 years and indicates water table depths ranging from 106 to 126 feet below the surface. That's an average of close to 80 feet deeper than the Gilchrist County location (Figure 3-6).

The USGS annually monitors groundwater levels in thousands of wells in the United States. This data can be utilized as part of the contractor's site due diligence process to validate geotechnical reports or to provide up-to-date monitoring information on the changing water table depth during periods of abnormal rain, which could have impacts on excavations days after the actual weather occurrences.

PRECONSTRUCTION SITE VISIT AND REVIEW

Thus far, we have discussed the use of geotechnical reports, water table databases, and site plans as a first step in site due diligence in preparation for project execution. Now our focus turns to the actual preconstruction site visit that is mandatory in preparing the project team for bid submission and ultimately for construction. All bidders who respond to a bid request must attest via a legal statement in the bid documents that they have visited the site location and have taken their site review into consideration while finalizing their bids for the project.

As you make your way to the site, it is important to understand geographically the location of the site. Prior to visiting the site, it is advised that you find the site location on a map to assess the best possible routes of travel for potential subcontractors and suppliers. Understanding the location of the project not only helps you to be fully aware of the best means for traveling to and from the site but gives you a sense of how the project location impacts the surrounding local community as well.

Prior to arrival to the site, it is always important to review the list of unknowns that you are going to focus on as a result of your site plan review in order to remove any uncertainties in the estimate development process. In preparation for your site location visit, you should assemble the necessary items to support your on-site activities as well. The recommended items include a digital camera, notepad, project site plans, geotechnical reports, easements, and a current survey.

Upon arrival at the site location, you should make notes on the accessibility of the location via the travel plan utilized. Size restrictions can have a major impact on the delivery as well as the means, methods, and handling of materials. Therefore, any potential overhead obstructions along the route taken for large material or modular deliveries to the construction site should be noted. As shown in figure 3-8, overhead obstructions can pose a serious, potentially fatal problem.

It is important to create a series of visual points of reference (aka landmarks) that will be utilized during the construction process. Examples include such things as the local school, grocery store, tower crane, bridge, building supplier, and so forth.

Find a starting point for the detailed site visit and lay out the site plan in the proper orientation to match your perspective (line of site) view. Make notes on the plan of anything that stands out that might have implications on the execution of the project. Large trees, overhead power lines, underground utilities, creeks, drainage berms, traffic lights, and adjacent properties are examples.

Pay close attention to any existing structures and site improvements. Existing structures are a double-edged sword in that they possibly could be used as site offices during construction, but they could also pose a hazardous threat if asbestos or radon is present in the structure. All existing structures that are planned for removal should be verified with the site plans, and special note should be taken of the materials and sizes of the structures to ensure proper planning is done with respect to the demolition and disposal operations necessary to completely remove existing structures and site improvements.

Existing hardscape and parking surfaces can provide an ideal construction laydown area for prefabrication and module handling as well as parking and material storage.

Items to Consider during the Site Visit

1. **Location**. Is the site in a location that will require special consideration for noise? Will the location restrict your working hours due to local ordinances? Is the site in an area considered historic?
2. **Electrical lines**. Are there existing power lines near the site that may hinder access by large vehicles, delivery trucks, or equipment? Do the power lines restrict the

Figure 3-8. Dump truck gets tangled in power lines, pulls down 12 utility poles outside Rush-Henrietta High School in upstate New York (July 24, 2018) WFLA ABC Affiliate.

location or utilization of cranes? This is vital information for decision-making surrounding the means and methods for construction, which clearly have direct impact on construction costs.

3. **Utility tie-ins**. Are the existing utility tie-ins located in an area that is easily accessible? Is the location in an area that is near final grade? How will utility tie-ins impact the construction schedule? Do the utility connections require cutting the roadway? Is underground boring required? All of these factors can increase the costs and regulatory implications.
4. **Location of property corners**. Has the owner's surveyor located the property corners and clearly identified the construction limits? This information is vital to ensuring the construction operations never encroach on the neighboring properties, which can lead to severe legal actions and project shutdown.
5. **Existing structures**. Does the site contain any existing structures? Are the existing structures adaptable for use during construction operations? Do the existing structures contain any hazardous materials? Have the disposal costs of the structures and related materials been taken into consideration in the contract cost?
6. **Existing site improvements**. Does the site contain any existing roadways, drainage ways, cleared road beds, or cleared right of ways? These improvements can be utilized as strategic laydown areas and preassembly locations and can be ideal locations for materials handling and storage. Hard surfaces allow for ease of movement as well as protection of the materials from ground saturation.

7. **Special natural features**. Does the site contain any special plants or animal habitats that would require protection or permits for disturbing? Does the site have any existing bodies of water or wetlands that must be protected from stormwater runoff? If so, does your project require that any portion of the wetlands be dredged or filled to accept stormwater discharge? Are there any environmental features that require special attention or protection during construction operations? Does the project require an Environmental Impact Statement (EIS)? The Environmental Protection Agency (EPA) provides a website listing of all EIS reports registered since 2004 (EPA, 2013). These statements provide specific details on all remediation actions that must be undertaken during the construction process to protect the surrounding environment. The U.S. Fish and Wildlife Service provides a database of maps indicating the locations of all federally designated wetlands at this URL (FWS, 2012 http://www.nwi.fws.gov).This searchable database is sometimes referred to as the National Wetlands Inventory (NWI). Such a database can assist in the due diligence process prior to commencing any construction operations. As shown in figure 3-9, native trees are being protected on the University of Florida campus adjacent to construction operations.

Figure 3-9. Perimeter protection of majestic oak trees on University of Florida Campus (Source: Author, 2024).

8. **Navigable waters**. Is the site located near any navigable rivers or bodies of water? If so, the U.S. Army Corps of Engineers regulates, via permitting procedures, any construction activities involving dredging and discharge of soils (fill materials) into specified locations along navigable waterways under Section 404 of the Clean Water Act. The Secretary of the Army, acting through the Corps of Engineers, may issue permits following a public hearing process. The governor of any state also holds the power to issue a permit for discharge of soils or dredging materials under certain conditions or situations (USACE, 2013).

Site History

If the site is located within a recognized historic district, the project team might be required to conduct a historic preservation survey of existing buildings. There is not a single authority that oversees historic property locations, which makes it difficult to ensure compliance with the applicable regulatory agencies (i.e., the property could be governed by local, regional, state, or federal guidelines depending on the type of historic recognition sought by the local community or owner). The guidelines are also influenced by the source of government funding utilized in any restoration operations. In addition, some locations will require construction projects to preserve or restore any historic structures. Historic locations often require special construction procedures to maintain the integrity of the historical significance of the site. For example, in cities such as Miami Beach, Boston, and Washington D.C., the building façades in some historic locations are required to remain intact while building a new structure or renovating an existing structure. Often this requires extensive false works to support the exteriors throughout the construction process. These locations of historical significance can also require special insurance or bonding by the contractors as a form of protection. In addition, special consideration must be taken by any new construction operations or renovations that are required to match existing structures and finishes. Sometimes, this may result in the contractor having to find used materials from previously dismantled structures via a recycling operation, which can be hard to find and expensive.

For federal historic preservation guidelines, *The U.S. Secretary of the Interior's Standards for the Treatment of Historic Properties* is recommended and provides various levels of treatments that can be applied to historic structures and landscapes, such as reconstruction, restoration, preservation, and rehabilitation. It should be noted that the treatment category varies based upon the overall goals that the owner has for the structure and whether the location will be utilized as a historic landmark by the general public, continues to be utilized for the original purpose for which it was built, or follows an adaptive reuse for a different purpose such as turning a historic home into a restaurant or retail shop. Depending on the treatment category, these federal guidelines provide information on protection, maintenance, and restoration/repair procedures. One thing to keep in mind is that historic structures contain materials that are natural, handcrafted products rather than machine-made. While most of these materials (wood and timbers, cut stone, brick, concrete, metal, etc.) are used in construction today, they may be of a different quality, size, and finished surface. For example, 18th-century handmade brick is quite different than 20th- or 21st-century machine-made brick.

Adjacent Property Owners and Relationships

Easements and Required Setbacks

Property easements and property line setbacks are established by each local governing municipality to provide adequate access to locations for such things as site accessibility, utility installation and maintenance, fire and emergency services access, and required landscaping and green spaces. Easements are critical to adjacent property owners, municipal utilities, and fire and emergency services and should never be impeded during the construction operations without prior notification of the adjacent property owner. This ensures that the owner, utility, or service provider will have continuous accessibility to their land locations and customers.

Location and Adjacent Property

One of the most critical relationships that must be managed during the construction operations phase is the relationship between the contractor's construction team and the adjacent property owners. Adjacent property owners have specific rights to protect and maintain their property and any real improvements on those properties in the same way that the contractor protects its construction site with a perimeter security fence against the risks of theft, personal injury, vandalism, and so forth. The following paragraphs contain further information on what could be considered unique adjacent property owners that require special consideration during the construction process and should be a part of every contractor's due diligence prior to completing cost estimates and beginning construction operations.

Railways: RRA

The U.S. railway system is a very complex and highly secured operation. The railway right of ways and official easements come in many shapes and sizes, as do the punishments for trespassing on railway properties, which is discussed later in this section. The width of railway right of ways vary from just 25 ft to more than 400 ft, with the placement of the tracks within the right of way and the required safety margin determining the final width allocated to support the operations on the track. Any land that is not considered part of the safety margin is designated as excess right of way. The typical right of way is 100-ft wide for a single operating track located in the center. The required minimum width of the safety margin is 8.5 ft on both sides of the centerline of the track (17 ft total) resulting in an excess right of way of 83 ft (41.5 ft added on either side of the track's safety margin). These restrictions drastically reduce the overall buildable site areas adjacent to railways (Schmick & Strachota, 2006).

Railway right of way restrictions on buildings and site improvements should be taken into consideration during the site planning and design stages of the project. The implications placed on construction operations are another critical consideration during the due diligence process due to the strict "no trespassing" laws applicable to rail tracks, facilities, and lands.

Figure 3-10 shows the casualties and injuries by type of person and the event on railway properties that resulted in the highest number of casualties (deaths and injuries) over the 10-month period from January to October of 2023. The table indicates there were a total of 5,387 incidents with 856 fatalities for all types of persons. The table also indicates when considering only trespassers and contractors during the same 10 months, there were 754 total deaths as a result of 976 incidents along railroad tracks. Trespassing on railway property and facilities has become a more serious problem in recent years. It is against the law in all states to trespass on any private property without the owner's permission or without having an official reason, and all states provide for minimal punishments. Details on a state-by-state basis covering trespassing laws as they pertain to railway property and equipment can be reviewed online (USDOT, 2024).

To reinforce the reason for placing so much emphasis on construction projects that are adjacent to railways, construction worker fatalities accounted for 146 of the 1,221 (12%) of all non-railway-related workers killed. In more detail, 91 were construction workers and 55 were in mining, gas, or utilities-related professions (electric, communications, and sanitary) (BLS, 2013).

In the majority of states, trespassing is in the sections of their respective codes concerned with property crimes and general offenses. A number of states specifically forbid trespassing on railway property and facilities and codify it in their respective sections concerning railways or utilities. When punishments are spelled out in the statutes, they are listed. Applicable statutes or municipal codes and related penalties are also listed if available.

CASUALTIES BY TYPE PERSON AND PRIMARY EVENT FROM FORM FRA F 6180.55A

2023

Selectons: Railroad - ALL
State - ALL County - ALL
Time Frame - Jan 2023 To Oct 2023

	Total Incidents		Total Casualties		Train Accs w/o HRC		Highway-Rail (HRC)		Other Events	
	Fatal	Inj	Kld	Inj	Kld	Inj	Kld	Inj	Kld	Inj
	0	2	.	2	.	.	.	.	.	2
Worker on duty - employee	7	2,708	7	2,809	.	58	1	55	6	2,696
Employee not on duty	0	53	.	61	.	.	.	.	.	61
Passenger on train	1	471	1	505	.	15	.	20	1	470
Nontrespasser on rr property	80	831	93	899	1	1	75	277	17	621
Trespassers	742	690	751	779	5	4	131	223	615	552
Worker on duty - contractor	1	81	1	83	.	.	.	.	1	83
Contractor - other	2	205	2	208	.	.	.	.	2	208
Worker on Duty - volunteer	0	3	.	3	.	.	.	.	.	3
Volunteer	0	3	.	3	.	.	.	.	.	3
Nontrespasser off rr property	1	13	1	35	.	22	.	7	1	6
---- Total	834	5,060	856	5,387	6	100	207	582	643	4,705

Total incidents are limited to those that result in fatal or nonfatal casualties

Figure 3-10. Casualties by Type of Person and Primary Events. Source: Federal Railroad Administration (FRA, 2024).

Airports: Federal Aviation Administration (FAA)

Any construction operations taking place adjacent to or near airport operations must comply will all Federal Aviation Administration (FAA) standards, and proper notification of the project must be made with the local governing FAA administrator in accordance with 49 CFR Part 77. Failure to make proper notification is a civil penalty under Section 902 of the Federal Aviation Act of 1958 (FAA, 2013).

As of January 2011, the regulations require the CM/GC (or other project team representative) to submit the required notification at least 45 days prior to the start of the proposed construction activities.

Any proposed construction activity requires submission of FAA Form 7460-1, “Notice of Proposed Construction or Alteration.” All project-related relevant information about the proposed construction, along with all necessary details of the type and location of the project, must be provided.

Typical detailed information requested by the FAA in order to conduct a formal review and impact assessment of a proposed construction project includes, but is not limited to, the following items:

- A scaled drawing or site plan showing the locations of any structures/alterations in relation to the nearest taxiways and runways. In some cases, a markup of the airport layout plan or a terminal area map is acceptable. These drawings must provide the adjacent distance of the proposed activities/structures to the nearest active runway centerlines.
- Distance from centerline of the end of the runway to the proposed activities/structures.
- Ground elevation to the highest point, including antennae or other spires, on all proposed structures, both temporary and permanent.
- The official geodetic coordinates conforming to North American Datum 1983, NAD 83[1] (Towermaps, 2014).
- Project execution plans, schedules, daily work hours, daily manpower details, employee background checks, security clearances, and so forth.

The purpose of this notification of any construction is to assess whether or not the operations will have any effects on the navigable airspace and serves as the basis for the following determinations:

- Evaluating the effect of the construction activities on the standard airport operating procedures.
- Determining the potential hazardous effect of the proposed construction on air navigation.
- Identifying mitigating measures to enhance safe air navigation.
- Charting of new objects for pilot awareness (tower cranes, buildings, antennae, power lines, batch plants, stock piles, etc.).
- Reviewing the construction of objects that alter the flight approach minimums to runways.
- Identifying and assessing any impacts on runway protection zones, safety areas, object-free areas, and obstacle-free zones.

Notification allows the FAA to review the project and identify potential hazards, both temporary and permanent, in advance of construction commencement to reduce the adverse

Figure 3-11. Aerial photo of Orlando International Airport (MCO), Orlando, FL (Source: Google Maps).

impacts to the safe and efficient use of navigable airspace. As shown in figure 3-11, an aerial photo of the Orlando International Airport in Orlando, Florida, it is easy to see that distance buffers exist in alignment with the approach patterns to the runways as evidenced by the long distances to the motorways from the runways.

To provide a better understanding of the impacts, the following are some clarifying examples of when the FAA imposes effects on construction:

- Any construction operations, permanent structure, or alteration that is 200-ft tall.
- Any construction activities
  - within 20,000 ft of a public use or military airport which exceeds a 100:1 surface from any point on the runway of each airport with at least one runway more than 3,200 ft.
  - within 10,000 ft of a public use or military airport which exceeds a 50:1 surface from any point on the runway of each airport with its longest runway no more than 3,200 ft.

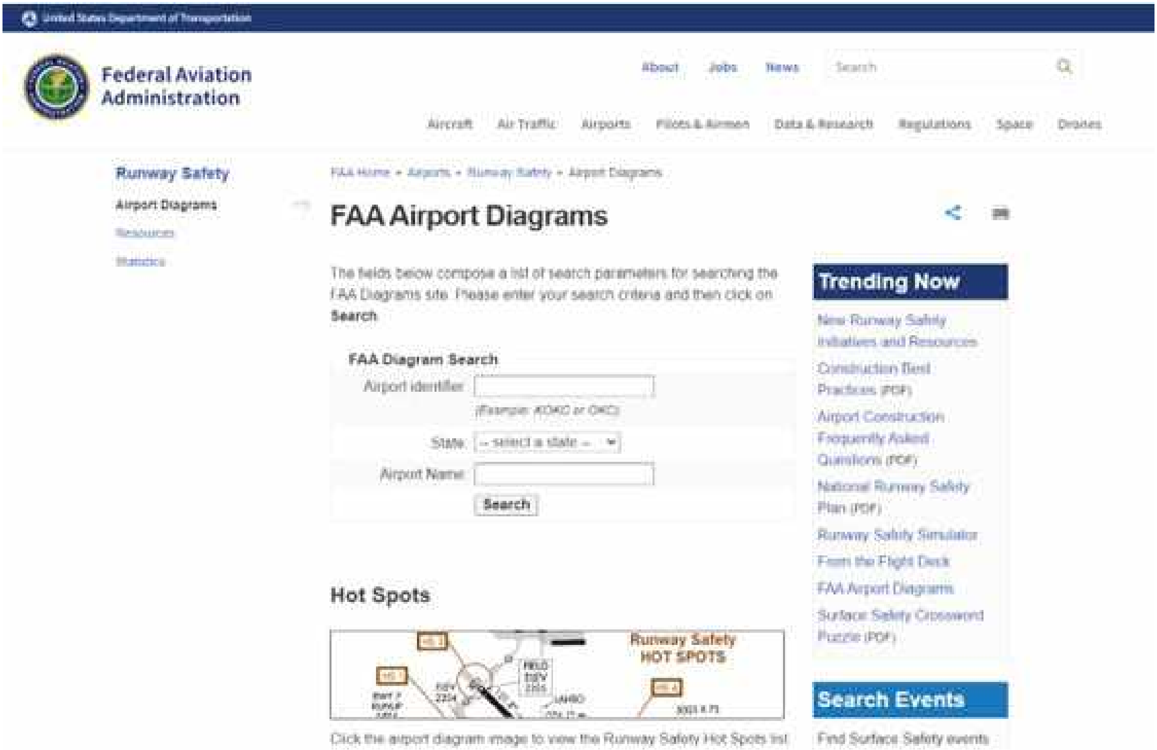


Figure 3-12. FAA Airport Diagram Website Portal (FAA, 2024)

  - within 5,000 ft of a public use heliport which exceeds a 25:1 surface.
- Any highway, railroad, or other traverse way for which the prescribed adjusted height would exceed the aforementioned standards.
- Any construction operations that will take place on a public use airport or heliport regardless of height or location.

During the site due diligence process, you can access the official airport diagrams from the FAA. Shown in figure 3-12, using the airport code or city location and state, the search engine provides PDF diagrams of all airports in the US. For comparison purposes, the aerial photo in figure 3-13 shows the diagram for the Orlando International Airport (MCO) in Orlando, Florida.

It is vital to understand that notifications must be filed whether or not the proposed construction, both permanent and temporary, will be taking place on or off airport property. Construction activities taking place on airport property are reviewed and controlled by the FAA Airports Division in direct coordination with the Flight Procedures, Technical Operations, and Air Traffic Control Divisions of the FAA. An online electronic method for preparing and submitting proposals for both on-airport and off-airport construction operations is available (FAA: OE/AAA, 2013).

Further considerations for construction operations include the use of certain radio frequencies during construction that could interfere with vital airport communications to pilots. Some radio communications may be banned from use by the project workforce to ensure the safety of airplanes and passengers.

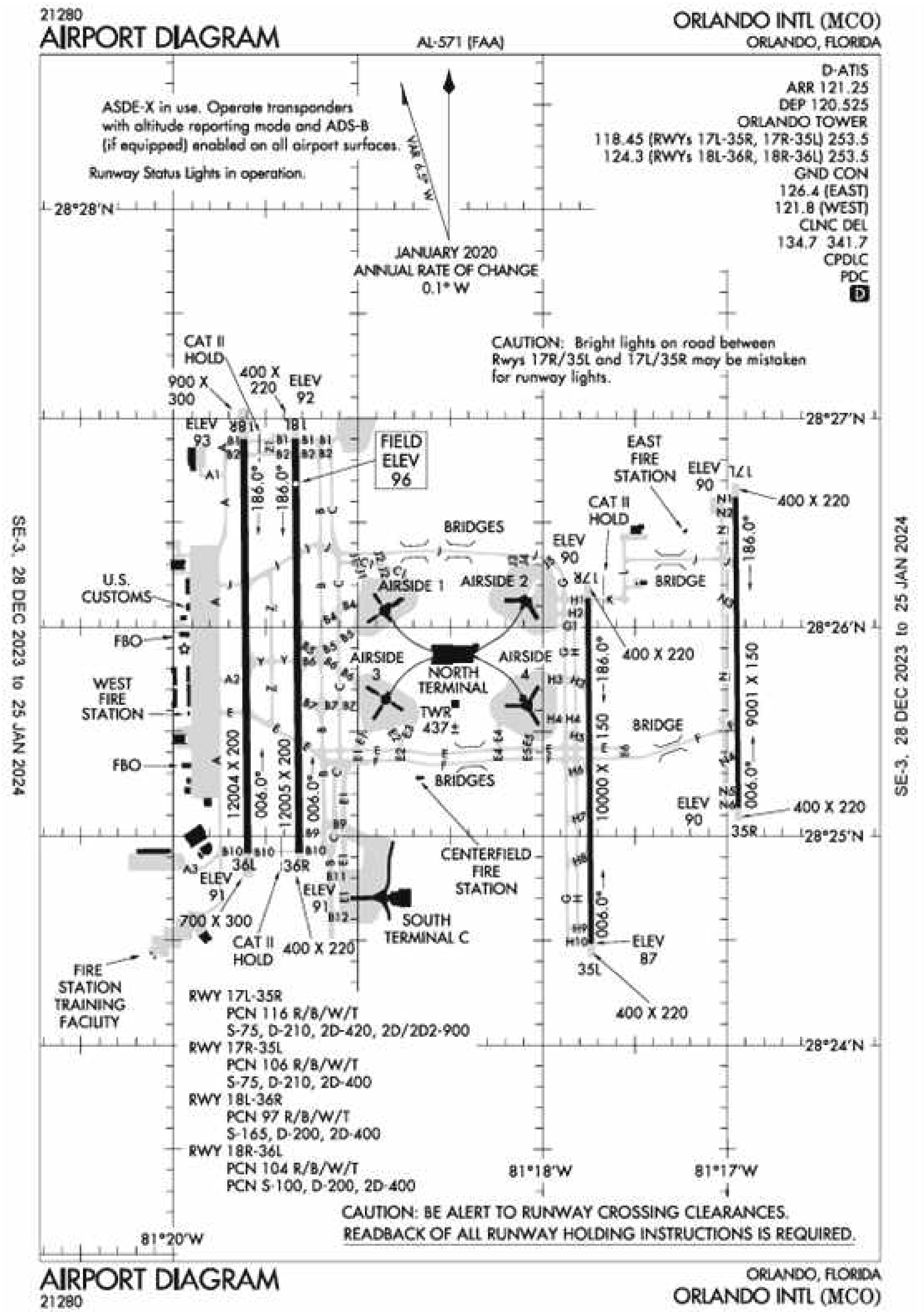


Figure 3-13. Orlando International Airport diagram. (FAA, 2024).

Figure 3-14. Aerial photo of Daytona Beach International Airport (Source Google Maps).

Figure 3-14 provides another great example of the required construction / road improvement buffers off the ends of the runways. In the picture you can see there are many hundreds of feet of green space without any obstructions on either end of the east-west and north-south runways.

Public Highways

The implications of building projects next to public roadways are most often revealed during the project site plan approval portion of preconstruction. Traffic impact studies provide the local municipality with the overall anticipated results of the completed project on the transportation system directly accessible to the project location. The site plan review process undertaken by local authorities having jurisdiction will typically disclose most of the restrictions that will be placed on the site during construction. Ultimately, any construction activity that takes place adjacent to the public highway systems in the United States is regulated by the U.S. Department of Transportation (USDOT) and the Federal Highway Administration (FHWA). Depending on the roadway classification, the governing authority can be at the local (county), state, or federal levels. In fact, a site that has adjacency to a state road on one axis of the site and an interstate highway on another site axis will have to conform to the regulations of both sets of authorities during the building process.

Prior to mobilization and beginning construction operations, it is vital to seek the local department of transportation's input on the execution plan for the project and how these operations may impact the roadway and allocated right of ways. This includes any construction traffic that will be required to cross right of way easements or to utilize these easements for material handling or transport. Special consideration must be taken for maintaining the safety and welfare of construction workers, equipment, materials, pedestrians, and all passengers traveling along the construction site and roadway boundaries. Added safety requirements, such as flaggers and increased perimeter fencing or traffic barricades, may be necessary. Additional restrictions may be required for mobilization of construction equipment to and from the project site due to heavy traffic patterns in the area. Similar restrictions can be placed on the delivery of materials to the construction site location to minimize the risk exposure to vehicular traffic and construction workers on-site, thereby requiring deliveries during only off-peak traffic periods, which can be during the early morning, evening, or nighttime hours. These types of delivery restrictions can have an impact on the schedule and production of the site operations that can result in increased costs. Pedestrian barricades or installation of temporary traffic signals could also be required to accommodate the construction site traffic patterns.

Navigable Waterways: U.S. Army Corps of Engineers (USACE)

Section 329.4 - General definition:

Navigable waters of the United States are those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce. A determination of navigability, once made, applies laterally over the entire surface of the waterbody, and is not extinguished by later actions or events which impede or destroy navigable capacity.

In accordance with the CFR 329.4 of USACE, a navigable waterway is generally described as "those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce. A determination of navigability, once made, applies laterally over the entire surface of the water body and is not extinguished by later actions or events which impede or destroy navigable capacity."

In interpreting this definition and determining whether or not the water body is deemed as navigable, the following three conditions must be met: (1) past, present, or potential presence of interstate or foreign commerce, (2) physical capabilities for use by commerce as in the aforementioned definition, and (3) defined geographic limits of the water body.

If the waterway is determined to be navigable, USACE will regulate, via permitting procedures, any construction activities involving dredging and discharge of soils (fill materials) into specified locations along navigable waterways under Section 404 of the Clean Water Act (USACE, 2013).

Shown in figure 3-15 is the visual representation of the Section 404 regulations defined for both tidal and fresh waters to aid in interpretation and understanding of the US Army Corps of Engineers jurisdictions with respect to Section 404 of the Clean Water Act.

Military Bases: Department of Defense (DOD) Installations

Similar to construction near an airport, defense installations such as military bases require the CM or GC to develop additional site management procedures to comply with USACE, DOD, Department of the Navy, Department of the Army, Department of the Air Force, and

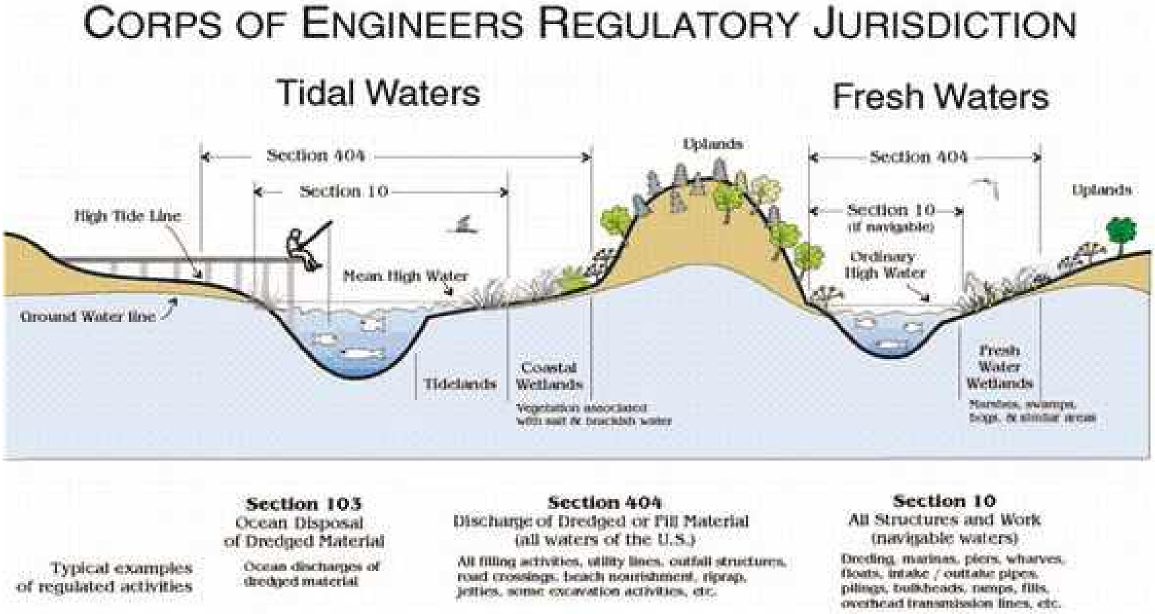


Figure 3-15. Corps of Engineers Regulatory Jurisdiction (USACE-Vicksburg, 2024)

Department of Homeland Security (DHS) regulations. During preparation for construction in the site due diligence phase, it is important to determine and document all the details of the work restrictions that will be or could be placed on the project due to its proximity to a defense installation. Depending upon the type of installation, varying levels of employee security may be applied to your project's workforce that will require obtaining security clearances or background checks on all on-site personnel. These include the standard E-verify system provided by the DHS. E-Verify is a free Internet system for anyone over the age of 16 to confirm someone's work eligibility in the United States (DHS, 2013).

In addition to personnel restrictions, site management must be prepared to respond to the base commanding offices for stoppages of work as a result of planned military operations or maneuvers. These work stoppages are for national security purposes as well as the safety of the military and construction personnel. Keep in mind that airbases will have many of the same restrictions on maintaining navigable airspace as previously discussed in reference to public airports. Naval bases share many of the same concerns as on navigable waterways, so USACE restrictions apply, with increased military security on the project perimeter adjacent to waterways utilized by naval forces.

Educational Facilities

When a construction site is located near or adjacent to an educational facility, several items must be considered during the preconstruction phase. The first compliance concern is to ensure that the personnel on the site do not have any work location restrictions placed on them due to any child-related criminal charges, which would prevent them from being allowed to reside or work within a preset distance (often 1,000 ft) of any school properties. The Adam Walsh Child Protection and Safety Act created the federal statute requiring a nationwide registry system that lists and tracks the location of all convicted sex offenders in the United States. This registry is available as a public record.

Educational facilities are fully operational on an almost-identical schedule to a normal construction workday (7:00–7:30 a.m. until 3:30–4:00 p.m.) and have major traffic congestion concerns during the morning hours and when school dismissal occurs in the afternoon. At primary and middle schools, there is heavy bus transportation and parent vehicle traffic that can become a problem for delivery of materials or even coordinating a continuous concrete placement that spans an entire day. In addition, special consideration must be made for the high volume of pedestrian traffic as children and parents walk to and from the neighborhood schools.

One must remember that construction sites are classified as a public nuisance, and it is the contractor's full responsibility to maintain a safe work site not only for the workforce but for the general public, who could gain access to the site, as well. Thus, when working in close proximity to any school, a heavily secured perimeter fence is a necessary general condition item to prevent trespassing by curious children and parents walking nearby. In addition, pedestrian barricades may be required to control the flow of pedestrians away from the construction site or closed sidewalks. These perimeter security measures must be inspected on a regular basis to ensure the safety of the site and to prevent unauthorized access. One method to reduce the curiosity level is to organize and host field trip visits by teachers, students, parents, and staff members. This is a great public relations concept and provides a safe and controlled means for educating the community at large.

All of the aforementioned points remain a part of the due diligence process if the construction site is located on or near a college campus, with a few additional items to consider. College campuses are operational during longer time periods, from early in the morning to late in the evening. It is not uncommon for college classes to begin at 7:30 a.m. and run until 9:00 p.m. The number of students, faculty, and staff are exponentially greater than that of a primary school, which increases the implications for site safety management, traffic concerns, and perimeter security. Coordination of the project must be carried out with the director of facilities on the campus and often requires the involvement of the campus risk management office as well. Figure 3-16 shows a pedestrian walkway adjacent to a construction project in the center of the University of Florida campus.

Hospitals

Projects in close proximity to or within an active hospital pose some unique challenges to the project team during the phases of site development and building construction and must be taken into consideration early in the process to fully capture the impacts in estimating, logistical planning, and execution. The hospital administration will need to be heavily involved in the preplanning of the operations, and a direct communications link should be established for daily interactions between the site supervisor and the hospital staff. Typically, the hospital will have a director of facilities, a building supervisor, and a chief of staff represent the interests of the hospital in this coordinated effort to maintain the highest level of care for their patients and staff during the construction. The detailed coordination of traffic patterns, deliveries, utility installations, outages, and disaster preparedness/emergency management must be completed and communicated on a daily basis. At a minimum, the PM and field superintendent will have a weekly meeting with the hospital team to ensure a continuous, smooth, functioning facility; however, briefings to the hospital staff representative each morning are recommended. The hospital administration also will provide at least one member of their team to participate in the monthly progress meetings to represent the best interests of the hospital in all aspects of

Figure 3-16. Construction activity on the campus of the University of Florida, Gainesville, FL. This walkway must be maintained with full accessibility to ensure the safety and effective flow of faculty, staff, and students through campus (Source: Author, 2024).

the ongoing construction operations. Examples of the major coordination needs that result in increased requirements for field management oversight include:

- Noise control and working hours.
- Deliveries that have an impact on the traffic into the hospital.
- Power and utility outages (each outage requires the hospital to switch to backup generator power to continue with surgical procedures and life-support systems).
- Any blasting or heavy rock removal using hoe-rams, which will cause vibrations that can affect sensitive, highly calibrated hospital equipment or even power surges/brownouts.
- Disaster-readiness/emergency-management plans to ensure access to the hospital.

Some other aspects of working in or near a hospital are related to the fact that they have heliports for medevac units and air rescue/emergency medical units that access the hospital or transport patients to other locations for increased levels of medical care. Heliports will require the same due diligence as discussed in the "Airports—Federal Aviation Administration" section of this chapter with respect to cranes, equipment, and building heights, as well as maintaining the required perimeter around the helipad.

Neighborhood, Office, or Community Associations

The intent of neighborhood, office, or community associations is to act on behalf of the homeowners or tenants in maintaining high standards of living (or working environments) to ensure appreciable property values through utilizing a set of restrictive covenants on the property. In addition to the restrictive covenants, these associations legally organize to represent the community with adjacent property owners and the local municipality to influence the surrounding construction and development activities to minimize the impacts on the property values within the community. These organizations are often represented at site plan approval planning hearings and zoning change requests.

Figure 3-17 shows a very tight construction operation in a downtown location. Notice the retail store operator standing just inside the doorway at the point where the sidewalk is closed. This project is obviously having an impact on the store's operations. Daily communications are the only way to effectively keep local tenants aware of the project's status and the continuous actions undertaken by the contractor to ensure that adjacent property owners are happy.

Figure 3-17. Restricted construction site in Darmstadt, Germany.

If your site is located within a planned community or office campus that has restrictive covenants, it is imperative to review them in detail. Since restrictive covenants are agreed upon by the owners or tenants as part of the purchase or lease of the property, they are deemed voluntary and can actually place higher standards (requirements) on the construction specifications and operational guidelines than the local municipality or code enforcement offices.

These covenants often impose work-hour restrictions to reduce the time periods in the day that allow for noisy operations such as construction equipment. In addition, similar to historic locations, neighborhood covenants can place restrictions on the exterior materials and structural components of the planned building and related ancillary works. Such standards can have a direct cost impact and must be taken into account when preparing the cost estimate.

A regularly scheduled meeting with representatives of the association is a must for the project management team to provide an effective dialogue to gain the feedback and concerns of the residents and tenants who reside near the construction operations. Clear communications in this situation can eliminate rumors and misconceptions that can build through the various perspectives in a living or working community. The project site can be utilized as a communications platform by offering controlled site visits, which can provide interested residents and tenants an individual opportunity to learn firsthand how the project is progressing and the efforts being undertaken by the management team to protect their personal interests and property values. Please see figure 3-18 picturing the meeting of a St. Petersburg, Florida homeowners group.

Figure 3-18. A board member of a homeowner association talks to residents of St. Petersburg, FL about the upcoming project (St. Peterburg Downtown Partnership, 2023).

Site Constraints

One major part of the due diligence process for construction site management includes a detailed assessment of the site and identification of any constraints placed on the accessibility or daily operations being developed for the logistical execution of the project requirements. Figure 3-19 illustrates a great example of a site with several site constraints. See Figure 3-20 in order to be prepared to address site constraints. A brief rationale and approach to mitigating the constraints are provided.

Figure 3-19. Construction site in Darmstadt, Germany, with multiple constraints: restricted site access, no easy locations for deliveries and materials handling, lack of temporary parking, and a clear need for road closures during construction.

SOURCES OF INFORMATION

Local Municipal Government Websites and GIS Database

The National Spatial Data Infrastructure (NSDI) is a consistent means to share geographic data among all users that could produce significant savings for data collection and use and enhance decision-making. Executive Order 12906 called for the establishment of the NSDI, defined as the technologies, policies, and people necessary to promote sharing of geospatial

Potential Site Constraint Items	Due Diligence Concerns
Site Access/Ingress and Egress	Does the site and construction work location(s) provide for full ingress and egress of vehicles, manpower, equipment, and materials to efficiently and safely complete the project scope of work?
Construction Site Entrance	Where is the most ideal location for the site entrance? Will the project be better served to have a separate entrance for workers and another entrance for materials and equipment deliveries?
Truck Wash Racks	Will the project need to install wash racks for use by all trucks and heavy equipment to be washed down prior to exiting onto the road?
Temporary Parking	Is there adequate area for providing parking for all workers on-site during peak loading periods of the project schedule? If not, will it be required to lease an off-site parking location and provide a shuttle to transport workers? Will we need to lay down gravel or other stone to stabilize the ground surface to support the temporary parking location?
Loading Zones/Delivery	Does the site provide adequate areas to off-load materials without disrupting the normal flow of worker and crew movements on the site during construction? If not, will it be necessary to secure a street-side loading zone for material handling? Will this require considering just in time (JIT) delivery of materials to support the schedule?
Daily Road Restrictions	Is the project located in a municipal jurisdiction that has restrictive use time periods throughout the day on heavy trucks and large equipment deliveries that will require further detailed coordination of activities on the schedule and perhaps additional second or third shifts?
Easements	Are all of the easements clearly identified on the site plan? Are these easements restricted or can they be utilized during construction operations as long as they are not made inaccessible by the construction process?
Construction Limits/Boundaries	Are the limits of construction easily identified on the site plan? Can these limitations be easily established, visibly maintained, and controlled on-site? Do these limitations force any reconsideration of the project execution plans due to any potential infringement on them if the original plans are followed?
Property Corner Locations	Have all property corners been located by a registered professional land surveyor? Are they easily visible and maintained?
Emergency Medical and Fire/Rescue Services	Is the site within the required medical emergency response time range or will it be required to have an emergency medical technician employed on-site? What is the location of the nearest fire station? Are we required to install/maintain a temporary standpipe system in case of a fire emergency?
Location of Utilities	Are the utility locations in areas where there will be a large amount of earthwork to reach final grade? Are the utility tie-ins taking place with the easements or are they under the sidewalks or roads?
Temporary Utilities	How difficult is it to get temporary power and water? Will the temporary power be adequate for all construction needs (i.e., tower cranes, batching plants)?

Figure 3-20. Potential site constraints for consideration during due diligence.

data throughout all levels of government, the private and nonprofit sectors, and the academic community. The goal of NDSI was to reduce duplication of effort among government agencies and municipalities to improve geographical data management systems, which would provide the public access to multiple sets of public information in a single online interface. Such systems are much more cost-effective and efficient for both public and private sector utilization, while users can access information on ownership, property taxes, zoning, geographical data, utility easements, and much more. All of this is done in a more sustainable, paperless manner using electronic file formats (FGDC, 2013).

The movement of all public records on land data to the Internet-based systems mandated by the aforementioned executive order creating the NSDI was one of the most beneficial actions in the last decade for land development and real estate professionals. The use of an interactive online database for all public records pertaining to property and infrastructure information has increased the efficiency of the construction due diligence process. Nowadays, instead of driving to the county or city property records offices and digging through sheets and sheets of land survey records and binders or microfiche of property ownership records, one can simply access this information many times faster from the comfort of his/her own office computer or mobile device. As shown in figure 3-21, which is a screenshot from the Alachua County Florida GIS data website, these online systems begin with an overview map of the location, and then you can use the zoom-in function to focus on your site location.

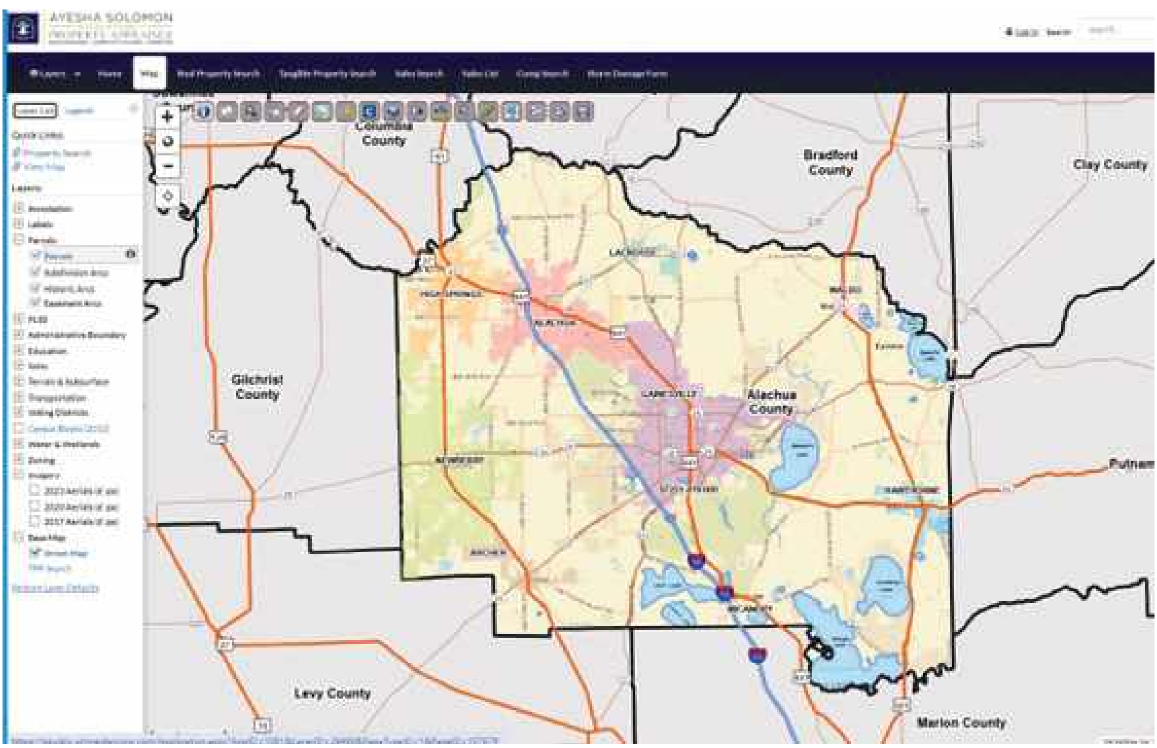


Figure 3-21. Opening Page of Alachua County Florida GIS Data (Alachua GIS, 2024).

The information that is typically made available in different layers on these GIS data maps includes:

- Parcel numbers
- Owner information
- Subdivisions
- Plat pages
- Tax districts
- School districts
- Sanitary utilities
- Storm utilities
- Water utilities
- Boundaries
- Topography—contours
- Topography—spot elevations
- Fire stations
- Police stations
- Hospitals
- Soil classifications
- Zoning—land use type
- Aerial photography

The information viewed is determined by which layers are chosen to view. Multiple layers can be viewed simultaneously; however, too many layers can make interpretation difficult.

Ownership Information

The example screenshot in figure 3-22 shows the aerial satellite imagery of the Ben Hill Griffin Stadium (aka "The Swamp") and Exactec Arena properties on the University of Florida campus in Gainesville, Florida. By clicking on the identify function at the top command line, the parcel information is provided on the right as indicated by the parcel number. Clicking on the parcel number shown in the information box provides further details on the parcel, such as the owner's name, address, and school district location (see figure 3-23). More details than are shown in this screenshot include the valuation history, sales disclosure history, dwelling information, building information, and lot size information. Each screenshot of information also can be provided in a printable view.

To further explain the value of this information, let us look at an ongoing development shown in figure 3-24. The aerial photograph shows Country Way Phase 2 Subdivision in Newberry, Florida. As the developers plan/seek to grow the development further to the east, the adjacent property owners' information is extremely valuable.

Knowing who the adjacent property owners are is good information for the project team so that they can contact the owners directly and maintain a good working relationship with them and the local community. This information can be vital if the project team is searching to secure (lease) additional land to use for material storage, parking, or preassembly during the construction operations, or even in planning further eastward expansion of the development. Figure 3-25 provides the Parcel Information Screen, which includes the parcel number, the owner's name, and the property address. A unique feature shown in the "Property Information" section in the left column is the ability to access property sketches, which often include buildings, along with maps and photos.

ZONING

Figure 3-26 shows a screenshot from the Alachua County Florida GIS system showing the satellite imagery of the intersection of SR 222 and I-75 in North West Gainesville, Florida.

Figure 3-22. Ben Hill Griffin Stadium (aka "The Swamp") and Exactec Arena properties at the University of Florida (Alachua GIS, 2024).

Parcel Summary

Parcel ID	15505-030-000
Prop ID	90231
Location Address	105 GALE LEMERAND DR BLDG 0160 GAINESVILLE, FL 32612 See more addresses...
Neighborhood/Area	145406.99
Subdivision	
Legal Description	N1/2 OF NE1/4 OF SW1/4 OR 689/122 1/21 OF UNIV OF FLA PARCEL (Note: *The Description above is not to be used on legal documents.)
Property Use Code	STATE-NOT TIITF (08700)
Sec/Twp/Rng	06-10-20
Tax Area	GAINESVILLE (3600)
Acres	17.87
Homesteaded	False

Figure 3-23. Parcel summary data, City of Gainesville, Alachua County, Florida.

Figure 3-24. Country Way subdivision development, Newberry, Florida (GIS, 2024).

Figure 3-25. Due East adjacent property information of Country Way Development, Newberry, Florida (Alachua, 2024).

Figure 3-26. Aerial Photograph of Intersection of SR 222 and Interstate I-75 (Alachua GIS, 2024)

Figure 3-27. Zoning and Land Use (Alachua, 2024).

Figure 3-27 shows a screenshot from the Alachua County Florida GIS system illustrating the current zoning for the properties within the window being viewed. The color code on the right side of the screen is the guide to the current zoning for the parcels. Another screen will allow you to view the future zoning of all parcels in the county.

Codes and Ordinances

Detailed reference materials on local municipal codes and ordinances that govern the construction process for the site location are vital to every project. These codes and ordinances can limit the activities and the design for both temporary and permanent structures and site improvements. One online reference source of codes and ordinances throughout the United States is Municode. The welcome webpage for Municode is shown in figure 3-28. The Municode website provides active links to every state as shown in the screenshot in figure 3-29, where we have chosen the state of Florida as indicated at the top of the screen in figure 3-30. Once you choose the state using a simple click of the mouse, you are provided a list of municipalities broken down by cities, townships, and counties to access the location of your project (Municode, 2024).

A screenshot of the Florida municipality listing is shown in figure 3-30. After choosing a municipality, a PDF-formatted reference document is opened with the codes and ordinances for that location. Figure 3-31 is a screenshot of the opening page of the Gainesville, Florida Municipal Code. Figure 3-32 is a screenshot after clicking “Section 6.6 Demolition of Structures” (on the left side). This screenshot shows the code details for Section 6.6 Demolition of Structures.

Figure 3-28. Municode: Codes and ordinances reference site (Municode, 2024).

Figure 3-29. Screenshot showing U.S. map for selecting state location (Municode, 2024).

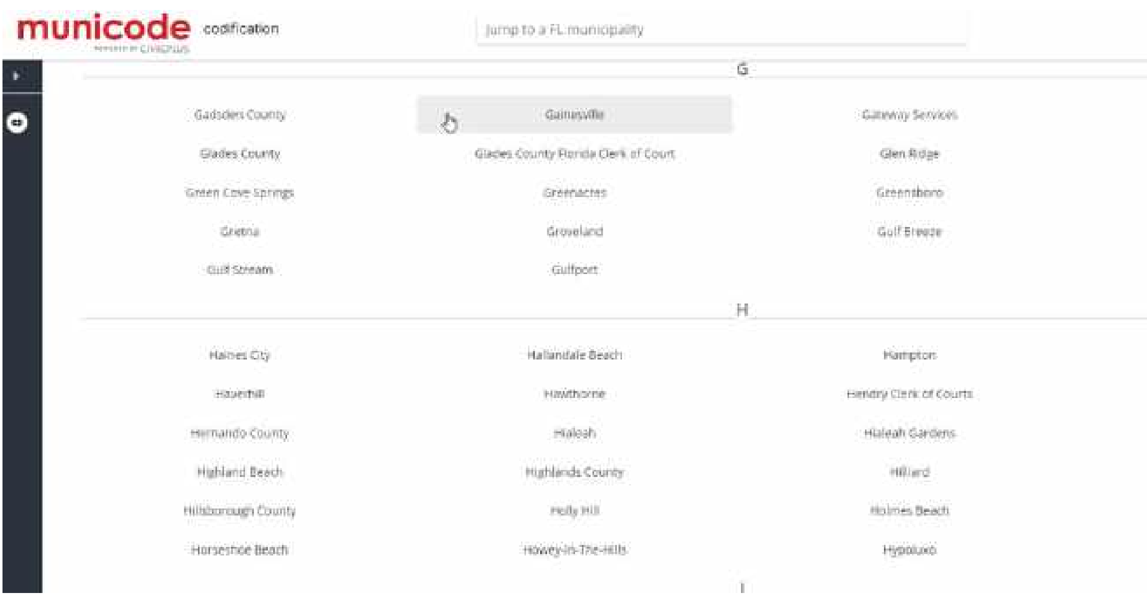


Figure 3-30. Screenshot showing a partial list of Florida municipalities (Municode, 2024).

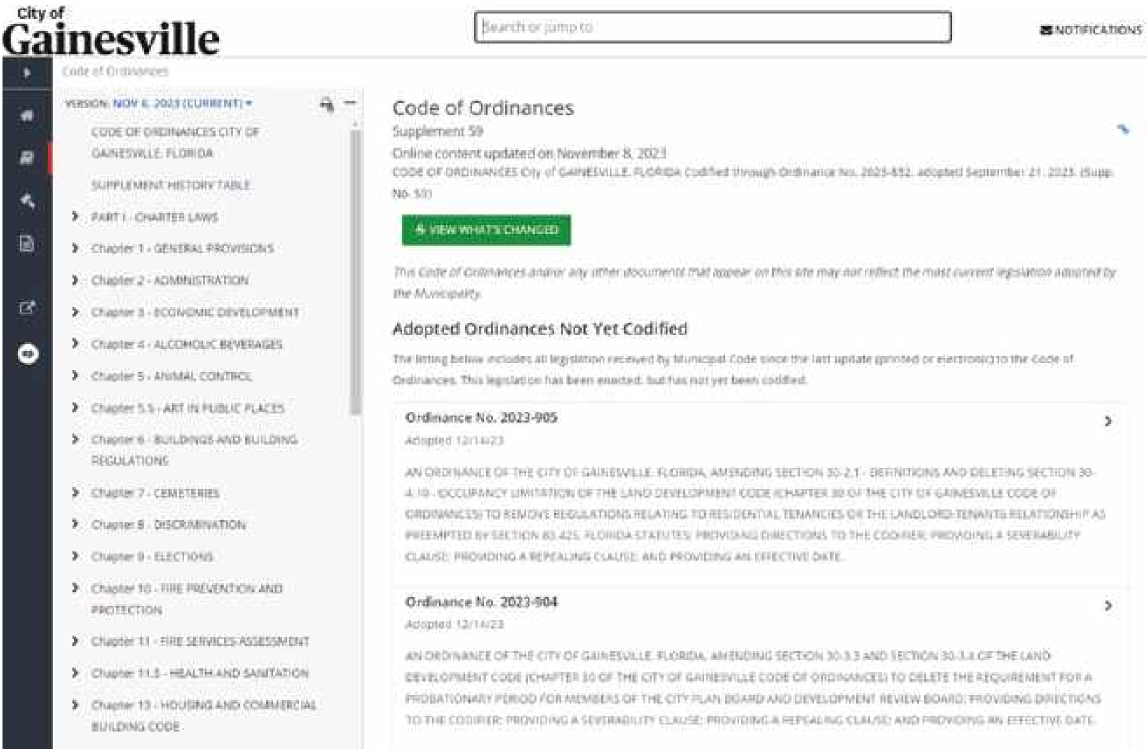


Figure 3-31. Screenshot of accessing the Gainesville Municipal Code (Municode, 2024).

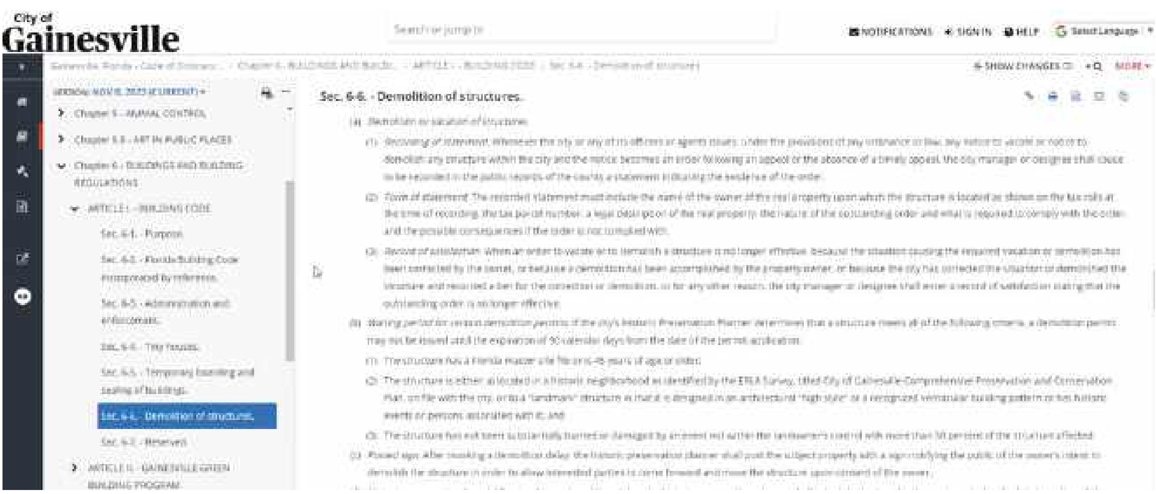


Figure 3-32. Screenshot of Section 6.6—Demolition of Structures in the Gainesville Municipal Code (Municode, 2024).

Permitting Requirements

It is imperative for a contractor preparing for an upcoming project to understand the permitting process within the municipality where the project is located well in advance of starting any actual construction. The permitting costs and procedures and the overall requirements can differ widely across a region or even among adjacent townships. Proper due diligence to understand the jurisdiction's permitting requirements is frequently taken for granted by the GC/CM.

First, it must be determined which party (project owner or contractor) is responsible for obtaining and paying for a construction permit. This information is usually found in the front section of the project specifications or in the instructions to bidders. It is important to know who is responsible for the permit because of the cost and time implications associated with the permitting process. There is a direct cost associated with the permit application, which is typically based on the estimated contract value of the project, as well as overhead costs associated with the personnel time commitment required for filling out applications, pulling together all required documents, visiting the governing municipal permitting office for submission, and spending time in direct communication with the application reviewers. Permitting in some jurisdictions has become so time-consuming and complex that special service firms have been created that focus solely on providing these permitting application processing services. These services are becoming very popular because the firms providing them have become experts at the procedures and are very familiar with the reviewers in the permitting office, which aids the contractor in the overall expediting of the permit application. In addition, these service providers allow the construction project team members to focus on the preconstruction phases without being burdened with this potentially time-consuming effort.

Depending on the municipal requirements, multiple permits may be necessary for the project. Some locations only require a single building permit, which covers everything from site development through structures, finishes, and final inspections. In other locations, the permitting is broken down to match the phases of construction, and each phase has an associated permit. An example would be where a local municipality has a series of permits to cover construction site entrance, site clearing, site development, foundations, structures, exteriors, systems, roofing, and so on. Keep in mind that each of these permits has a cost attached to it. One advantage of permitting that follows the phases of construction is that in the case of DB or fast-track construction, the construction can begin as soon as the design stages are completed, thus allowing the project to complete site work and site development while the foundation, structure, and building designs are being completed. This is particularly valuable in jurisdictions where it can take long periods (up to one year) of time to obtain the building permit. If the permitting is not in stages, then the project would be delayed the entire time frame of the application and review process.

Specialty trade permits, such as mechanical, electrical, elevator, pools, and roofing, could be considered a common situation in construction, and the associated costs are borne by the specialty contractor.

It is imperative to learn all of the construction-related permit requirements for each project location. Never operate under the assumption that the procedures are the same from one town to another, even within the same state or county.

The critical questions to ask are:

- Who is responsible for obtaining the permit?
- Is there a single permit or multiple permits required by the jurisdiction?
- What are the impact fees,[2] if any, and who is required by the contract documents to pay them prior to permitting? Are these fees required to be paid upon submittal of the site plan for approval?
- What are the types and costs of site development and building permits?
- What are the costs for obtaining the permit(s)? Who is responsible for these costs?
- What permits are required for sanitary sewer, potable water, electric service, cable TV, and telephone line installation?

SECURITY/RISK MANAGEMENT

Project sites can contain a multitude of existing natural and man-made risks that need to be taken into consideration as a part of project due diligence. Some risks are readily identified in advance of mobilization and commencement of construction operations through known existing conditions. Potential hazards that are often identified at construction sites are the result of the hazard being documented on adjacent properties in the area.

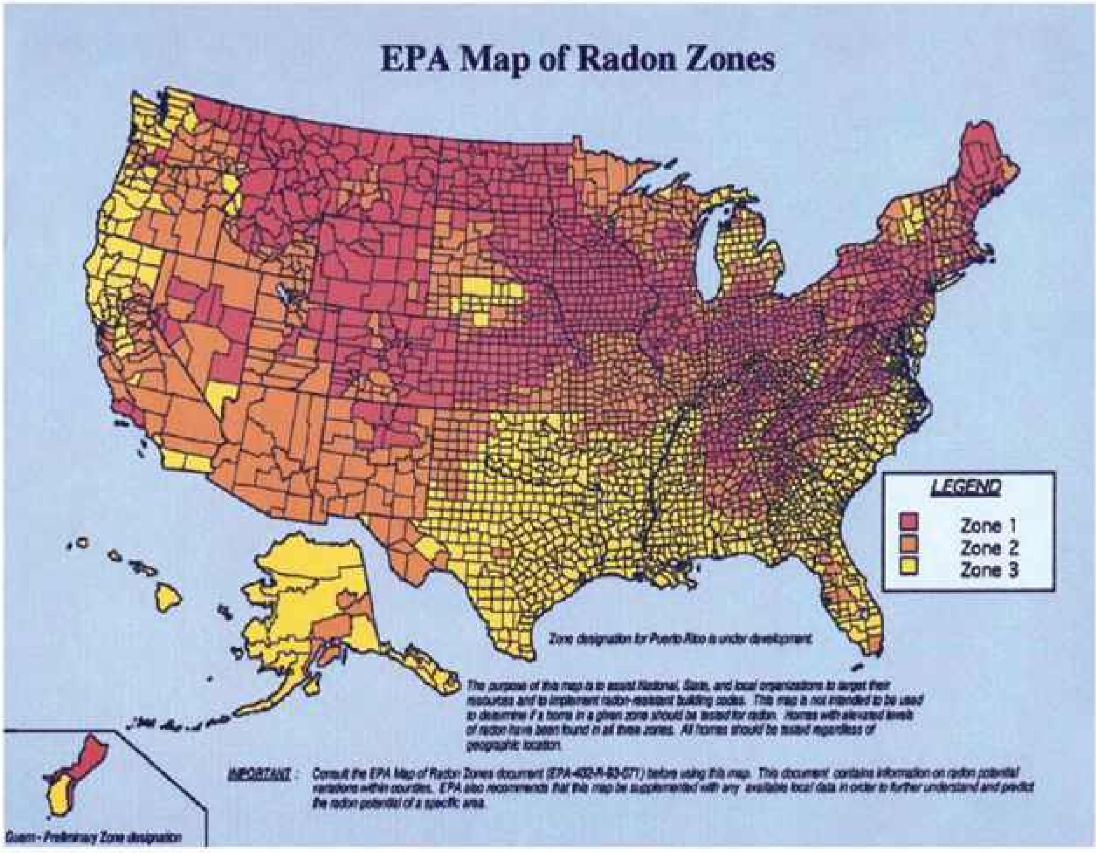
Radon Gases

One example of a natural hazard that can exist underground in undisturbed soils is radon gas. Radon gas can be found in dangerously high concentrations throughout the regions of the United States shown in red in figure 3-32. The red color indicates the highest levels of radon gas, which can pose health dangers when inhaled by humans. The regions shown in yellow have the lowest levels of radon, which present the lowest health threats.

Understanding the level of radon gas that exists on a site is important in an overall safety management plan as well as its impact on building system designs in order to mitigate the effect on building occupants. Additionally, there are a number of states that regulate those contractors who provide radon assessment and mitigation services through licensing requirements. States that currently enforce requirements on service providers include California, Delaware, Florida, Illinois, Indiana, Iowa, Kentucky, Maine, New Hampshire, New Jersey, Ohio, Pennsylvania, Rhode Island, Virginia, and West Virginia. Most of these states have been shown to have high levels of radon gas concentrations (red regions) as indicated in figure 3-33.

Asbestos

While asbestos is a hazardous mineral, it is most often found in existing buildings after being treated with additive chemicals in the manufacture of building products such as floor tiles, insulations, adhesives, fireproofing, and roofing products. Asbestos becomes a major health concern when the fibers become airborne and can be ingested into a person's lungs. For any existing structures, due diligence must be performed to determine the potential for the presence of asbestos in the building materials used. If asbestos is suspected or determined to exist



What do the colors mean?

	Zone 1 (red zones)	Highest potential; average indoor radon levels may be greater than 4 pCi/L (picocuries per liter)
	Zone 2 (orange zones)	Moderate potential; average indoor radon levels may be between 2 and 4 pCi/L
	Zone 3 (yellow zones)	Low potential; average indoor radon levels may be less than 2 pCi/L

Figure 3-33. U.S. map showing radon levels (Environmental Protection Agency, 2024).

in the structure, special, highly regulated procedures must be followed during the removal and/or demolition process. All asbestos-related operations must be performed exclusively by registered asbestos removal contractors. Due to the high level of training and certification required, coupled with the federal regulatory oversight, any asbestos removal operation is an expensive undertaking.

Prior Site Uses

Site uses prior to the most current activities planned for a site location can pose interesting challenges to a contractor during the construction phases of a project. It is imperative that the contractor understands the hazards that may be waiting to be exposed during the earthwork or utility installations. Prior site uses can provide quick insight into what potential unknowns may be unearthed during construction. The contractor needs to be aware of these potential hazards in every project and effectively communicate the plan of action should items be discovered.

Listed in figure 3-34 are some typical examples of hazards that may exist for the shown prior use of the site.

Prior Site Use	Potential Hazards
Gas Stations/Automotive Repair Shops	Steel-walled fuel tanks, double-walled fiberglass fuel tanks, oil disposal wells, grease traps, contaminated soils from automotive-related chemicals and solvents
Dry Cleaners	Chemical traps from cleaning solvents
Hair Salons	Chemical traps, hair treatment chemicals
Military Bases	Weapons disposal sites, fuel deposits and tanks, artillery ranges with undetonated rounds, bombing ranges with undetonated rounds
Manufacturing Plants	Chemical traps, heavy metals, asbestos, solvents

Figure 3-34. Potential hazards from prior site uses.

- Does the site have any former uses that could have caused the deposit of hazardous materials?
- If any hazardous materials exist, will this render your project undesirable to your target market despite adequate clean up measures?
- Does your site contain or is it immediately adjacent to electric and magnetic fields caused by power lines?

SITE DUE DILIGENCE CHECKLIST

Geotechnical Factors—*Geology*

- What is the bedrock depth and location throughout the site?
- Does the site have any sinkholes?

Geotechnical Factors—*Soils*

- What are the types of soils and their locations on the site?
- Has the project's geotechnical report been reviewed?
- What are the percolation rates for the soil?
- What are the shrinking and swelling characteristics of the soil?
- Will this site location require any special construction methods to install building foundations, roads, or utilities?

Geotechnical Factors—*Topographical Factors*

- Is the site too steep for normal construction operations?
- Where are the locations of slopes that would adversely affect the installation and function of proposed stormwater management systems, utilities, roads, and building placement?
- What are the methods we intend to use to stabilize cut and filled areas?
- What are the methods we intend to use for limiting erosion and sedimentation before and after site development?
- Can earthwork operations result in a balance of cut-and-fill requirements?
- Will it be necessary to haul in suitable fill materials? Will it be necessary to haul off any excess materials?

Site Features—*Location*

- Is the site located within a recognizable "territory," such as downtown, uptown, or waterfront area?
- If so, does this "territory" have any increased construction requirements or work restrictions?
- What are the adjacent properties to the site location? What are their primary business operations?
- Where are there easements and required setbacks? What are the dimensions of these easements/setbacks? Will they affect the site operations or material storage?
- Is the site adjacent to any railways?
- Is the site near any airports?
- Is the site adjacent to federal highways?
- Is the site adjacent to waterways?
- Is the site adjacent to military bases?
- Is the site adjacent to schools?

Site Features—*Natural Features*

- Does the site have any existing water bodies that must be protected from development by controlling or cleaning stormwater runoff into the water body?
- Are there any designated floodplains or frequently flooded areas?
- Are there any federally designated wetlands areas?
- Does the site contain any areas appearing to be wetlands?
- If so, does your project require any portion of the wetlands to be dredged, filled, or accept stormwater discharge?
- What type of existing vegetation is found on the site?

- Does the site have any special features (e.g., large specimen trees, hills, rock outcroppings, or other special landforms) that are visually appealing and might increase the marketability of the project?
- Does the site contain any special habitats of plants or animals that would require protection or permits for disturbing?

Hazards

- Does the site have any former uses that could have caused the deposit of hazardous materials?
- If any hazardous materials exist, what will be required for adequate cleanup measures?
- Does the site contain or is it immediately adjacent to electric power lines?
- Is the site located in an area where soils are known to be prone to radon contamination?

Improvements

- Does the site contain any existing structures?
- Can existing structures be adapted for use in your project?

Site History

- Is the site located within a recognized historic district?
- Will you be required to conduct a historical preservation survey of existing buildings or possible locations of historic structures foundations?
- Will you be required to preserve or restore any historic structures?
- Does the site have any archeological significance?

Regulatory—*Codes and Ordinances*

- Have you conducted a code review to establish all pertinent building, life, health, and safety codes relevant to your project?
- Are there any special building codes that apply to your project due to its location (e.g., coastal zone, earthquake zone)?
- What are the types and costs of site development and building permits?
- What are the impact fees, if any, and how do they affect project feasibility?
- What permits are required for sanitary sewer, potable water, power, cable TV, and telephone line installation?

Regulatory—*Environmental Permits and Special Studies*

- Does your project require an Environmental Impact Statement?
- Does your project contain a FEMA-designated floodplain and are special permits required to locate buildings or discharge stormwater runoff?

- What are the various types of environmental permits required; what is the application process of each; what are the tests and reports required for each application; and how do the various permit procedures affect your project schedule?

Political Factors

- Are there any neighborhood associations that might pose opposition to your project?
- Have you met with the appropriate groups to determine their concerns?

Off-Site Factors

- Are the locations for tap-ins and hookups conveniently located?

CONCLUSION

The focus of this chapter was on proper site due diligence from the perspective of the site management team. Proper due diligence is essential to raise overall awareness and minimize the impact on effective construction project execution as a result of site constraints. These constraints can be both within and outside the site location and construction limits. Knowing the site location and the surrounding properties enables construction PMs to more effectively complete the construction on schedule and on budget.

Some key points to remember include:

- Due diligence is an organized procedure (refer to the Site Due Diligence Checklist provided).
- Every project is unique due to its specific location.
- Site history and prior site uses have a direct impact on the potential for hazardous materials being found.
- Historical preservation guidelines are usually regulated at the local or regional level of the government and are not always recognized or controlled at the federal agency level.
- Regulations (permit requirements, codes, working hours, deliveries) are set by local municipalities and governing bodies. Never assume that they are the same as before.
- Site location determines material handling and construction methods, which directly impact construction budgets.
- Site plan review is a logical first step in understanding the project prior to the site visit.
- It is important to meet your adjacent property owners prior to start of construction operations to better understand their concerns and specific needs.
- Special considerations must be made for schools, navigable waterways, hospitals, airports, military installations, highways, and so forth.
- There are numerous sources of information readily available through local government websites and GIS databases.

While this chapter discussed many aspects of proper site due diligence from a contractor's point of view, readers are strongly urged to expand their site due diligence understanding by reviewing the references provided in this chapter and visiting the websites discussed in the text.

QUESTIONS, PROBLEMS, AND EXERCISES

1. When does the site due diligence process begin?
2. Explain why every construction project site is considered unique.
3. Why is it important for a contractor to visit the project site location during the bidding/estimating phase?
4. How can improper site due diligence impact construction costs? Give examples.
5. How can historical site locations impact the construction process?
6. Give examples of site constraints and how they can impact construction.
7. What is radon gas?
8. How can previous site usage provide potential hazards for new construction projects?
9. Why is it vital to have a good relationship with adjacent property owners and tenants throughout all phases of the construction project?

NOTES

1. North American Datum of 1983 (NAD83) is an earth-centered datum based on the Geodetic Reference System of 1980. The size and shape of the earth was determined through measurements made by satellites and other sophisticated electronic equipment; the measurements accurately represent the earth to within two meters. Source: http://www.towermaps.com/nad.htm.
2. Impact fees are the costs associated with public utilities and the impact that the project will have on the local services provided by the municipality. These fees can include support for sanitary sewer expansion, electrical services expansion, water services, fire and emergency services, road improvements, public school construction, and so forth. Visit www.impactfees.com to start accessing information on local impact fees broken down by state, county, and city location.

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CHAPTER 4

SITE ORGANIZATION AND LAYOUT

James O'Connor

INTRODUCTION

Can Web-Based Tools and Computer Applications Assist Us?

An efficiently organized construction site layout has a significant impact on the productivity, material handling, logistics, costs, and overall duration of a project. A good site layout is vital to ensuring a safe work environment and effective and efficient construction operations. It is the contractor's task to plan his choice of temporary works, buildings, and services. The site layout is usually planned in detail during the precontract period and updated during the construction phase.

EFFICIENT SITE ORGANIZATION AND LAYOUT CONSIDERATIONS BEFORE CONSTRUCTION

What is Efficient Site Organization and Layout?

Construction site layout planning involves the identification, sizing, and positioning of temporary and permanent facilities within the boundaries of a construction site. Temporary facilities include office accommodations, storage facilities, and personal hygiene areas. It is important that the project manager visit the site before construction in order to ascertain the following:

- Size of the site (total area available for building, etc.)
- Location of the site (brownfield city location or greenfield)
- Size and location of the proposed buildings and areas to be demolished

The site manager also needs to assess the construction project in order to determine the following information:

- Accommodations required
- Material storage requirements
- Plant required
- Access availability
- Construction sequence (if a number of buildings are being constructed).

To plan the site layout, it is necessary to have drawings showing the site boundaries, the existing buildings and services, the proposed buildings and services, and the proposed site development.

Building contractors are usually carrying out their work on other people's premises. That is to say, the premises are normally either owned by or controlled by someone other than the building contractor. It is therefore important to clearly identify the site before starting work.

Figure 4-1. A typical site setup during construction.

The work instructions or contract documents should adequately define the site, but if there is doubt, clarifying information should be requested. Once the site is clearly identified and the contracts have been signed, the client and the contractor must agree on the start date. The contractor then can formally take possession of the land or premises to occupy it for his work. However, it is important to establish both the right to occupy and the date and time for occupation as it is usually expected that responsibility for the site or premises passes to the contractor when he takes possession.

After taking possession of the site, one of the first actions then is to identify and secure its boundaries, which should be done immediately for the following reasons:

1. **Warning**. To let the public know, especially children, of the potential danger. Some people, unless warned or restricted, will feel free to walk around building sites "just out of interest . . . to see what is going on." Children, of course, see a building site as an adventure playground.
2. **Security**. To keep out vandals and thieves.
3. **Control**. To set the limits of the work area for site personnel.

Key Factors That Influence Site Organization and Layout

There are a number of factors that influence the contractor's site organization and layout, including:

- The amount of available free space in the contractor's possession outside of the building footprint
- The space allocated by the client for site organization facilities on the drawings
- The locations of the existing buildings on the site and the building to be constructed

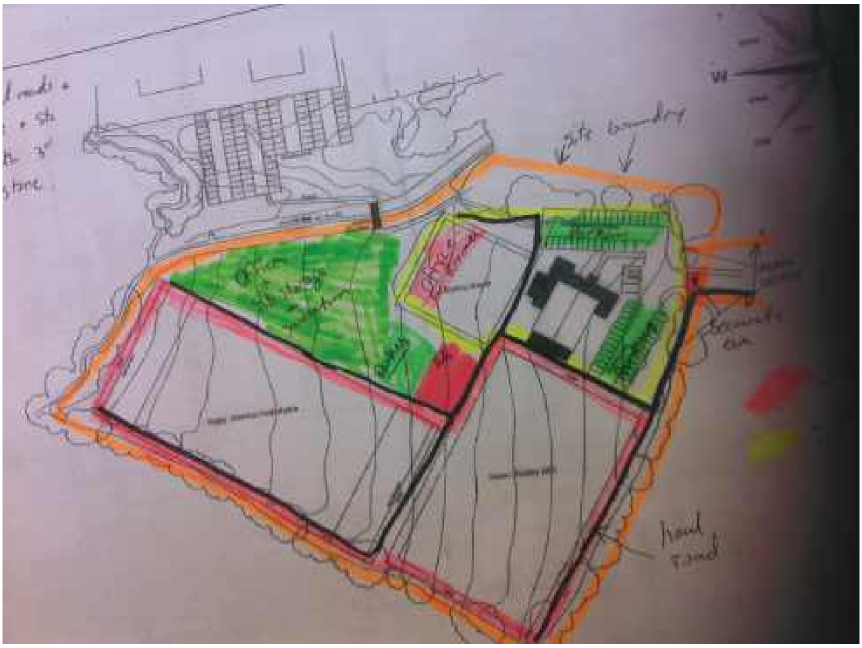


Figure 4-2. Planning the site layout before construction starts.

- The location of the material storage areas and requirements
- The location of plant areas
- The location of the site offices
- The location of temporary services
- The location of fencing and hoarding
- Construction waste considerations
- Site access and exit considerations
- Health and safety considerations

Traditionally, when the contractor's site layout is drawn, a transparent overlay and/or cut-outs are used to achieve the most efficient and effective layout. This may also be carried out digitally using various software packages. The following elements should be considered:

- Space for the use of a crane (*cranage* in Ireland and the U.K.) and other plant needs
- Site accommodations and material storage
- Communications
- Access
- View of the work
- Security
- Noise
- Setting out grid
- Other considerations

Figure 4-3. Assessing the nearby road network around the site for access into the site and material storage.

THE SITE BEFORE CONSTRUCTION AND THE SITE VISIT

Site clearance work will depend on the obstructions existing on the site when the contractor takes possession. This work may involve demolition of buildings or other structures, felling and removal of trees and shrubs, and removal of undergrowth and other unwanted debris. In other words, the work includes all that is necessary to enable the structure to be built in the designated area and for the remaining site area to be used for accommodation, storage, and movement. Clearing the site beforehand makes it possible to more efficiently designate the spaces on the preplanning site plan for temporary accommodations, materials storage, prefabrication, major fixed plant areas, and surface movement routes, some of which are seen in figure 4-5.

Temporary roads cost money both to build and to remove. Consideration of the extent and cost of their provision has to be weighed against the likely improvements in productivity arising from uninterrupted and efficient surface movement of the plant equipment and materials around the site.

If the construction duration is short, the work is to take place during dry summer months, and the surface soil is firm and well drained, there may be no need to construct temporary roads. Also, if permanent roads are part of the work of the project, then the base of these can be laid and used as site transport routes during the construction period.

Figure 4-4. The site before construction. What does it look like; what are the ground conditions; are there neighbors in close proximity?

Figure 4-5. Typical site setup during construction on an Irish construction site.

SITE BOUNDARY, SITE ACCESS SECURITY, AND SIGNAGE

Site hoarding (a close-boarded or panelled barrier in Ireland and the U.K.) provides a solid barrier that gives maximum protection from site operations to passersby and, if built high enough, makes it difficult for intruders to enter the site by climbing. Normally, a site boundary is marked and secured by means of hoardings that are commonly 6 to 8 ft high (1.8 to 2.4 m, see figure 4-6). The panels may be of 1-inch-thick (25 mm) sheathing-grade plywood or corrugated galvanized steel sheets. Plywood panels may be individually nailed to 2 inch x 3 inch (50 mm x 75 mm) timber framing or nailed to 2 inch x 4 inch (50 mm x 100 mm) timber waling rails. Fences are usually constructed out of stout wire mesh fastened to vertical posts (typical in the United States, see figure 4-7). Height and strength of construction depend on the degree of security required.

Signs

First and foremost, signs are intended to attract people's attention and then to tell them something. Some thought therefore should be given to their design, construction, location, and erection. Well-designed and erected signs give a good impression of the organization in charge of the site; and, conversely, poorly constructed and badly erected signs will create a poor impression.

Signs are placed on and around building sites in order to:

- Enable visitors and delivery vehicle drivers to locate the site and place of entry
- Tell the public about the work.
- Warn visitors and site staff of possible hazards
- Advertise the names of the contractors and others connected with the work. A well-signed and tidy site is the equivalent of good packaging for consumer goods and the most powerful advertising medium for a builder. Architects and other consultants can usually provide standard-sized name boards (4 ft x 1 ft; 1.2 m x 0.3 m) for incorporation onto the main contractor's board.

When erecting signs, it should be remembered that most visitors and all deliveries arrive by road vehicles, and appropriate signs should be placed so as to be visible to vehicle drivers before they reach the site.

Site Security

The prevention of damage and theft should be considered when planning a site layout. Security precautions should aim to protect valuables on the site by preventing access by professional criminals, opportunist thieves, vandals, and the curious.

The typical methods used for preventing damage and theft will depend upon the following considerations:

- The location of the site. A site in an urban area is likely to be a target for vandals and thieves.
- The geography of the site. A site that is spread out and open is more likely to suffer theft than a compact site where closer control of materials can be exercised.
- The type of goods stored. Items that are small and easily carried are more likely to be stolen than large awkward goods, but valuable items are targets for theft irrespective of their size.

Figure 4-6. Typical hoarding: A solid perimeter barrier on a construction site in Ireland.

Figure 4-7. Typical fencing with concrete traffic bollards on a construction site in the United States.

Figure 4-8. Typical site safety signage used during construction.

Types of Protection

- Perimeter barricades should be open fencing, whenever possible, which enables intruders to be observed.
- Provision for access security should strive to have only one gate for entry and exit.
- Gates should be lockable and non-lift-off.
- The office for the material checker/store manager/static security guards should be located at the site gate and have a window that provides a clear view of all entering and exiting.
- Secure storage areas for items such as tools and fuel should be erected.
- Surveillance of the site should be done by a patrolling security guard employed by the contractor or an outside security firm or by using Internet surveillance systems.
- Illuminating storage areas and offices at night can deter intruders by enabling them to be seen by security and passersby.
- Parking lots should be positioned away from storage areas and be visible from the site supervisor's office.
- The plant should be immobilized when not required for use.
- Keys should be issued on a limited basis and require a signature to obtain them.

Access

Most new building construction requires deliveries to the site of considerable quantities of heavy and bulky materials as well as the removal of demolition or excavation debris. In addition, large and heavy equipment may have to be brought to the site and taken away on completion. Access therefore must be provided to the site for large and heavily loaded road vehicles.

Before ordering heavy materials and equipment, the builder should check the access to the site from the nearest main public road, looking for obstructions in width, height, and vehicle-turning radius. In addition, the likely effects of heavy construction traffic on nearby roads and bridges as well as any services buried beneath the road (sewers, gas lines, water mains, etc.) need to be assessed.

If there is any doubt about the ability of a road to carry the expected traffic, the local highway authority should be consulted for advice. If normal loads are expected or delivery vehicles need to off-load from a busy road adjacent to a site, the builder should contact local police, who may agree to control traffic or restrict public parking. It is an offense to allow vehicles to deposit mud onto a public road. When vehicles are leaving a muddy construction site, arrangements should be made to either clean the wheels by hosing with water or to clean any mud from the road. This can be done by erecting a wheel wash at the exit or manually using power washer shovels and brooms. It also may be necessary to consider using motorized sweepers on the roads outside the site.

Figure 4-9. What site access is available into the construction site? Is there a clear view for drivers? Is the gate wide enough to take the deliveries expected during construction?

SITE CLEARANCE AND TEMPORARY ROADS

After taking possession of the site and erecting boundary fences, gates, and signs, the next tasks are usually site clearance and temporary road layout. The temporary road layout should be planned while taking into account the location of the new buildings, temporary and permanent services, site offices, and material storage areas. The topsoil is stripped from the site and stored. The temporary roads are then constructed by stripping the soil to the required depth, depending on the weight of anticipated construction traffic, and covering it with a geotextile isolating membrane such as Terram. The temporary road surface is then laid using a combination of crushed stone and 616 (base material to large stone) and 804 (0 to 3 inches) aggregate, or whatever material is available. Where temporary roads and material storage areas are being constructed in the future permanent road location, the permanent road construction should be as specified in the contract documents by the engineer. The top layer of stone in this area then can be scraped off and redressed to take the top layers of macadam or concrete when constructing the permanent roads.

TEMPORARY SITE ACCOMMODATION OFFICES, WELFARE FACILITIES, AND NEW AND EXISTING SERVICES

The organization and layout of the site offices are extremely important to the practical day-to-day operations of the project. The location of the site offices and welfare facilities should enable efficient, practical management of site personnel through the eyes of the PM.

Figure 4-10. Temporary construction road layout built on the location of the future permanent roads.

Site offices are a temporary item and can be relocated if desired. Site offices and welfare facilities are usually the first things installed on the site. It is necessary to provide shelter from the weather for site personnel to enable them to do their work effectively and efficiently. Temporary site buildings may be purchased and owned by the contractor or leased for the duration of individual contracts. Portable cabins or converted steel shipping containers can be used as temporary office structures. The offices need to be centrally located for all members of the workforce. A good location can increase security and productivity on the construction site. The stacking of site offices can be an economical solution if space is limited.

The two most common forms are ready-made and finished mobile or portable buildings. The smaller sizes may have a chassis and road wheels for towing between sites, while larger units must be craned onto and off road vehicles for transport. Almost all temporary buildings have jacking legs for leveling them on uneven sites and may be ready-wired with socket outlets and fittings for electricity and telephone outlets. The quality, security, finishes, and construction are extremely high in more expensive types and compare favorably to good-quality permanent offices.

Separate offices equipped with a desk, chairs, filing cabinets, a computer, drawing racks, and a telephone are usually provided for:

- Project manager/construction site manager/site agent
- Superintendent/general foreman
- Site surveyor or cost engineer
- Site engineers
- Section or trades foreman
- Meeting room
- Subcontractors' offices and stores
- Store man/site clerk
- Other

Figure 4-11. Typical site office layout on an Irish construction site.

Figure 4-12. Typical site office layout on an Irish construction site.

Offices are preferably sited close to the main road entrance to the site for ease of access by visitors and to enable readily controlled entry and exit to the site. The windows in the site supervisor's office should, if possible, provide a view of the whole site, particularly the building work. The material checker/store man/static security guards' office obviously should be placed alongside the site gates to facilitate monitoring site deliveries, among other things. On large sites, especially where designated subcontractors are employed, a separate conference room may be provided for site meetings, safety training, and so forth.

Welfare facilities should comply with legislation that defines the minimum standards of provision. In Ireland, the Construction (Health and Welfare) Regulations outline the requirements for canteens and washing and drying facilities, but similar requirements may exist elsewhere. The provision of these must be in proportion to the number of personnel on the site throughout the building process.

TEMPORARY SERVICES LOCATIONS: WHERE ARE THEY AND WHAT IS PROPOSED?

Early identification of services that are available at the site is extremely important in relation to safety and the needs of the project. All temporary works need water, telephone, broadband, sewerage, and electricity to operate efficiently. Temporary connections are made by the suppliers of these services and the local authority.

Applications for temporary services should be made to the appropriate supplier sufficiently in advance of commencing work as to ensure connection when required. At the preconstruction planning stage, the required demand for each service should be determined, and then, in conjunction with the supply authority, the nearest permanent supply source to the site should be located and its capacity established.

Service suppliers normally charge the full cost of providing temporary installations for building projects to the contractors. Therefore, it is frequently more economical to have a permanent supply installed to the site boundary, for which the client pays, if time permits. A temporary connection to the site then can be made for the duration of the project.

In order to decide on a site layout, it is important to consider the location of temporary and permanent service routes on the site. Before work commences, these relevant service providers should be contacted:

- Electricity—buried cables and overhead cables
- Telecom—Wi-Fi buried cables and overhead cables
- Gas—buried gas mains
- Local authority—buried water mains, sewers, and stormwater mains
- Cable TV providers in the area—buried and overhead cables
- Other services—as required

Before excavating the area, a search for signs of these services, such as manholes, minipillars, existing services, old trench repairs, and so forth, should be carried out. A CAT and Genny (radiodetection equipment) should be used to locate buried cable services. If required, erect goal posts and bunting to warn machine operators of overhead lines.

Water

Application for water supply to the site must be made to the local authority or water provider. The application is normally in writing and is usually accompanied by a site plan on which the proposed point of entry for the water supply and capacity required is marked. The authority's supply pipe will normally terminate with an in-line meter having isolating valves on either side along the site boundary. The builder can then connect his site service pipe to the supply pipe.

Electricity

Application for electricity supply must be made to regional power providers. The application process is normally in writing and accompanied by a site plan on which the proposed point of entry for the supply and details of the demand load in power and voltage is marked. Check with the local supplier for their requirements.

The board's supply cable (240-v single phase or 415-v three phase) will usually terminate with an isolating fuse and meter housed in a freestanding box at the site boundary. When the builder has installed his site electrical services, they will be tested by a board engineer and if found satisfactory will be connected to the main supply.

For safety reasons, it is recommended that a unit distribution system be used for temporary site services. This should be planned and designed as part of the site organization and layout and updated as conditions change during construction. Such a system separates the 415-v, 3-ph supply to heavy plant, the 240-v site office supply, and the stepped down 110-v power tool and lighting supply to construction areas.

Sewage Disposal

Application for a connection to a public sewer must be made to the local public works authority or sewer district. The application must be in writing and accompanied by a site plan showing the position of the proposed connection. If, as is usual, the sewer is beneath a public road, application must also be approved by the office with jurisdiction for public roads. Some local authorities may allow builders to make the sewer connection, while others will insist that their public works departments carry out the work.

EFFICIENT SITE ORGANIZATION AND LAYOUT CONSIDERATIONS DURING CONSTRUCTION

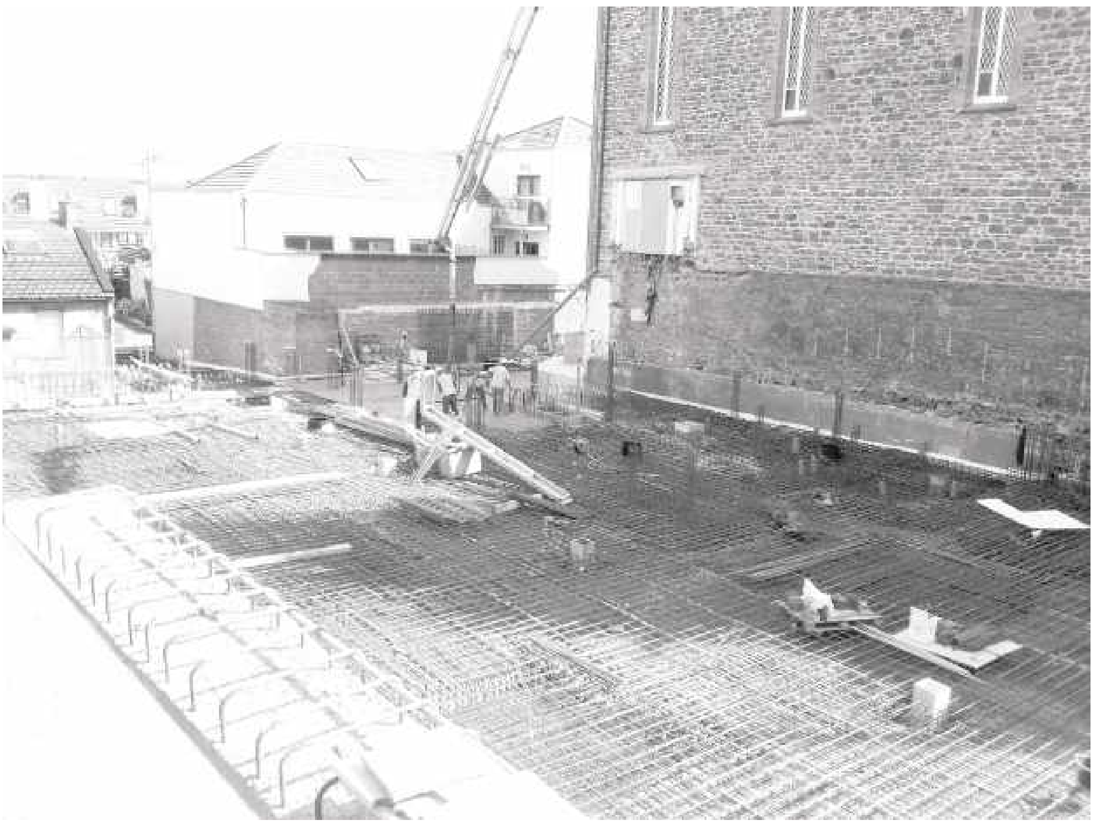


Figure 4-13. The building site during construction.

Figure 4-14. The building site during construction.

Figure 4-15. Cranage on the building site during construction.

MATERIAL STORAGE AND PLANT ALLOCATION AND ITS INTERFACE WITH SITE LAYOUT

Material Storage Areas

The material storage area is required for safety, waste reduction, security, and safe delivery and storage of construction materials. Any site of notable size will require the provision of a substantial material storage yard or compound, which will change as construction progresses on the site. The material storage yard or compound can be located within the site boundaries or off-site; however, it is more beneficial to have material stored as close as possible to its final place of use to avoid double handling and damage. There are a number of organizational benefits of having a material storage compound:

- It provides waterproof shelter for timber, cement, perishable items, etc.
- It provides planned and organized material storage as close as possible to the area of use.
- It provides a safe storage area for combustibles such as oxyacetylene gas, paint, and chemical substances used within the construction process.
- It eliminates theft to a certain degree.
- It can provide illumination of the storage area, if required.
- It provides security for valuable materials or goods.
- It prolongs the shelf life of perishable materials.
- It can seal off the storage area from public view.
- It assists in good productivity on the site.
- It can prevent waste or damage to materials if the storage area is prepared properly for the material being stored.

Organization and Layout of Plant and Machinery Compound

The plant and machinery storage requirements will vary throughout the construction contract as the project progresses. An excavation or concrete formwork contractor will require considerably more space than other contractors for plant and machinery. The location of the plant and machinery yard can prove to be beneficial or detrimental to the build. The following points need to be considered when deciding on the layout of the plant and machinery compound:

- The size and number of plant items and machinery need to be considered.
- Fuel and oil storage areas for the plant need to be taken into account.
- A storage compound for plant and machinery would prove beneficial as it controls the use and allocation on-site and assures that it is safe when not in use.
- An off-site location for a plant yard could be considered if there is limited space on the site.
- The proximity of the site to the compound needs to be addressed.
- Security issues need to be addressed.
- A good compound layout can increase efficiency, improve logistics, and decrease lost time.

Figure 4-16. Typical site material storage and layout on an Irish construction site.

Figure 4-17. A building site during construction.

- The location should enable better control of environmental noise.
- It may be beneficial to create a phased plant and machinery storage plan as work progresses.

Construction Waste Considerations and Their Interface with Site Layout

The disposal of construction waste needs to be an accommodation within the site layout. Wasting materials increases the cost of the project and decreases the amount of profit. Current legislation in Ireland and other locations throughout the world requires each contractor to develop a waste management plan for the construction project. The plan identifies and evaluates the waste on the site and proposes strategies to deal with the waste. The effective use of segregated skips (dumpsters), employee training, and so forth leads to a cleaner site, resulting in fewer injuries. It also promotes good practical use of materials and general health and safety on the site while also saving money due to waste reduction. There are a number of organizational benefits of using proper waste collection and recycling areas.

- Waste should be kept to an absolute minimum.
- Close observation should be maintained to ensure unnecessary wasting of materials.
- Placing skips in proper areas can help with access and exit of delivery and collection of waste.
- Separate skips for recyclable materials raises awareness and promotes good material usage among site personnel.

PUBLIC RELATIONS

Most people want the improved facilities that new buildings bring but do not want construction work near their homes; consequently, they consider building projects a nuisance. Therefore, builders are frequently unwelcome visitors to the local residents. It pays to give some attention to relations with the public and especially nearby residents, if only to avoid hostile action that might delay the work. Public relations should be considered when the site layout is being developed. The following list shows some things that can be done to improve public relations during a project:

- Be friendly, talk to the public, and listen to their concerns.
- Emphasize the transient nature of the work by showing drawings or a model of the finished building.
- Satisfy the public's curiosity (provide viewing panels or organize escorted visits).
- Try to avoid creating safety hazards (especially to children), such as unfenced holes and gaps in site fences, mud and obstruction of footpaths, excessive noise, nuisances, and excessive dust from heavy traffic on the roads.
- Incorporate personal vehicle parking for site workers on the site in order to avoid cars being parked outside nearby houses.
- Educate workers on the effects that loud swearing and catcalls by site workers can have on the public.

SITE ORGANIZATION AND LAYOUT USING WEB-BASED TOOLS AND COMPUTER APPLICATIONS

Introduction to Web-Based Tools and Computer Applications (Google, AutoCAD, BIM, Revit, etc.)

Site Organization and Layout using Google Maps

In recent years, there have been many advances in web-based tools and software packages that can assist with preparing the site organization and layout plan. The construction team responsible for planning the site layout can use these new technologies to replace the manual use of transparent overlays or cutouts to achieve the most efficient and effective layout. The following sections explain how some of these applications can be used.

Visiting the Site Using Web-Based Tools

In recent years, technological innovation has led to the development of web-based tools and software. Google first made this technology available, particularly with the following products:

- Google Maps
- Google Earth
- Google Street Finder

The following screenshots, figures 4-19 through 4-22, which are Google Maps 1, 2, 3, and 4, respectively, show how to access Google Maps. How to zoom in to a specific location to see a road map of the area is also illustrated.

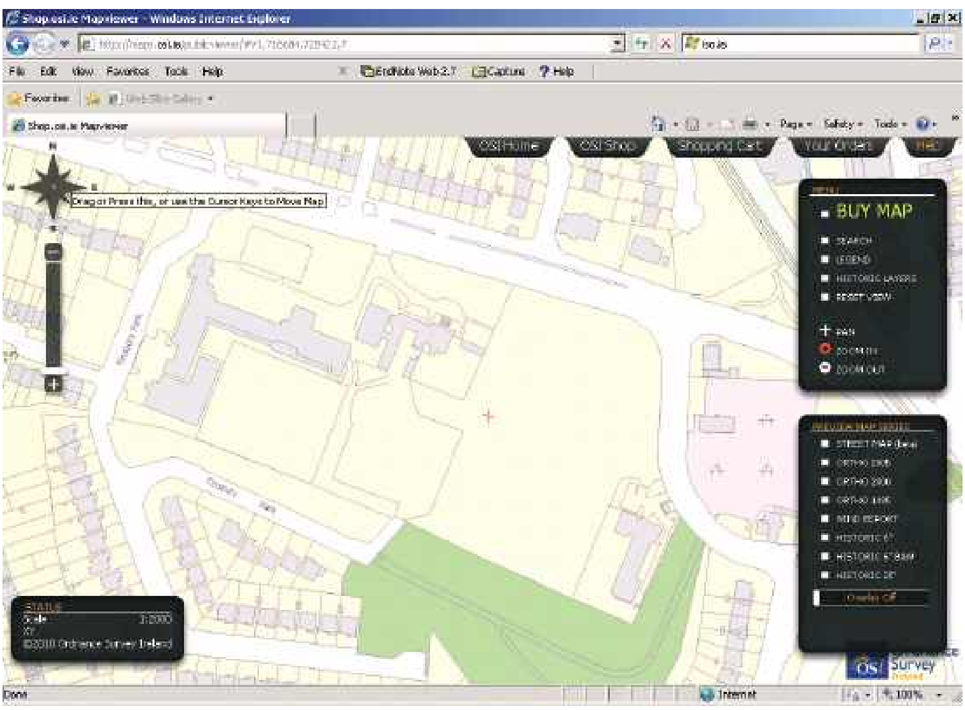


Figure 4-18. Site layout using Ordinance Survey Maps (www.osi.ie).

Accessing Google Maps

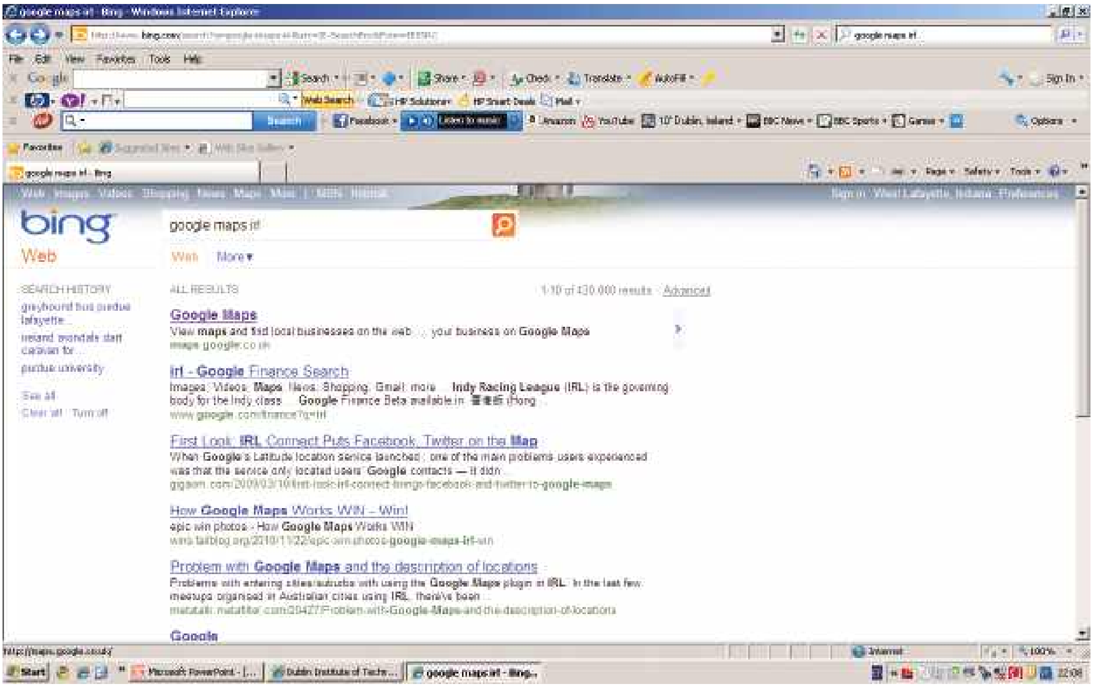


Figure 4-19. Accessing Google Maps 1 (search browser for Google maps).

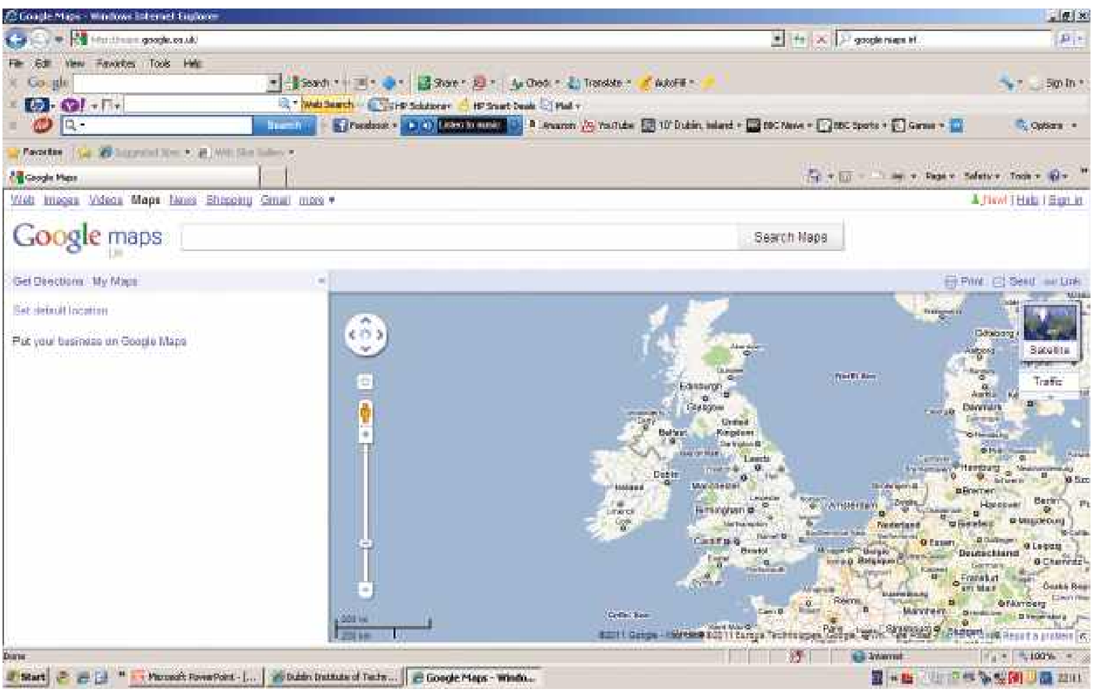


Figure 4-20. Accessing Google Maps 2. Zoom in on country, in this case Ireland.

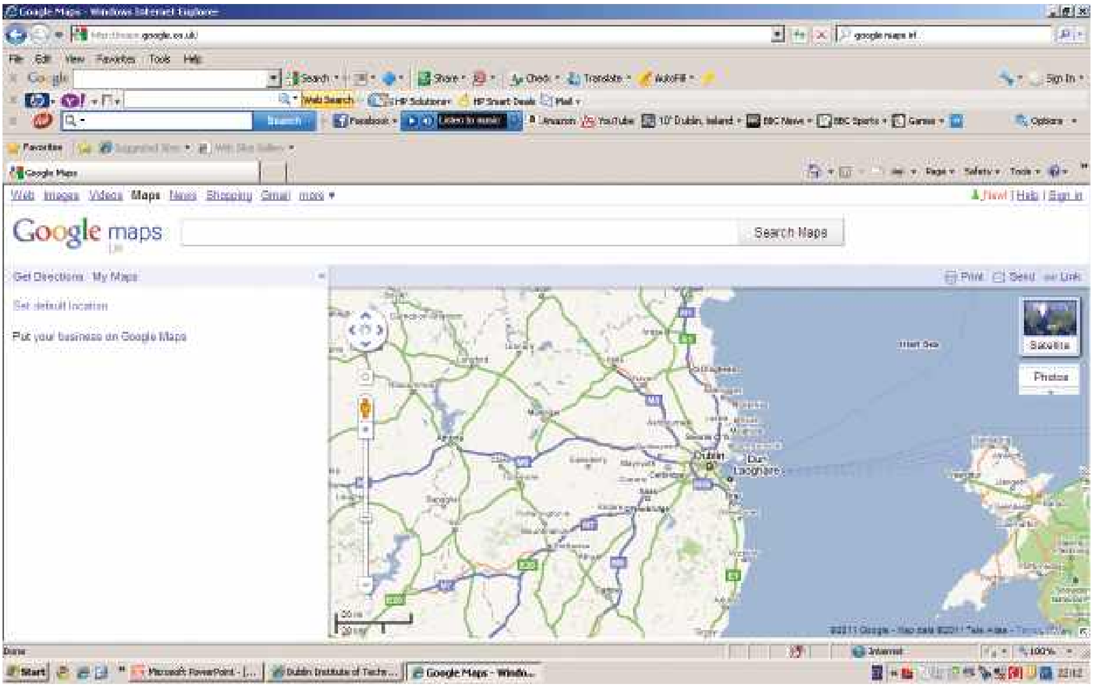


Figure 4-21. Accessing Google Maps 3. Zoom in on place, Dublin.

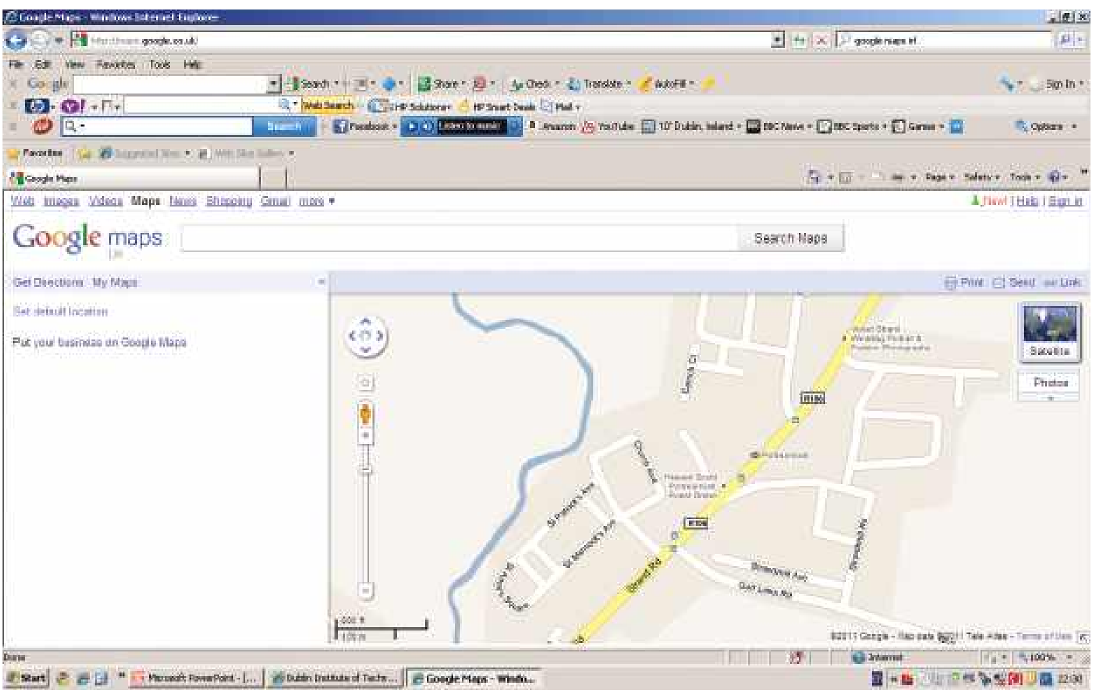


Figure 4-22. Accessing Google Maps 4. Zoom in on streets.

Google also developed another web product, Google Earth, which provides a real-life satellite picture of the area for which the planner searches. The following screenshots, figures 4-23 through 4-26, Google Earth 1, 2, 3, and 4, respectively, show how to access Google Earth.

Accessing Google Earth

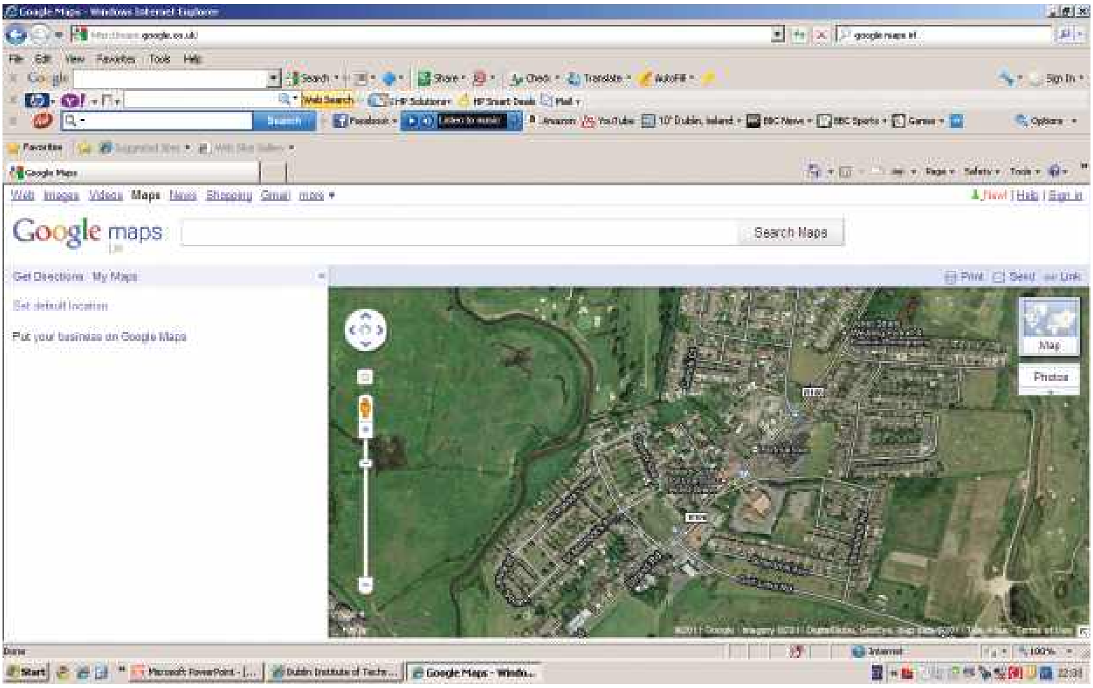


Figure 4-23. Accessing Google Earth 1. Load Google Earth into the search engine.

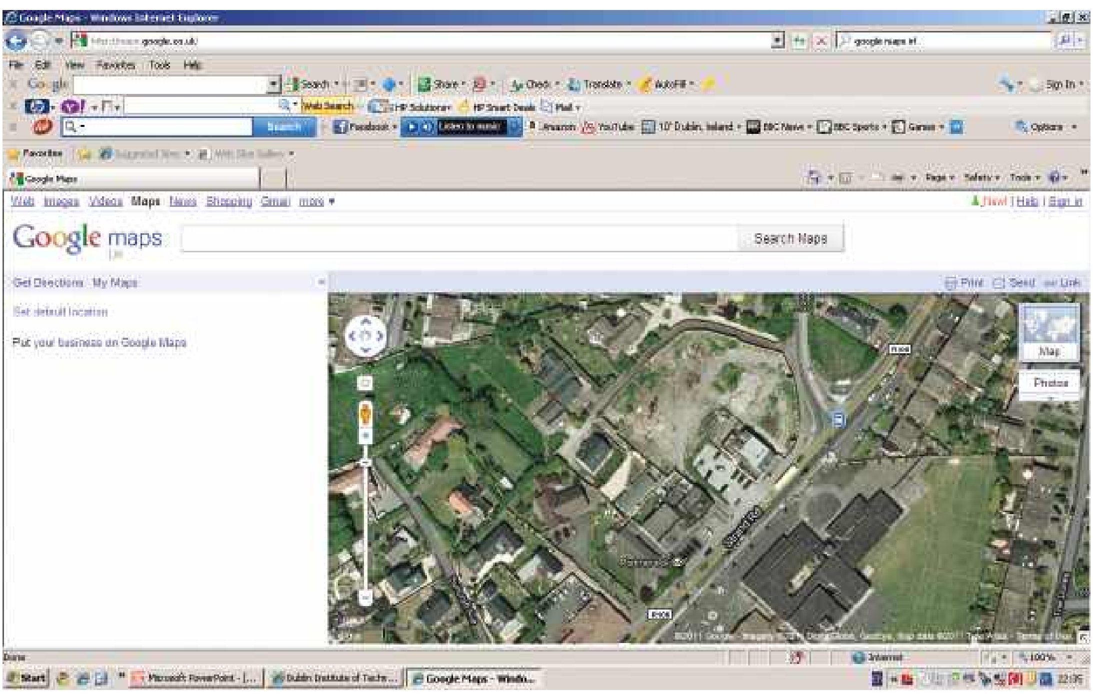


Figure 4-24. Accessing Google Earth 2. Zoom in on area.

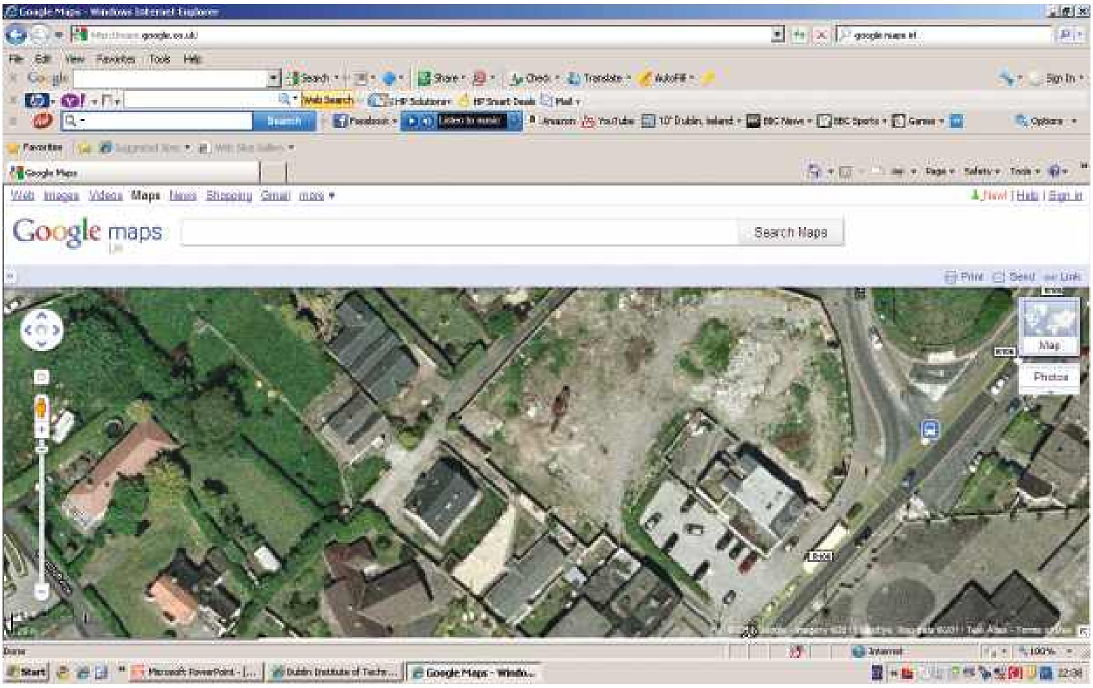


Figure 4-25. Accessing Google Earth 3.

Figure 4-26. Accessing Google Earth 4.

A screenshot from Google Earth can be taken and marked with various colors to highlight the site boundaries and surrounding network as per figures 4-27 through 4-29.

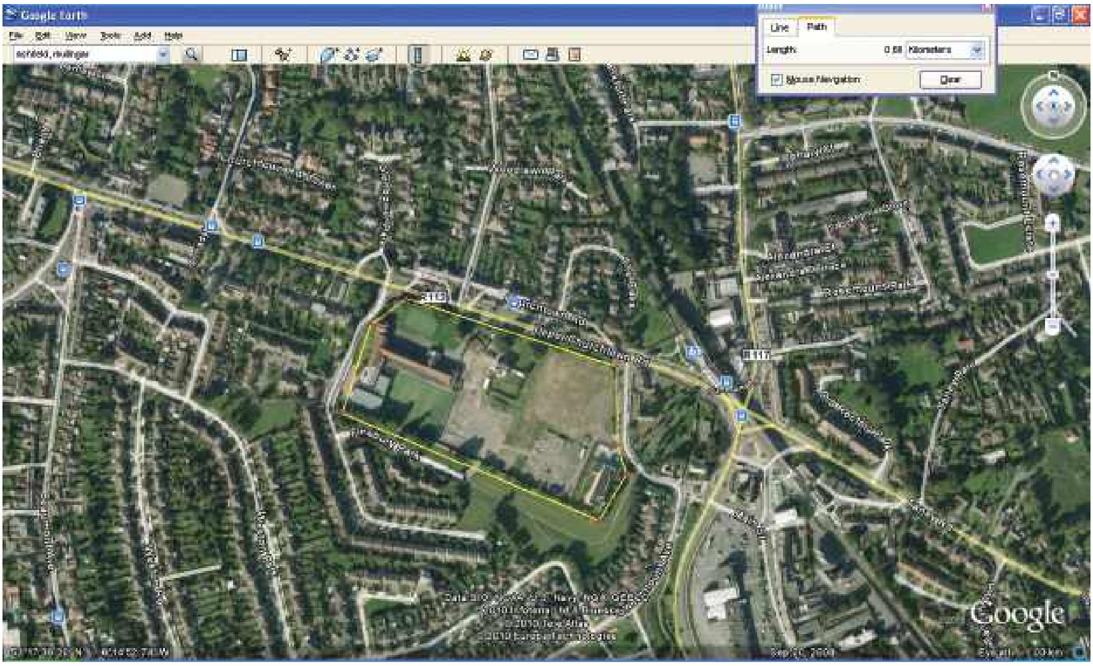


Figure 4-27. Using the Google Earth screenshot of the proposed construction site, the construction site boundaries are highlighted in yellow.

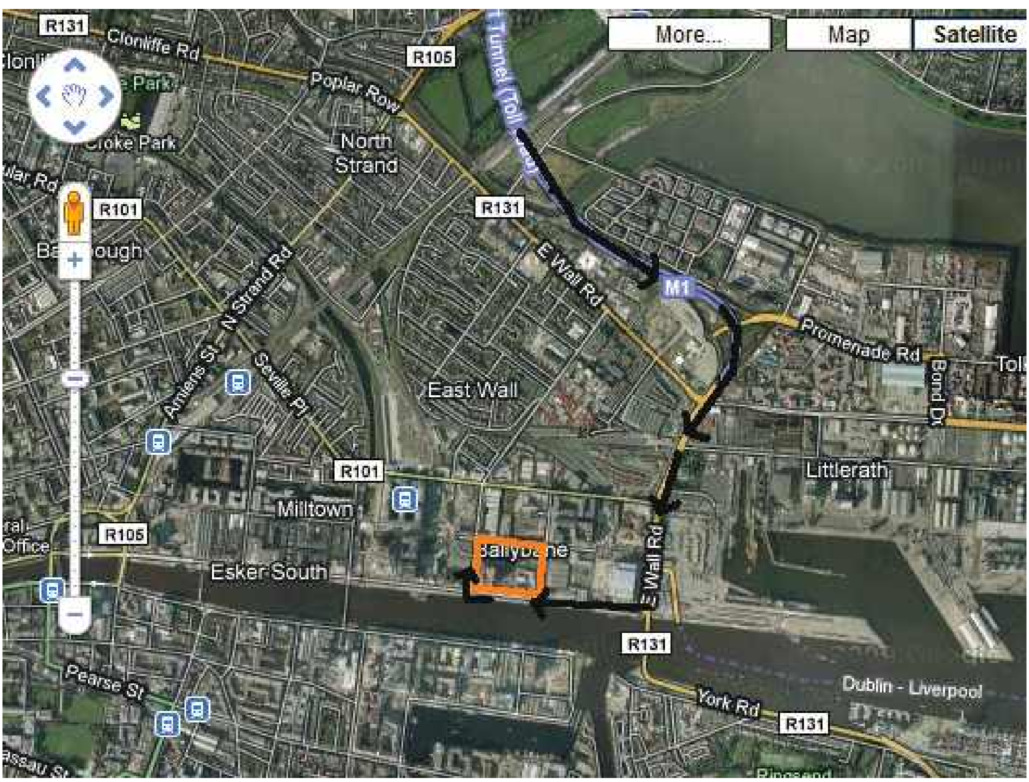


Figure 4-28. Using the Google Earth screenshot of the proposed construction site, the construction traffic access route from the tunnel is highlighted in black.

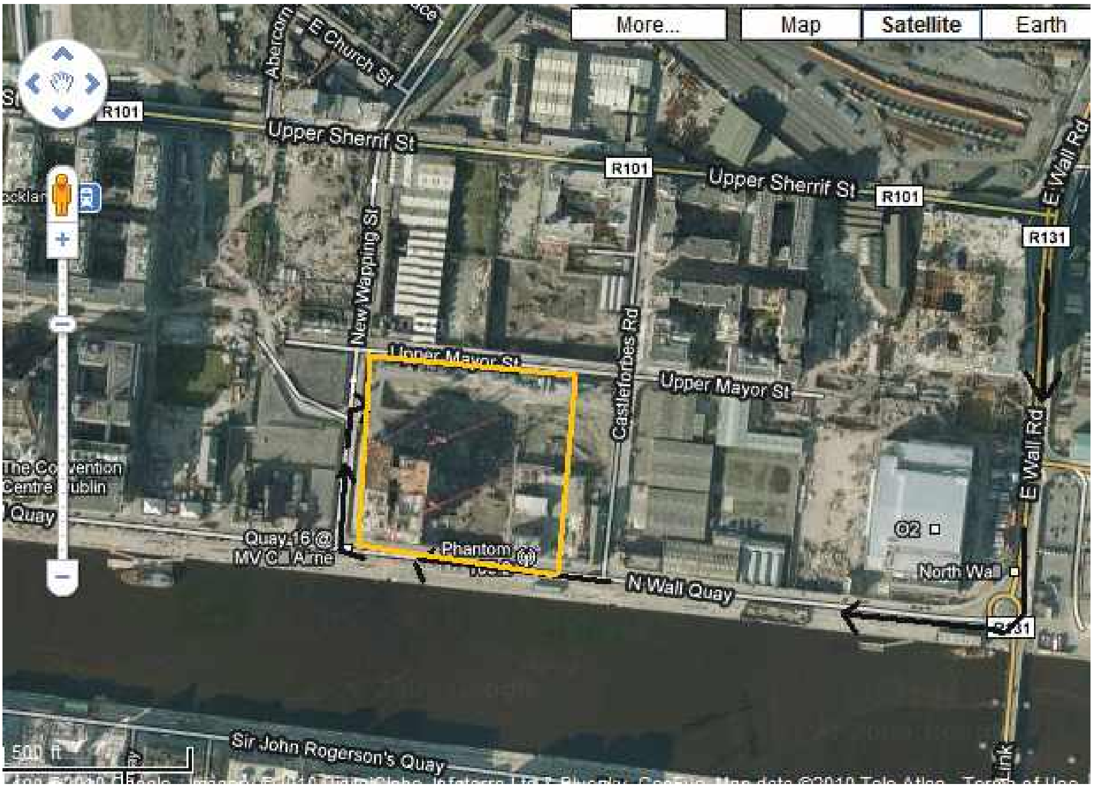


Figure 4-29. Using the Google Earth screenshot of the proposed construction site, the construction site boundaries are highlighted in orange on a zoomed-in view of the surrounding streets.

Site Layout Using Google Maps: A Worked Example

The management committee of a local church and school have approached you, as a DB contractor, to build the following buildings and ancillary works on a site that has been donated to them by a local benefactor. The management committee provides you with the following site plan and drawings for a building that they were going to construct three years ago on an alternative site, which did not go ahead because of legal issues with the site.

The following assumptions have been made for this example:

- The church and school buildings are to be built on the site as shown.
- The ball court, parking, and junior and grass play areas can be altered on the site upon agreement with the architect and client to take into account the new site location.

As the DB contractor, you are required to prepare a site organization and layout plan for the project using Google Earth.

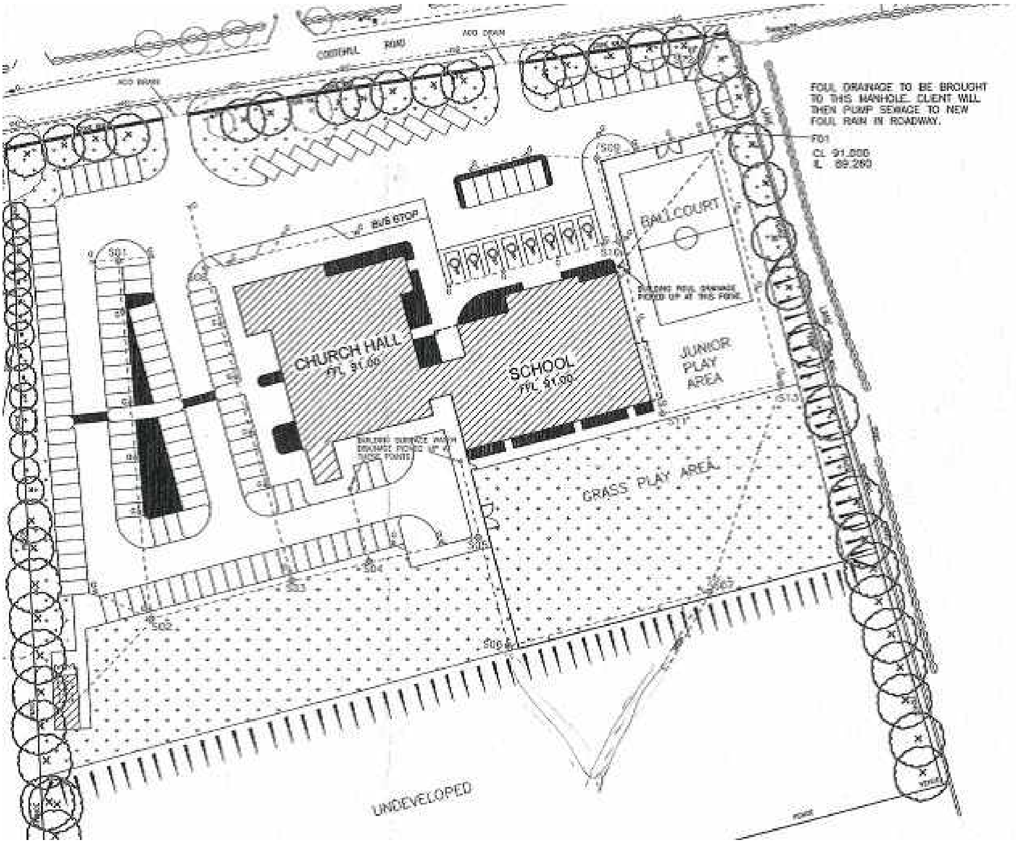


Figure 4-30. A plan of the proposed church, school, and ancillary works including parking, a ball court, and play areas, which the management committee planned to build on an alternative site three years ago.

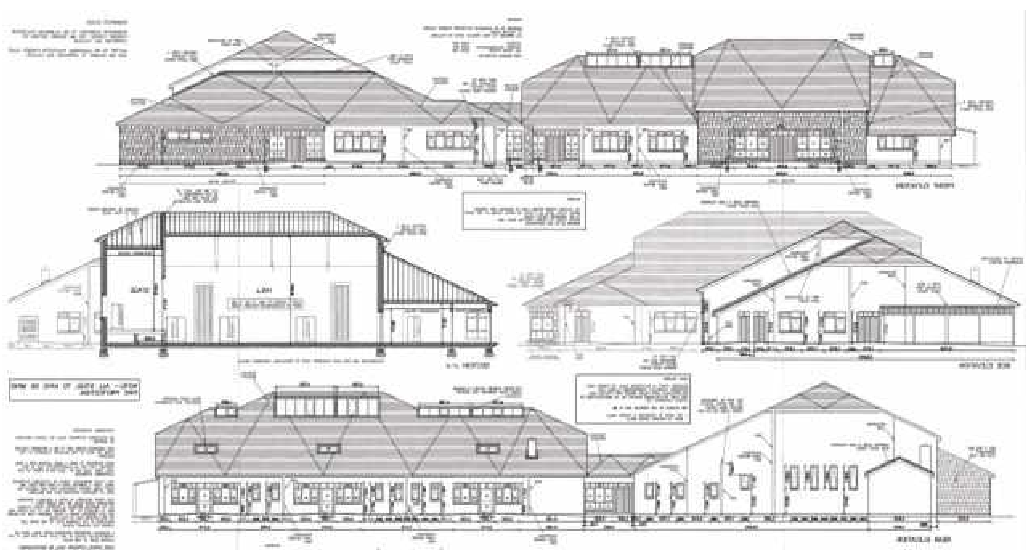


Figure 4-31. Elevations of the proposed buildings, which the management committee had planned to build on an alternative site three years ago.

The first task is to zoom in on the new site using Google Earth and then identify the site boundary, as shown below in yellow in figure 4-32.

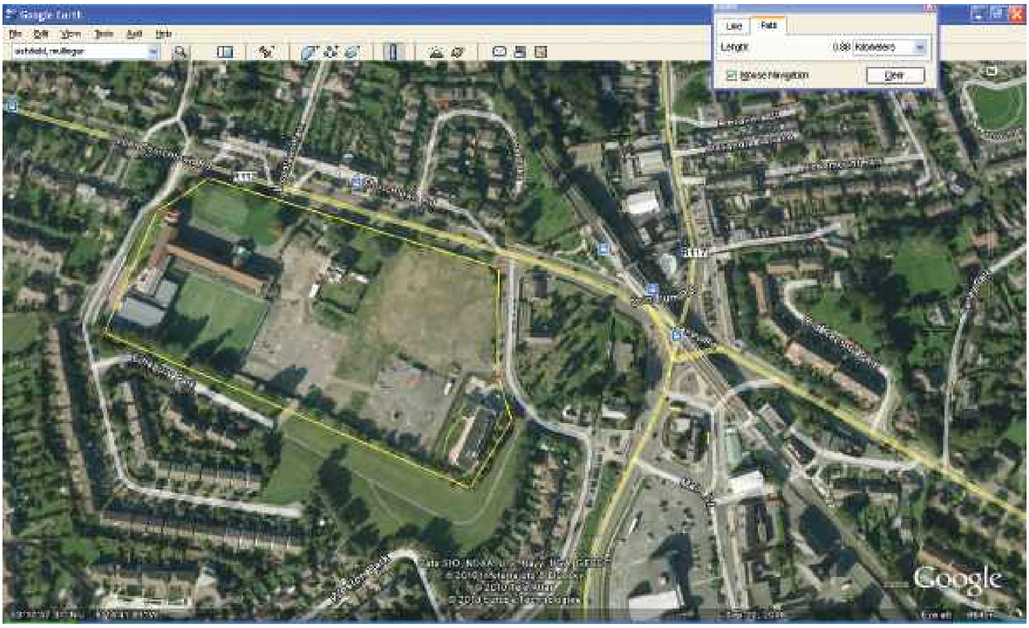


Figure 4-32. Establishing the site perimeter electronically for the proposed building on the newly donated site.

Google Earth also can be used to identify the site traffic flow and local road layout beside the construction site as shown in figure 4-33. The local council can often also provide information on traffic flows around the site at various times during the day.

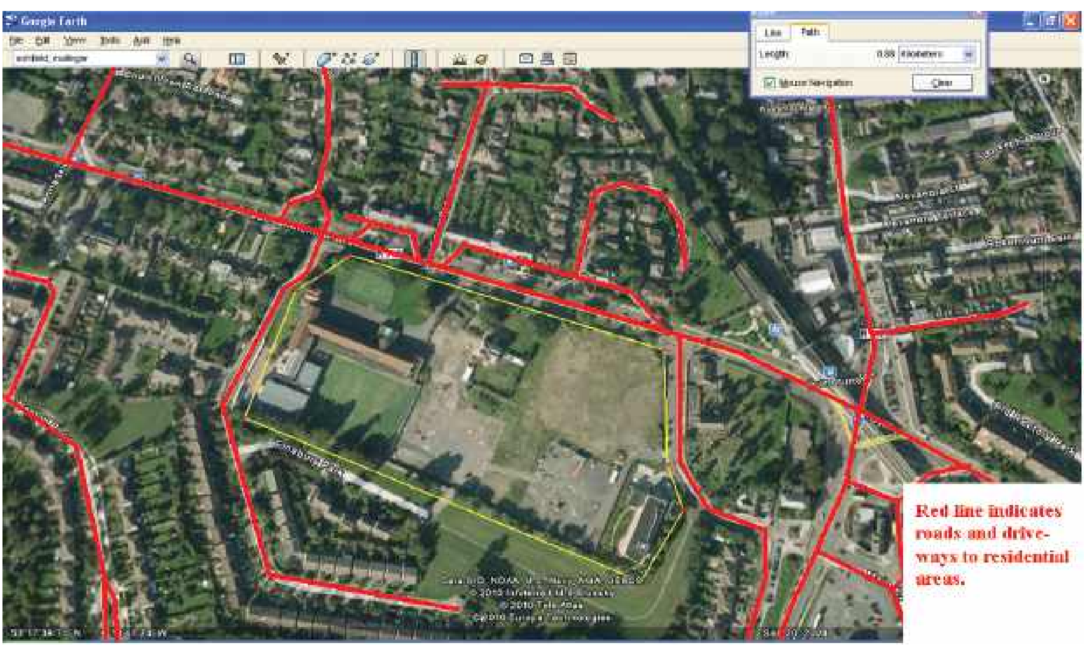


Figure 4-33. Site traffic flow using Google Maps.

The next task is to overlay the buildings on the site as shown in figure 4-34. This can be done using a scaled AutoCAD version of the building or scaled in the relevant locations as shown in figure 4-34. Red line indicates roads and driveways to residential areas.

Figure 4-34. Overlay of the buildings on the site. This was done using a scaled version of the building put in the relevant locations on the site. Note that some of the parking, ball court, and play areas have changed locations with the agreement of the architect and the client.

The next task is to decide on the access, temporary roads, storage, and office areas as shown in figures 4-35 and 4-36.

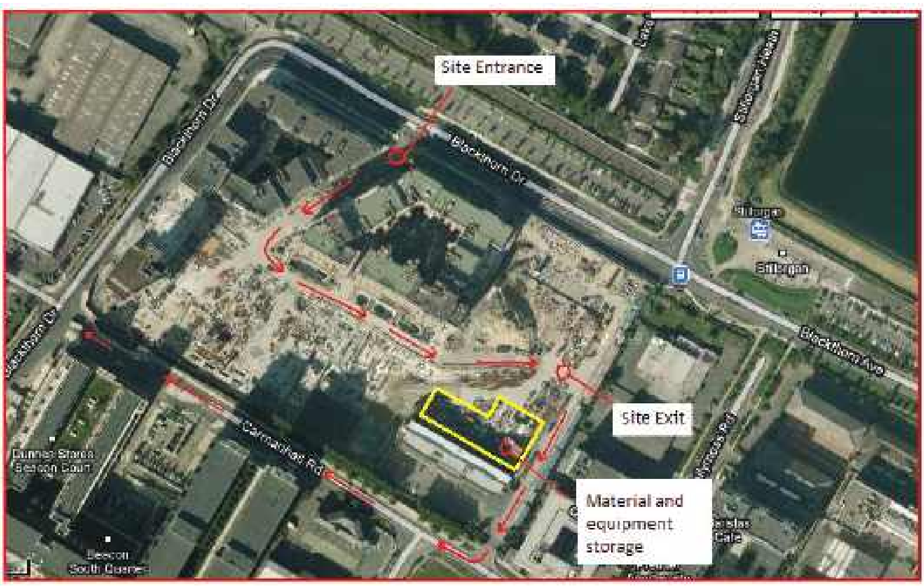


Figure 4-35. Site entrance, temporary roads, and material storage locations.

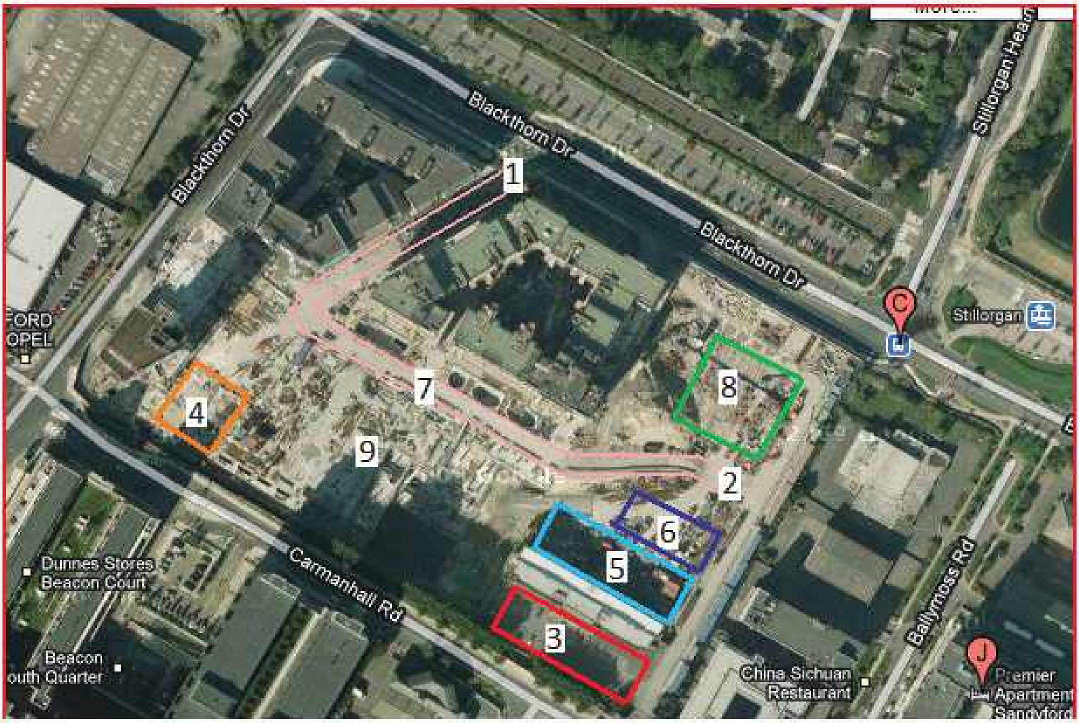


Figure 4-36. The final site organization and layout for the site drawn over the Google Earth image.

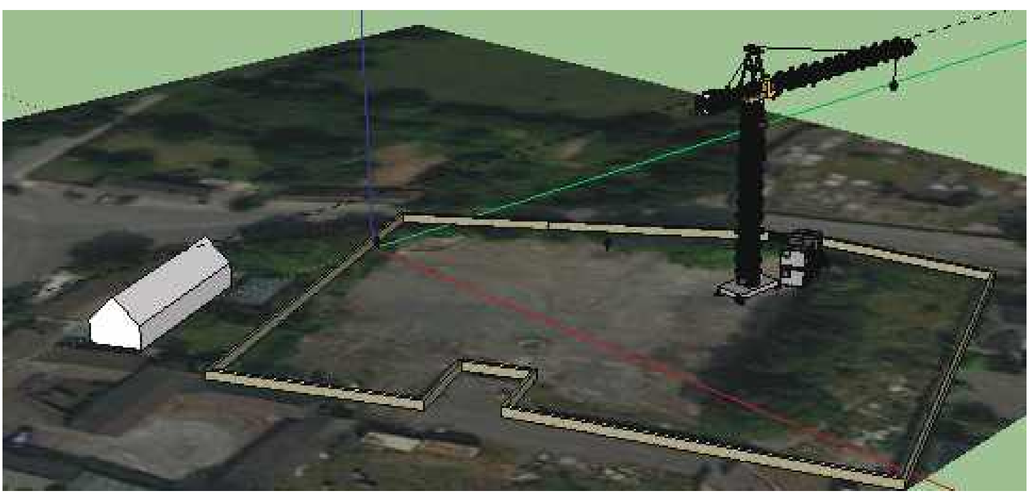


Figure 4-37. A typical site organization and layout drawn over the Google Earth image.

CONCLUSION

Planning the organization and layout of a building site is a key task that has to be carried out by the construction contractor. It is essential to get this right the first time as it can impact the time it takes to complete the work, the amount of money a contractor spends, the quality of the work, pedestrian and traffic access, as well as the storage of materials and the plant and the safety, health, and working conditions of workers. The recent advances in web-based technologies such as Google Earth, Google Maps, and Google Street Finder offer construction contractors new ways to approach the planning of the site organization and layout from their offices, provided they have access to a computer and an Internet connection. The number of new software packages and web-based applications is growing all the time. BIM, Autodesk's Navisworks, and point cloud recognition all have a role to play in future construction site organization and layout.

QUESTIONS, PROBLEMS, AND EXERCISES

1. Compare and contrast the impact on the site setup for a construction site in a brown field site location with that in a green field site location.
2. What are the key areas that a CM should consider when planning the site organization and layout for the construction project?
3. Can we ever have enough offices and laydown space for efficient construction to take place? Discuss.
4. Google Earth can be a useful tool at a manager's disposal while he is planning his site organization and layout for the construction project. Pick a local site (existing, greenfield or brownfield) in your area and show how this tool can be used for planning the site organization and layout.

SECTION II

THE SITE AND FIELD ENGINEERING ISSUES

A number of construction-oriented publications include many of the site management issues mentioned in other sections of this book. However, experience teaches that technical engineering matters must also be considered if truly comprehensive site planning shall be performed.

It is not intended that the contents of this section should suffice for deeper, formal coursework in the subjects. Enough information is presented that prospective superintendents should understand the activities, which might comprise common field engineering, soil retention and stabilization, and drainage, as well as the need to plan for these engineering activities. They should also take away a good idea of the services and assets that must be timely subcontracted or requisitioned to accomplish these tasks for a typical building construction project. Simply stated, a competent superintendent must have a sufficient technical background in order to properly plan construction activities on his or her site.

CHAPTER 5

BUILDING LAYOUT

Douglas P. Keith

Some of this chapter has been previously published in W. G. Crawford. (2004). *Construction surveying and layout*, 3rd ed. ©Creative Construction, LLC. That material is reproduced with the permission of Creative Construction, LLC.

INTRODUCTION

This chapter assumes that the reader has learned basic surveying skills and calculation processes. Therefore, the focus of this chapter is on concepts, principles, and practices needed to successfully plan, place, and check the layout of building construction activities.

Project controls are horizontal and vertical planes that form a three-dimensional (3-D) network that directly relates ground dimensions and location to the building structure, bridge, or roadway design. This allows one to go directly to any location or point, because they are all tied together geometrically and in the case of coordinates, mathematically.

Control points can be arranged in various ways by methods as simple as batter boards to known coordinates. The primary control should have no tolerance for error as they should be located as accurately as the methods and equipment will allow.

Regardless what method of control is to be employed on your construction site, there is one common theme that should be the most important aspect of any layout—*planning*. All aspects of any layout should be well thought out. Make planning a habit and your layout will occur with fewer mistakes and errors. The following paragraphs describe ways to help with your planning.

PLANNING

Visualize the project: Familiarize yourself with the plans and specifications. Picture in your mind what the structure will look like. Think about critical lines that are the core of the structure. Reading, studying, and learning the plans and specifications are the first steps toward visualization.

Sketch the structure: As you start visualizing the project, begin to draw rough sketches of how you see the structure and how the control will accommodate the layout process. This process will help reduce mistakes and errors in designing the control for the structure layout.

Schedule the layout: Look at and study the activity schedule to get a feel for the sequence of construction events. Using the schedule will enable you to plan your work ahead for times when layout will be intensive. Plan to establish the control well in advance of critical layout times so the control will be available when needed.

Consult: Consulting with your supervisor or other experienced members of the staff is a positive attribute. Ask for their layout preferences and suggestions for improvement to your plan. The better field engineers will check with all available resources prior to layout.

Visit sites: Prior to construction activities, visit the jobsite and walk around to discover what exists in the surroundings. Be aware of factors that may affect layout, including trees, hills, existing structures, utility markers, or any other issues that could inhibit layout. Take pictures of the entire area as a method of recording the terrain and any obstructions. Search for property corners to see if they appear to have been disturbed. Look for the benchmark that was used in the design phase of the project. Find areas that will offer good protection for control monuments that will be out of the way of construction activities.

Plan the offsets: Come up with a plan to establish offsets. Two to four feet inside column lines are common. Vertical datum could be two to four feet above finished elevations for floors. Whatever offset is decided upon as a project standard, communicate this information to all project personnel.

Be flexible: Not all measurements or actual construction will come out as planned. Unforeseen events, errors, issues, and conditions may cause adjustments to be made to the actual construction or layout of adjacent work. All changes and adjustments need to be approved by the superintendent and subcontractors in the field.

PROJECT CONTROL

The most important layout procedure to be performed during the construction process is establishing the project control to be used for the work. The precision and care used to establish project control must be exact and the tolerance for error as close to zero as possible.

As mentioned before, planning is the key element to establishing the project control. When planning the control, the field engineer must consider the type of project that is being built. Is there more than one building? Is it a bridge or a wastewater treatment plant? Identify the type of project and determine the best method for establishing the project control by reviewing the plans and specifications and visiting the site.

The Site

Factors that need to be addressed regarding the site are:

1. Is the site in an urban or rural area?
2. Urban areas may be restrictive for space to allow the control to be protected from construction activities due to congestion. Rural areas normally provide more space for the control to be out of the way of construction activities.
3. Terrain must be considered. Is the terrain steep or in a flood plain? These conditions could present difficulties for control protection and usability.
4. Check some of the site dimensions on the plans to see if they agree with the actual conditions on the ground. Does the project actually fit the site? Do the property corners measure the same as indicated on the plans? If not, call the professional land surveyor to compare the results of what you have measured versus the plan

dimensions. Remember, unless you are a legally licensed land surveyor for the state you are working in, you *cannot* move, reestablish, or alter any property markers.

Selection of the Layout Method

With a thorough understanding of the scope of work, site visitation, and review of the contract documents, the method of layout can be determined. Some consideration should be given to the surveying equipment that is available, the competency of the layout crew, the preference of the superintendent, and the competence of the crafts who will be using your staking information. Several layout methods will be discussed, such as radial, intersection, baseline, and 3/4/5, as well as the pros and cons of each method.

Designing the Control

Once the method is determined, the control can be designed to fit the needs of the project. The control is going to be used through the entire time span of the project. Ask questions such as:

- What control lines are needed for form work?
- Where will the haul road be located?
- Where will the job trailers be located?
- Where is the laydown area going to be located?
- What control will be needed after the frame is erected?
- Are there any traffic obstacles?
- As the job progresses, there will be changes to the structure. Can I still see my targets?
- Target stability from demolition or frost heave?
- Will there be construction interference, such as form work, scaffolding, cranes, and temporary structures?
- Is safety is always a concern during the entire life of the project?

Always make sure that you prepare for working through and around obstructions and plan the control so that each monument has at least two other monuments in view.

Monumentation

Put some thought into the types of monuments that will be used. They should be permanent, solid, identifiable, well marked, referenced, and protected. There are two types of control: horizontal and vertical. The control may be either horizontal or vertical, or they may be combined.

Horizontal Control

Horizontal control has a hierarchy that includes primary, secondary, and working stages.

Primary means permanent and is generally located at the outer limits of the construction area or maybe off-site to provide the most protection. It must last throughout the life of the project. The tolerance for the primary should be as close as your equipment will allow. Many contractors will often hire a professional surveyor to establish the primary control as their equipment is usually of higher quality than what is typically owned by the construction company. Additionally, the monumentation for the primary control should be constructed with concrete and placed to a depth that is below the frost line or, if in expansive soil, placed as deep as the bedrock and with a slip shield around the monument pin that will protect it from vertical movement of expanding and shrinking soil conditions. A common practice is to cast a set of tripod legs into the concrete monument when the setup of an instrument is required on a daily basis. This could be expensive to build, but when many projects cost several hundred million dollars to build, the expenditure of $10,000 for primary control could be warranted.

Secondary means semipermanent and is usually placed inside the construction limits; therefore, a lot of planning is required for the placement of the secondary control. It may be constructed in the form of batter boards, driven rebar pins, wooden stakes, or even concrete monuments. If existing concrete or pavements are nearby, then scribe “X’s” on them. Secondary control should be approximately within 100 ft of the construction activity. The life expectancy of secondary control should be for a few months and measured to less than 0.01 ft for tolerance.

Working control is very temporary. It may be nothing more than chalk lines and is usually covered up with the construction activity immediately. It should be established as close to the construction as needed and have a tolerance of one-half of that of the construction tolerance for what is to be built. For example, if you are placing grade stakes for earthwork, the typical tolerance for placing earth is to the nearest 0.10 ft; therefore, the tolerance for the grade stakes should be to 0.05 ft.

Control must have no mistakes. While establishing primary control, repeat all measurements at least three times to ensure the closest possible true measurement. Change your procedure or equipment in your measurements. This will help avoid the same mistakes that might have occurred the first time.

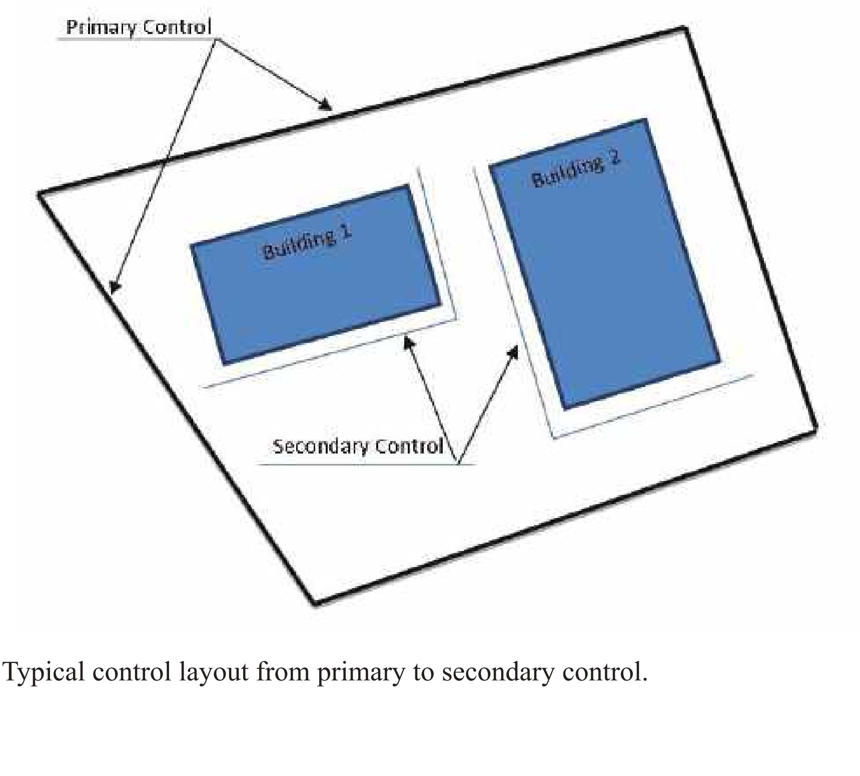


Figure 5-1. Typical control layout from primary to secondary control.

Vertical Control

Develop a plan for establishing benchmarks on the construction site. Most existing benchmarks (BMs) that were used for the design process are located some distance from the site and require the need for temporary benchmarks (TBMs) for construction. When establishing the TBM network for the site, try to establish the TBMs 200 to 300 ft apart and in view of other TBMs. Most important is to start at an existing known BM and run a level loop through the site and close the loop to another known BM. If there is a discrepancy between the known BMs, contact the designer to establish which BM is to be used for the datum. TBMs should be established on solid items such as fire hydrants, existing concrete, anchor bolts, rebar pins driven into the ground, or spikes in power poles. They should be recorded in the field book and described completely as to where and what the TBM is with the elevation. While setting any TBM, be sure to always close the level loop to a known BM. If you do not close the loop, then you run the risk of building something at the wrong elevation, and it will have to be removed and replaced at the expense of the construction company!

Preservation of Points

To preserve the horizontal and vertical control, one must provide protection. This may be in the form of concrete barriers that surround the point to wooden lath with flagging. As soon as practical, always transfer the horizontal and vertical control to the structure that you are building. After the first concrete pour, at grade, transfer the vertical control to the slab, then establish the horizontal lines to the slab as this will lock down where the rest of the structure is to be built.

Planning and good communication is the key to a well-functioning and profitable construction project.

Figure 5-2. Unprotected monument.

RULES OF LAYOUT

People who perform layout for construction projects may have their own method and procedures that they employ. However, the following rules, which have evolved over the years, have proved to be successful.

Layout from Critical to Noncritical Dimensions

In a building or bridge, there are certain lines that are considered critical to the overall layout of the structure. On a bridge, the road pavement must meet the bridge at both ends in the horizontal and vertical planes. In a tall building, the elevator shafts must be plumb and square and the rest of the building must be built around the elevator shaft. In both examples, the critical lines are usually easy to identify. Once the critical lines are established, the work can proceed to noncritical lines. Noncritical lines must also be established with precision, but other lines are not dependent on them.

Begin in the Middle and Work Outward

For many types of structures, it is a good practice to establish the center line control of the structure then work toward the edges of the structure. If there are any minor errors in the center line layout, they will be distributed to opposite edges, therefore making the error even smaller, and have a smaller effect on the completed layout.

Avoid Cumulative Errors

When laying out consecutive distances (e.g., 25-ft column spacing for a building), it is not a good practice to make the first 25-ft measurement then move the zero end of the chain to the first point and measure another 25-ft space. Instead, lay out the entire chain and hold zero at the starting point then mark 25, 50, 75, and 100 ft. Moving the zero end of the chain for each measurement runs the risk of introducing error for the spacing of sequential columns.

Use Long Backsights and Short Foresights

A backsight has a known elevation, much like a benchmark, while a foresight does not. The simple concept of using long backsights and short foresights during the layout process has the effect of reducing sighting or instrumental errors by nearly the ratio of the two distances. Therefore, this principle should always be employed in layout activities.

Surround the Construction Site with Control

Surround the construction site with control outside the construction limits. If this is done, then the long backsight–short foresight concept will usually be available and will help reduce instrumental and sighting errors.

Work to Practical Tolerances

Some specifications may list tolerances that are expected to be followed. However, if the tolerances are not stated in the contract documents, then the superintendent should direct that the standard tolerances for construction activities will be followed. If in doubt of the tolerance to use, ask higher authority so that no time is wasted trying to lay out points to a tolerance that is not necessary. A good rule of thumb would be “one-half of what follows.” This means that

Figure 5-3. County monument.

Figure 5-4. Contractor primary control.

Figure 5-5. Contractor secondary control.

when laying out points for earthwork, and the tolerance for earthwork is to be 0.10 ft, the layout points need to be at a tolerance of 0.05 ft.

Be Consistent

The layout needs to communicate to the crafts or anyone associated with the project exactly what is intended. The following items must be consistent and should be established as a company policy.

Consistent offsets: Maintain consistent offsets for your layout. If one stake offset is 2 ft and others are at 4 ft, then odds are something will ultimately be built incorrectly by 2 ft. Therefore consistent offsets for stakes are imperative, and one needs to communicate to the crafts that all offsets are the same.

Figure 5-6. Drainage structure grade stake information to 0.01 ft.

Figure 5-7. Offset stake and color code ribbon.

Consistent staking: Make sure all stakes have the layout information in the same place on the stake or lath with the same format. This will be a signature showing the care and attitude of the person who set the stakes on the construction site. It will build confidence for the crafts who build from the staking.

Consistent flagging: The color coding of the surveying ribbon placed on the stakes is as important as the right size of nut for a bolt. There are standards for different industries for color coding stakes that should be followed. In highway construction, for example, pink ribbon is used for right of way staking, blue is for earth grades, and yellow is used for structures. Many stakes will be placed for many construction activities that may occur at the same time, and the color helps the crafts find the right information without confusion.

Figure 5-8. Survey staking ribbon color codes.

Consistent measuring: The distance, angle, and elevation measuring techniques are nothing more than good practices to follow to help reduce errors.

CHECK THE LAYOUT

Checking the layout is considered the most important component of the layout process. Unfortunately, many layouts are not checked due to time constraints. However, with the technology of today's equipment, there is no reason not to check your work. Always check your calculations prior to layout. Check for design errors and inform your superintendent if found. Once the layout has been completed, check the layout with a different method of layout so as not

Figure 5-9. Checking grade with laser.

to reproduce the same error again. Perhaps use different equipment if available, such as GPS versus total station. The bottom line: Check it!

The risk of building something wrong at high cost is very probable. If the item is built in the wrong place or the dimensions are incorrect and minor alterations of other construction activities will not adequately compensate for the error, then the remedy is to remove and rebuild the component. If the replaced component lies on the project schedule critical path, then remaining construction activities might be delayed.

CONSTRUCTION ACTIVITY CHECKLIST (LIFT DRAWING)

A common practice by some successful contractors employs the use of *lift drawings* to avoid these costly mistakes. Many contractors call this procedure a "Concrete Pour Checklist." Subcontractors might create the lift drawings, but some highly successful GCs create them as well.

The following information about the lift drawing procedure was developed by Hensel Phelps Construction Company, which is adamant about using lift drawings on all of their projects. Hensel Phelps has graciously allowed the use of their content for this book.

Scope

If a person cannot draw what should be built from the contract documents, how can they build it? The lift drawing process is nothing more than building the job on paper to see what information is missing and to learn the construction details of the building. The lift drawing is the paper conceptualization of the structure you want to build and serves as a checklist to help reduce omissions and errors.

Once completed, use the lift drawing as a communication tool to keep everyone working from the same information and to accurately convey to the foreman or subcontractor what to construct, what to embed, and where it is located. It substitutes for all other drawings with the exception of formwork and reinforcing drawings. The lift drawing also provides the following:

1. A tool for pour checking, labor coding, production reporting, and recording placement quantities.
2. Reduction of the probability of errors and omissions by bringing many drawings together on one page, as this reduces interference of features in the depicted assembly.

Getting Started

It must be remembered that construction companies are contractually bound to the plans, specifications, information requests, architect's supplementary instructions, addenda, bulletins, and submittal information, as well as all information approved and provided by the architectural firm. If these sources do not contribute enough information to draw what we intend to build, then we will not be able to build it.

Before starting, ask the following questions:

1. What is your general theory about how lift drawings should be approached?
2. What do you want them to look like?
3. On what size paper should it be printed?
4. When should it be completed?

Since no two construction projects are alike and each project designer presents new challenges in conveying the documents to field operations, it is necessary to make each lift drawing job-specific. The information and the format should fit the needs of your specific project owner and architect. This manual will assist you in making some of these decisions. Please follow every step and attempt to fully understand the principles before proceeding.

Sources

Information for lift drawings can come from various sources, including contract drawings, manufacturer's drawings (shop drawings), and subcontractor drawings. Information also can be obtained from suppliers' catalogs and cut sheets. The craft superintendents can provide helpful information regarding installation dimensioning for such items as drainage piping, electrical conduit, and so forth.

The project drawings and specifications, requests for information (RFIs, by which the contractor seeks clarification of the contract documents and related matters), addenda, and submittals can also provide information for lift drawings.

Main Functions of Lift Drawings

1. Simplify the contract drawings
2. Identify exactly what work your company will be performing
3. Create a simple drawing that identifies exactly what is going to be built
4. Combine necessary information onto one drawing per phase
5. Determine if problems exist with coordination and location of all phases of work (especially in gridlines)
6. Provide an aid to scheduling an activity
7. Provide a drawing to subcontractors to keep everyone working to the same dimensions
8. Serve as a layout drawing for the field engineers
9. Check shop drawings that have been submitted by subcontractors
10. Provide an aid to superintendents for the purpose of visualization
11. Perform as general dimension checks
12. Perform as coordination drawings

Formatting Examples

Most of the sections shown in figure 5-11 are self-explanatory, except the general notes, to-do list, and the open questions. You should include these in your drawing to communicate very specific information, such as:

1. General notes. This information is derived from initially reading the general notes in the contract documents and the specifications. Include what the craft and superintendents will need to know.
2. To-do list. This is a list of the remaining items to be completed with the lift drawing.

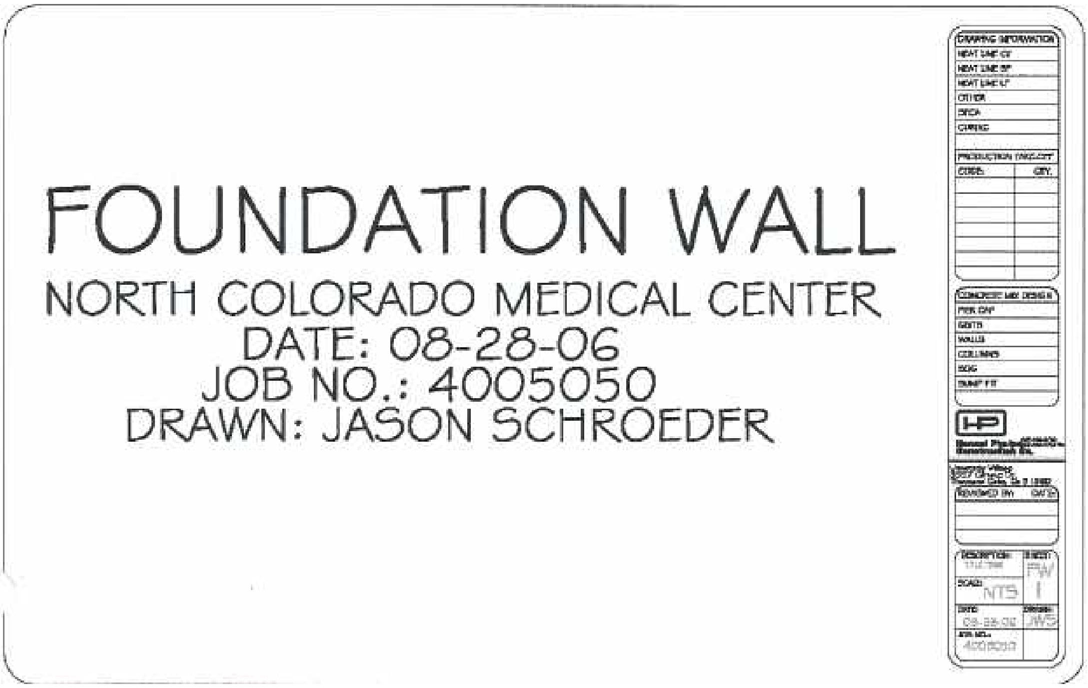


Figure 5-10. On this title page, the title block is completely formatted, and the proper information is shown to describe the lift drawing. Packets without title pages often confuse the people attempting to use them and may reduce the confidence they have in them.

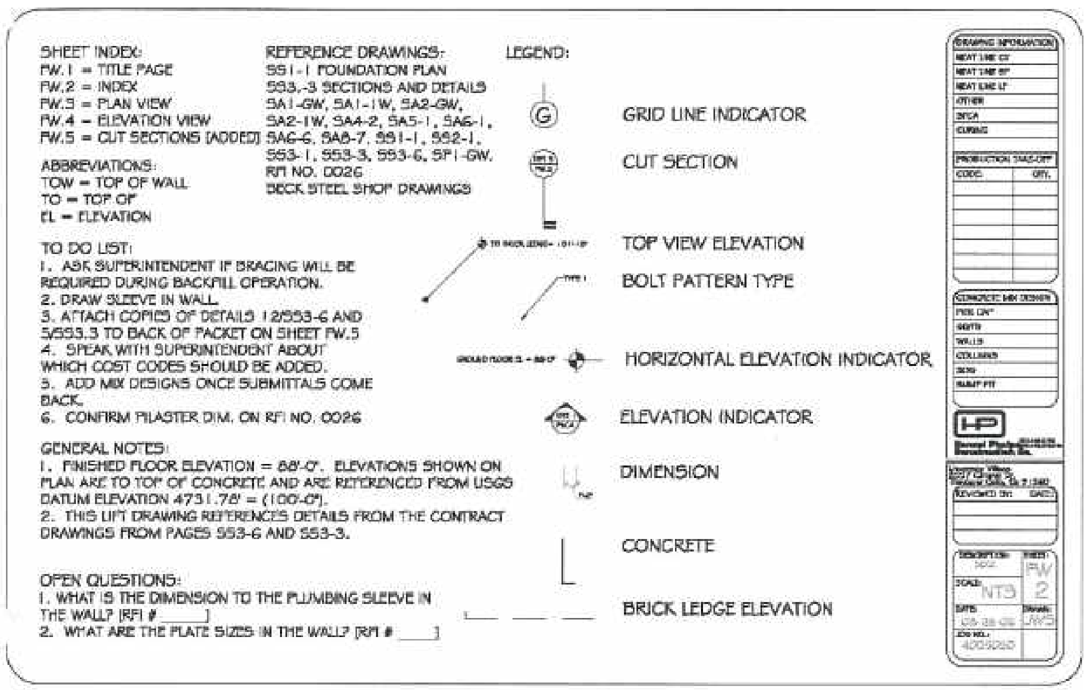


Figure 5-11. On this drawing, one can see the index, abbreviations, legend, general notes, to-do list, and open questions.

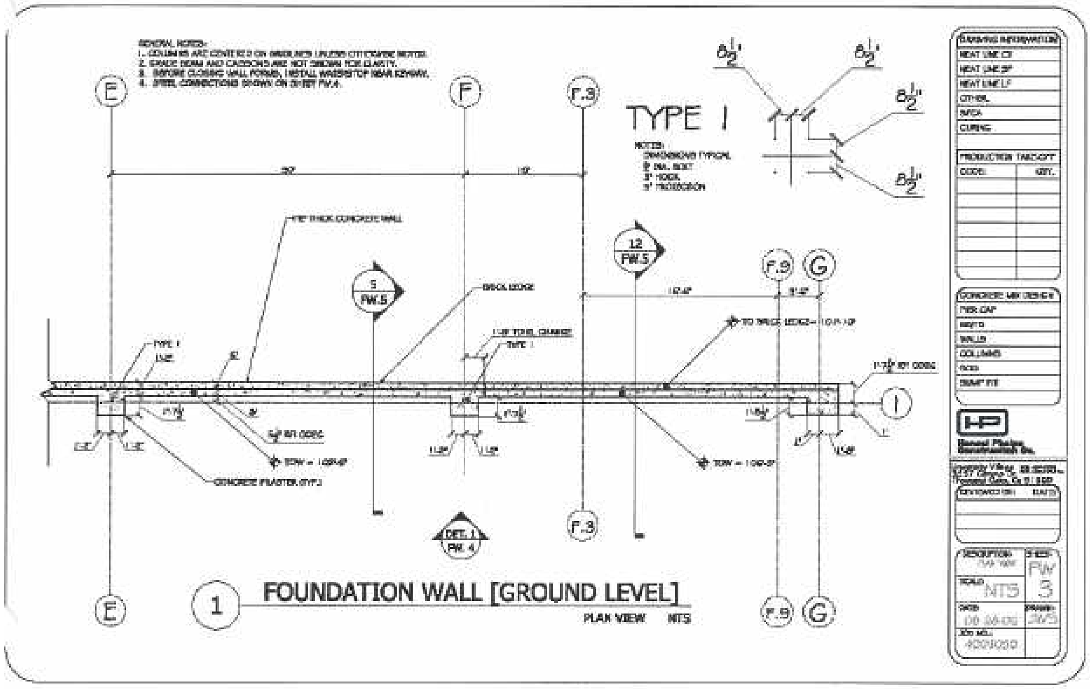


Figure 5-12. Notice the formatting on the plan view. Your drawings should look similar to this one.

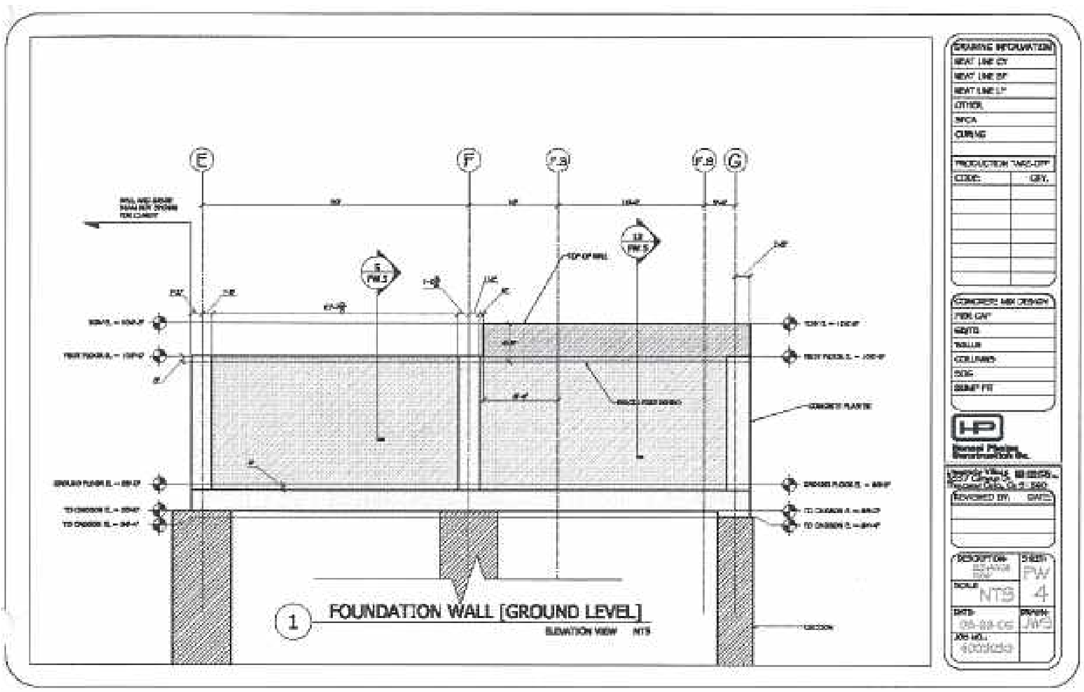


Figure 5-13. Foundation wall lift drawing elevation view.

3. List unfinished items here so reviewers know what needs to be completed. It is an excellent means to ensure that one does not forget something before using the lift drawing. Only list things that cannot be immediately completed.
4. Open questions. This is a list of questions that need to be asked or written in an RFI. Maintain this list for the reviewers. It will also help maintain updated information and keep track of constructability issues.

Principles

Although hand drafting is sometimes used, lift drawings are best created on a CAD system due to the repetitive steps that occur. Additionally, hand drawing skills are not commonly taught nowadays. Regardless of how they are drawn, they should meet some basic criteria:

- Follow industry standards for drawings regarding line weight, line type, lettering, dimensioning, and sectioning.
- Be consistent from drawing to drawing so that individuals who are using them will become accustomed to the style and will understand them more easily and quickly.
- Place concise and clear notes on the drawing so there is only one interpretation.

The primary objective of lift drawings is to consolidate information from scores of plan sheets to just one sheet per phase so that it is easy to read. Think about ways to represent the information in a manner that everyone understands.

Basics

All concrete outline information is to be shown, including openings, passages, and recesses, complete with individual and locating dimensions. Lift drawings should also include reference lines (at least one used for actual field location), such as for centerline of unit, an offset line, and appropriate station.

Dimensions and Elevations

Dimensions used on drawings should be those actually used in the field. Additional dimensions can be added to facilitate a check in the field or office. All dimensions should be closed. Indicate elevations at the top and bottom of sections and at other intermediate points as necessary. Also indicate dimension intervals between elevations. Dimensions are usually to the nearest 1/8 in and elevations to the nearest 0.01 ft.

Embeds

All embedded material information should be included but is not limited to:

- Piping
- Anchor bolts
- Frames
- Ground wire
- Pipe sleeves
- Conduit inserts
- Welding plates

All of these items must be shown complete with location dimensions. Identify embedded items on the drawing by stating their size, kind of material, supplier's mark number, and any other information that will aid field personnel in locating the item quickly.

Embedded pipe and electrical conduit should be detailed on the drawing. Pipe should be detailed with size, type, and elevation (centerline or flow line) at fitting locations and ends. Electrical conduit should be identified by size and run location. The lift drawing process will identify major conflicts that can be resolved prior to work in the field.

Bill of Materials

Each drawing has a bill of materials showing all items that will be embedded in the lift drawing, plus the volume of concrete to be placed. The bill of materials should indicate materials used on each page.

Finishes

Indicate finished-surface outlines on "plan view" as wood float, hard trowel, or broom finish, as required. Indicate direction of concrete floor slopes and give appropriate elevations on the plan at break points, hatch frames, and other openings and edges. Also indicate surface treatments and joint fillers, as required.

Production Summary

Each drawing will have a production summary for coding labor on time cards and for reporting production. The summary should include such things as the labor recap code, description, unit of measure, and production quantity.

References

Reference drawings to adjacent lift drawings, identified by lift drawing numbers. Shade portions of adjacent lift drawings as shown on the plan drawings. Put shading on the back side of the drawing if the drawing is being converted into blueprints. Any color except yellow is satisfactory.

PROCEDURE

Create a pour sequence drawing that can be used to determine the separation of lift drawing sections for slabs.

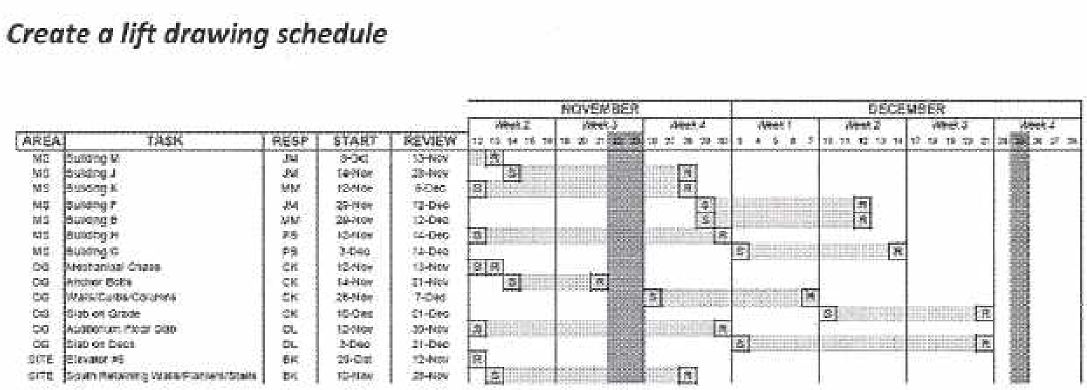


Figure 5-14. The schedule keys the lift drawing to the period when the work will be done.

Agree on a title block that conforms to the requirements preferred by your company.

Set up your AutoCAD file. This includes adjusting your personal settings, setting the units properly, and formatting dimension styles and text styles. Remember: AutoCAD is a drawing tool only.

Speak with the management team. What would they like to see included in the lift drawing? Form a plan with them in order to better focus on what is needed.

Speak with the carpenter foreman and agree on a format and review process. It is best to review the lift drawing with the carpenter foreman throughout the process to eventually produce something he or she will understand.

Look at the sheet index of drawings and highlight the sheets needed for the lift drawing. Place sticky tabs on each highlighted page. Each of the pages should be fully researched before the lift drawing is complete. The tabs will help you remember to research all the information required to complete the lift drawing.

Read the general notes and specifications for the selection of drawings before beginning. Highlight anything that might be useful in the lift drawing or that will need to be addressed. This will help you understand the drawings and form a general understanding of the required lift drawing information. The applicable information found in the general notes and specifications should be entered into the general notes of your lift drawing.

Look at the typical details at the front of the structural drawings. These details are often not referenced from the plan views of the drawings. Study and understand these details before starting the lift drawing so details are accommodated and not forgotten.

Now, form a general understanding of the required lift drawing information. Go to the appropriate floor plans or important sheets and understand them enough that you can visualize the construction in a 3-D representation. It is important to have a general understanding of the drawings before starting the lift drawing.

Next, draw the building gridlines. Draw them from the architectural drawings, ensuring that they match. If they do not match, write an RFI to the owner's representative for clarification. **Do not scale grid dimensions with an actual scale or overlay drawings!** Instead, compare structural grid dimensions with architectural grid dimensions, if necessary.

The next essential part of the drawing is the plan. Planning entails visualizing the drawing and deciding how large the drawing should be printed, what should be included, and how it should be organized. It has been said that the lift drawing should be on one sheet. People have mistakenly taken that to mean that all the information for one building should be on one sheet. That is nearly impossible. Each phase of construction per building should be on one sheet, and therefore numerous sheets may be used for one building or general phase of work. This organization of drawings should be one of the main focuses of our organizational plan.

Before starting, determine the approximate area required for sections and details. Choose the sheet size accordingly and choose a plot size. Finally, design the title block.

While generating a lift drawing, there is one burning question the planner needs to keep asking: **Is there enough information on the lift drawing to build from it?**

A logic tree is provided next to help answer this question:

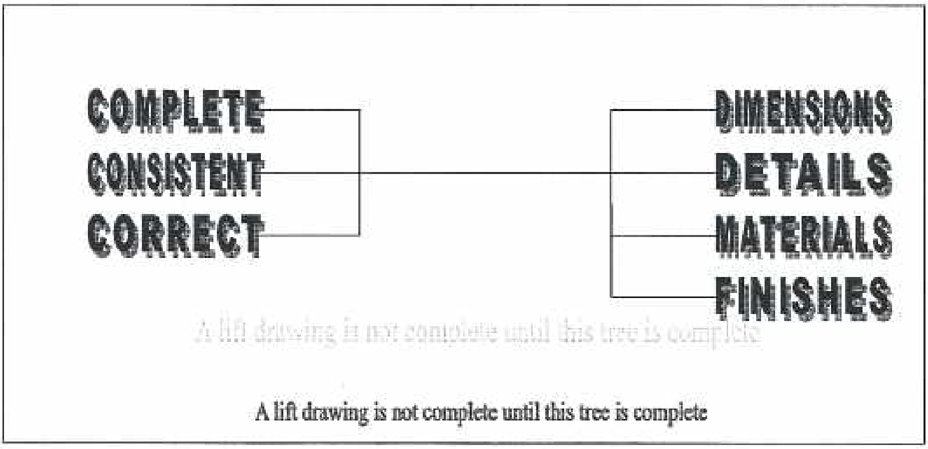


Figure 5-15. Check all aspects of the drawing against these criteria.

Begin the lift drawing by considering all that is on the Lift Drawing Review Card checklist while reviewing it at various times throughout the process. The outlines of the objects mentioned in figure 5-16 should be drawn first.

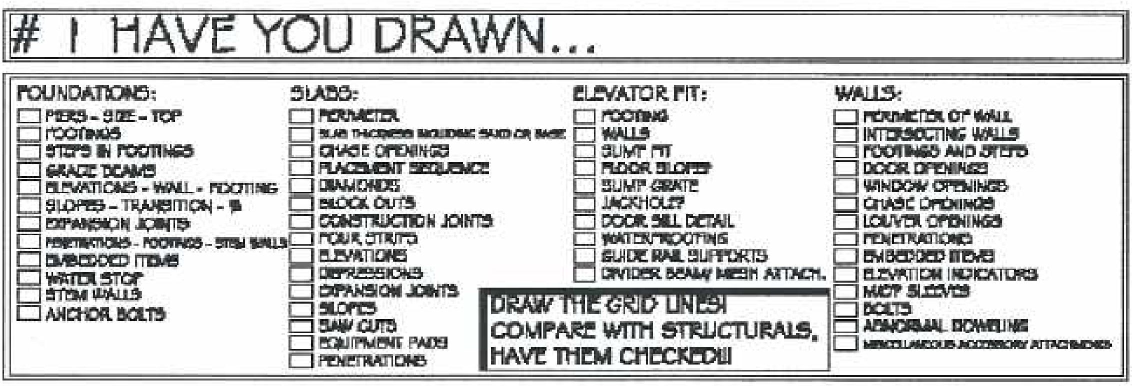


Figure 5-16. The listed elements should be drawn first.

Formatting the drawing is usually done before the due date of the lift drawing. There is no general instruction for formatting lift drawings. The best way is to look at examples of lift drawings for other projects. Section #5, in the following figure, is a checklist to follow while formatting the lift drawing.

The review is one of the final steps in the lift drawing process. The two primary goals for the lift drawing process are (1) having the correct information and (2) knowing where it comes from. The two checks in this process for those goals are maintaining the index and following the Lift Drawing Review Card.

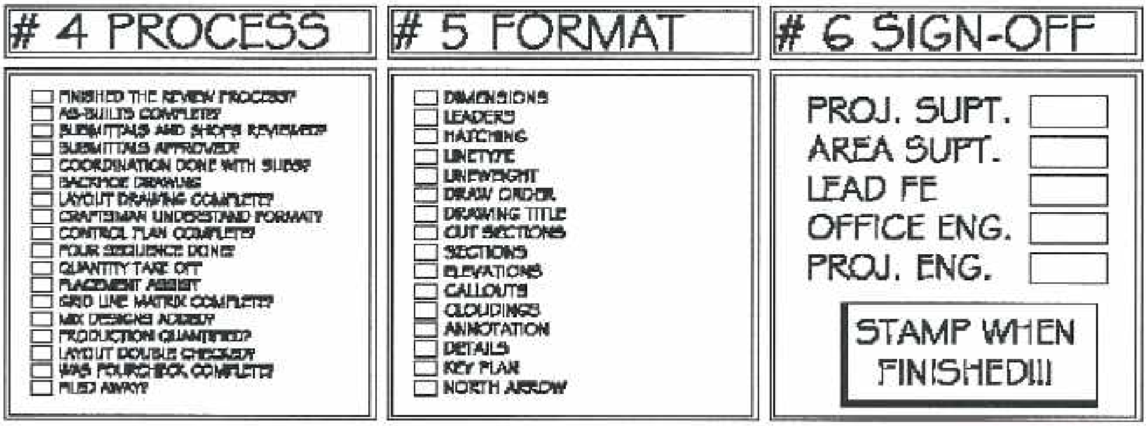


Figure 5-17. The lift drawing process, format, and approval checklist.

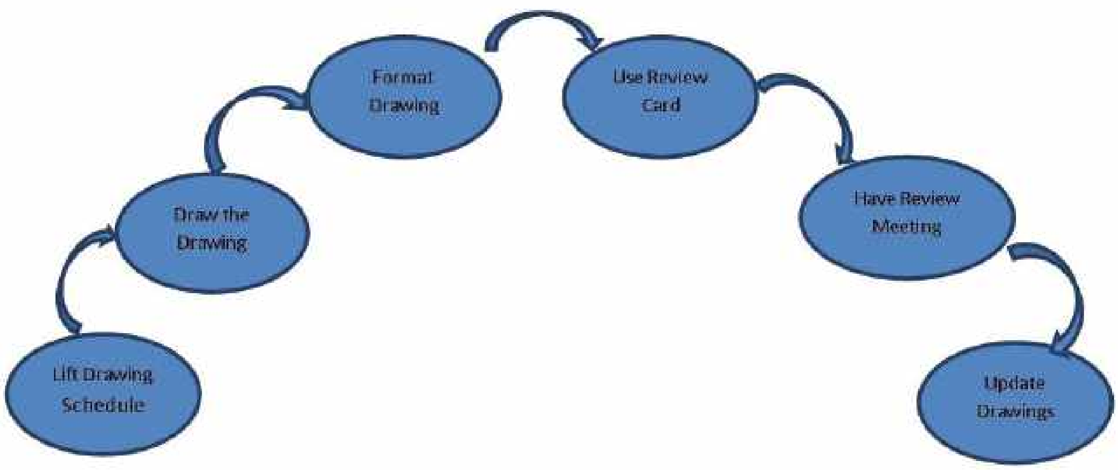


Figure 5-18. Lift drawing action sequence.

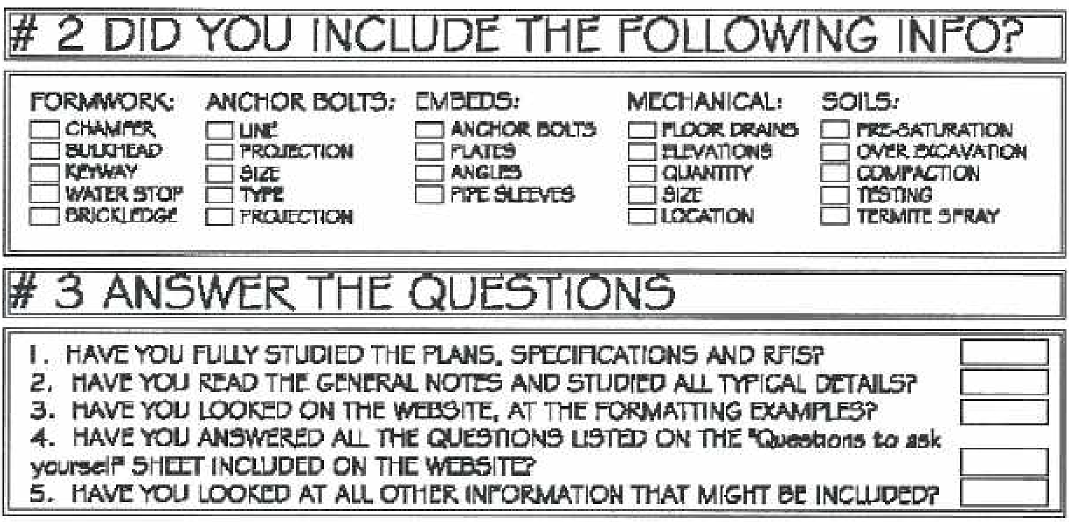
Timeline:

1. Two months before construction date: begin drawing from contract documents.
2. Five weeks before construction date: copy staff and carpenters on the lift drawings and have them review.
3. Three weeks before construction date: submit lift drawings to all subcontractors for coordination and review.

Reference the Lift Drawing Review Card (figure 5-20) to ensure your lift drawing is complete.

Some key rules to reading plans are as follows:

1. Read general notes first and foremost.
2. Become familiar with the symbols and abbreviations; do not assume you know what they mean.
3. Look at the page notes first when referencing any sheet in your drawing.
4. Reference all the cut sections and systematically track your research by highlighting the cut section indicators when researching the plan view of a foundation plan.
5. Place a sticky tab on the drawing when questions arise; list the detail and page. Then write the question with its corresponding RFI number. When the RFI comes back answered, post the drawing in the same place.
6. Post your personal set of drawings as well as the record set to be more successful.



2 DID YOU INCLUDE THE FOLLOWING INFO?

FORMWORK:
- [ ] CHAMFER
- [ ] BULKHEAD
- [ ] KEYWAY
- [ ] WATER STOP
- [ ] BRICKLEDGE

ANCHOR BOLTS:
- [ ] LINE
- [ ] PROJECTION
- [ ] SIZE
- [ ] TYPE
- [ ] PROJECTION

EMBEDS:
- [ ] ANCHOR BOLTS
- [ ] PLATES
- [ ] ANGLES
- [ ] PIPE SLEEVES

MECHANICAL:
- [ ] FLOOR DRAINS
- [ ] ELEVATIONS
- [ ] QUANTITY
- [ ] SIZE
- [ ] LOCATION

SOILS:
- [ ] PRE-SATURATION
- [ ] OVER EXCAVATION
- [ ] COMPACTION
- [ ] TESTING
- [ ] TERMITE SPRAY

3 ANSWER THE QUESTIONS

1. HAVE YOU FULLY STUDIED THE PLANS, SPECIFICATIONS AND RFIS? [ ]
2. HAVE YOU READ THE GENERAL NOTES AND STUDIED ALL TYPICAL DETAILS? [ ]
3. HAVE YOU LOOKED ON THE WEBSITE, AT THE FORMATTING EXAMPLES? [ ]
4. HAVE YOU ANSWERED ALL THE QUESTIONS LISTED ON THE "Questions to ask yourself" SHEET INCLUDED ON THE WEBSITE? [ ]
5. HAVE YOU LOOKED AT ALL OTHER INFORMATION THAT MIGHT BE INCLUDED? [ ]

Figure 5-19. Lift drawing review checklist.

The "Questions to Ask Yourself" sheet is a list of questions that a superintendent should be able to answer "off the top of her head" in the field before placing concrete for a foundation. The list forces thought about things a person should know from reading the plans and sets forth a basic expectation of knowledge.

LIFT DRAWING REVIEW CARD

1 HAVE YOU DRAWN...

FOUNDATIONS:
- PIERS - SIZE - TOP
- FOOTINGS
- STEPS IN FOOTINGS
- GRADE BEAMS
- ELEVATIONS - WALL - FOOTING
- SLOPES - TRANSITION - %
- EXPANSION JOINTS
- PENETRATIONS - FOOTINGS - STEM WALLS
- EMBEDDED ITEMS
- WATER STOP
- STEM WALLS
- ANCHOR BOLTS

SLABS:
- PERIMETER
- SLAB THICKNESS INCLUDING SAND OR BASE
- CHASE OPENINGS
- PLACEMENT SEQUENCE
- DIAMONDS
- BLOCK OUTS
- CONSTRUCTION JOINTS
- POUR STRIPS
- ELEVATIONS
- DEPRESSIONS
- EXPANSION JOINTS
- SLOPES
- SAW CUTS
- EQUIPMENT PADS
- PENETRATIONS

ELEVATOR PIT:
- FOOTING
- WALLS
- SUMP PIT
- FLOOR SLOPE?
- SUMP GRATE
- JACKHOLE?
- DOOR SILL DETAIL
- WATERPROOFING
- GUIDE RAIL SUPPORTS
- DIVIDER BEAM MESH ATTACH.

WALLS:
- PERIMETER OF WALL
- INTERSECTING WALLS
- FOOTINGS AND STEPS
- DOOR OPENINGS
- WINDOW OPENINGS
- CHASE OPENINGS
- LOUVER OPENINGS
- PENETRATIONS
- EMBEDDED ITEMS
- ELEVATION INDICATORS
- MEP SLEEVES
- BOLTS
- ABNORMAL DOWELING
- MISCELLANEOUS ACCESSORY ATTACHMENTS

DRAW THE GRID LINES!
COMPARE WITH STRUCTURALS,
HAVE THEM CHECKED!!!

2 DID YOU INCLUDE THE FOLLOWING INFO?

FORMWORK:
- CHAMFER
- BULKHEAD
- KEYWAY
- WATER STOP
- BRICKLEDGE

ANCHOR BOLTS:
- LINE
- PROJECTION
- SIZE
- TYPE
- PROJECTION

EMBEDS:
- ANCHOR BOLTS
- PLATES
- ANGLES
- PIPE SLEEVES

MECHANICAL:
- FLOOR DRAINS
- ELEVATIONS
- QUANTITY
- SIZE
- LOCATION

SOILS:
- PRE-SATURATION
- OVER EXCAVATION
- COMPACTION
- TESTING
- TERMITE SPRAY

3 ANSWER THE QUESTIONS

1. HAVE YOU FULLY STUDIED THE PLANS, SPECIFICATIONS AND RFIS?
2. HAVE YOU READ THE GENERAL NOTES AND STUDIED ALL TYPICAL DETAILS?
3. HAVE YOU LOOKED ON THE WEBSITE, AT THE FORMATTING EXAMPLES?
4. HAVE YOU ANSWERED ALL THE QUESTIONS LISTED ON THE "Questions to ask yourself" SHEET INCLUDED ON THE WEBSITE?
5. HAVE YOU LOOKED AT ALL OTHER INFORMATION THAT MIGHT BE INCLUDED?

4 PROCESS

- FINISHED THE REVIEW PROCESS?
- AS-BUILTS COMPLETE?
- SUBMITTALS AND SHOPS REVIEWED?
- SUBMITTALS APPROVED?
- COORDINATION DONE WITH SUBS?
- BACKHOE DRAWING
- LAYOUT DRAWING COMPLETE?
- CRAFTSMAN UNDERSTAND FORMAT?
- CONTROL PLAN COMPLETE?
- POUR SEQUENCE DONE?
- QUANTITY TAKE OFF
- PLACEMENT ASSIST
- GRID LINE MATRIX COMPLETE?
- MIX DESIGNS ADDED?
- PRODUCTION QUANTIFIED?
- LAYOUT DOUBLE CHECKED?
- WAS POURCHECK COMPLETE?
- FILED AWAY?

5 FORMAT

- DIMENSIONS
- LEADERS
- HATCHING
- LINETYPE
- LINEWEIGHT
- DRAW ORDER
- DRAWING TITLE
- CUT SECTIONS
- SECTIONS
- ELEVATIONS
- CALLOUTS
- CLOUDINGS
- ANNOTATION
- DETAILS
- KEY PLAN
- NORTH ARROW

6 SIGN-OFF

- PROJ. SUPT.
- AREA SUPT.
- LEAD FE
- OFFICE ENG.
- PROJ. ENG.

STAMP WHEN FINISHED!!!

Figure 5-20. The series of checklists helps ensure lift drawing thoroughness.

CHAPTER 6

SOILS AND EXPEDIENT DRAINAGE

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INTRODUCTION

Some construction firms self-perform their earthwork, while others always subcontract the effort. This chapter exposes prospective superintendents to the terminology and concepts that should enable them to discuss soil and drainage issues with whoever constructs the geotechnical and expedient drainage structures. Soils affect the design and construction operations of every building site. Understanding these principles enables the field professional to anticipate how changes in soil or drainage conditions might affect construction operations and project performance. The contractor will likely not be the person who rigorously analyzes the effects of unexpected conditions, but knowing some of the elemental principles will enable a superintendent to recognize conditions that necessitate informing the owner's designer.

ROCK AND SOIL

Rock and soil cover the surfaces of the continents. Rock consists of natural mineral particles that are firmly bonded together. Soil is made up of unconsolidated deposits of disintegrated rock particles of various shapes, sizes, and character. It is essential for contractors, as well as civil engineers, to understand the formation of the natural soil deposits and soil behaviors related to construction. A broad understanding of the geology of a region enables a better understanding of a detailed soils report for a construction site in that area.

Types of Rocks

Rock is usually divided into three categories based on the causes and processes of rock formation (Liu & Evett, 2004):

- **Igneous rocks** are rocks that are formed by the solidification of molten magma. The molten materials, which result from erupting volcanoes, are cooled down from very high temperatures and solidified either below or above the earth's surface. Igneous rocks that are formed below the earth's surface are usually coarse-grained, while those above the earth's surface are fine-grained. Minimally weathered basalt is an excellent source for crushed aggregate or a solid foundation.
- **Sedimentary rocks** are produced when mineral particles and fragmented rock particles are transported by natural forces, deposited in layers, and consolidated and hardened by the weight of the overlaying strata. Sedimentary rocks are the most common type of rocks on the earth's surface. They can be identified by their layered appearance. Some sandstone and limestone provide excellent foundations and aggregates.

- **Metamorphic rocks** are rocks that are formed when sedimentary or igneous rocks have been changed physically as well as chemically by considerably intense heat and pressure during their geological life.

Types of Soils

Rocks are the main source of soils. Through natural mechanical forces and chemical actions, rock masses disintegrate and decompose into smaller and smaller particles. This process of rock disintegration is referred to as weathering. There are two general types of weathering processes:

- **Mechanical weathering**. The large parent rock is disintegrated into smaller particles by natural forces, and the particles become materials such as gravel, sand, and silt. However, the mineral and chemical composition of the resulting material remains the same as those of the parent rock.
- **Chemical weathering**. The parent rock is decomposed into very small particles with a different mineral and chemical composition from those of the parent rock. That is, the chemical weathering process not only changes the particle sizes but also produces a material with a new chemical composition.

TYPES OF SOILS IN CONSTRUCTION

In terms of engineering and construction, soils are divided into three general groups: cohesionless, cohesive, and organic. Cohesionless, granular, or coarse-grained soils are the products of mechanical weathering processes and include gravels, sands, and silts. The particles of cohesionless soils do not tend to stick together. Cohesive soils are the result of the chemical weathering process and include clayey soils. The particles of cohesive soils tend to stick together and exhibit plasticity when mixed with water in certain proportions. Sands and silts can sometimes seem cohesive due to the surface tension of water absorbed in the soil. Organic soils are mixtures of mineral soils and decayed plant matter and are undesirable for use as the foundation materials of structures.

SOIL OR GEOTECHNICAL INVESTIGATION AND REPORTS

Construction professionals should pay close attention to the reports of investigations of the geology and soils found on and near a site. Construction site planners might obtain the following information from a soils report:

- Soil classification, which often can be applied to determine:
  - Safe excavation sloping and shoring requirements
  - Shrinkage and swell factors in order to determine the soil volume changes when soil is loose and compacted
  - Stabilization techniques required
  - Surface trafficability and drainage characteristics
- Soil moisture-density relationship for best compaction

- Critical depths:
  - Water table: to know if dewatering operations must be planned
  - Bedrock: to know if special excavation techniques will be needed
- Unusual chemical properties or contamination
- Load-bearing capacity (from Standard Penetration Test [SPT] N-value), soil classification, and moisture content at various depths from borehole logs

If these considerations are not factored into the cost estimate, then the remediation costs of their unexpected consequences can escalate quickly beyond the budget. Besides learning what one can expect to find at the site, full knowledge of the soils report also informs the builder of what probably should not be encountered. Then, if substantial differences are found between the report and the observations upon excavating the site, the builder can advise the owner's architect or engineer. In some cases, adverse conditions are discovered and a contract modification may be appropriate (see chapter 15). In other cases, unexpectedly good conditions emerge, and it may become possible to quickly adapt the foundation design and save significant costs.

Soils reports have no prescribed industry-wide content or format. Reports for smaller projects commonly comprise less investigation and information, and that expands risk.

Construction Operations Planning Information

Construction site planners commonly must draw some important information from soils reports. The soil types and depths, for example, are important for determining the required slopes of excavations. Although the correlation between the OSHA excavation slope criteria (see chapter 11) and a soil's classification is imperfect and must be confirmed case by case, some generalizations are often reliable. For example, cohesionless soil must commonly be gradually sloped and requires more excavation to prevent cave-in, while low compressibility and unfissured clay is generally expected to allow steeper slopes with less excavation. Soil classification information also may enable accurate estimation of swell and shrinkage, which is discussed later. The volume to which a mass of soil expands upon loosening by excavation determines how much area is required to store it on-site. Highly compressible clays, clayey silts, and organic soils might need to be excavated or stabilized in order to provide the site with a suitable operational surface, especially where rainfall is frequent.

A soils report provides information about the soil moisture content and the depth to the water table (see related parts of chapters 1 and 2). Dewatering (discussed later) may be required if the necessary excavations penetrate below the water table. Planners should remain cautious about the stated water table depth since it can vary substantially from season to season or as levels of nearby ponds and streams fluctuate.

SOIL CLASSIFICATION SYSTEMS

Soil properties are greatly affected by the proportions of different soil particle sizes as well as the soil characteristics when mixed with water. In fact, the particle size distribution and the plasticity of soils are the basis of soil classification systems in engineering and construction.

Soil classification systems enhance accurate and consistent communication about the likely engineering properties of soils. The provincial names for soils can be misleading, and the same name in different parts of the nation or world might be used to identify soils with very different behaviors, so beware. The properties of soils are largely determined by the particle size distribution of the coarse fraction and the plasticity of the fine fraction. Laboratory sieve analysis and Atterberg limit tests are the basis of the soil classifications applied on the building site. Among the known classification systems, the Unified Soil Classification System (USCS) and the American Association of State Highway and Transportation Officials (AASHTO) system are the most common in civil engineering and construction. The USCS is used by most federal agencies, such as the U.S. Department of the Interior's Bureau of Reclamation and the U.S. Army Corps of Engineers. The USCS also is used by civil engineering consulting companies and laboratories for structural design as well as for construction specifications. The AASHTO system is used by all state departments of transportation in the United States for highway construction projects.

Some knowledge of the classification systems used in reports enables the superintendent to anticipate the behaviors that can be expected of the soils found on a building site, thereby facilitating more thorough planning. Since the USCS is commonly used in soils reports pertaining to building construction, a detailed discussion of it is provided here.

Unified Soil Classification System (USCS)

The USCS categorizes soils as coarse-grained gravel or sand or as fine-grained silt or clay. If at least half of the soil sample by weight is retained on the array of sieves through which the sample is shaken, then the soil is determined to be coarse-grained, meaning that gravel or sand therefore predominates. If more than half of the coarse-grained fraction, not the whole sample, passes through the #4 sieve, which has openings of 4.75 mm, then the soil is classified as sand; larger sizes are regarded as gravel. A good distribution of coarse sizes makes the soil well graded; otherwise, it is classified as poorly graded. Poorly graded soil might be gap-graded if it is missing some sizes or is uniformly graded, if most of the sizes range closely together.

If more than half of the entire sample by weight sifts through the smallest sieve, No. 200, which has openings of 0.075 mm, then the soil is classified as silt or clay, both of which are fine-grained soils, or fines. When more than 5% by weight of the sample is fines, they are further tested to find their behavior at various water or moisture contents, which is calculated as follows:

$$\text{WC or } w\% = (\text{weight of water in soil sample} \div \text{weight of solids in soil sample}) \times 100\%,$$
$$\text{or } w\% = (W_w \div W_s) \times 100\%$$

Two tests determine the Atterberg limits, specifically, the plastic and the liquid limits. The plastic limit, denoted as PL or L_P or w_p, is the water or moisture content of the soil when its behavior is borderline between the semi-solid and plastic stages. The liquid limit, LL or L_L or w_l, is the water content when its behavior is borderline between the plastic and liquid stages. The difference between the liquid and plastic limits is the plasticity index, PI or I_P. The LL and PI enable classification of the fines as silt or clay, and the LL determines whether the soil is of high or low compressibility.

The USCS often uses combinations of symbols to represent types of soil.

Figure 6-1. Sieves with 19.0-mm and 0.075-mm openings. A stack of many sieves having progressively smaller openings from the top sieve to the bottom becomes the "nest" or array of sieves through which the sampled soil is shaken in order to obtain data by which to begin the soil classification process.

General Description	Classification and Symbol	Size (mm)	Test	Main Determinants of Behavior
Coarse-grained or Granular	Gravel, G	> 2.00	Sieve Analysis	Grain size distribution and mineral strength
	Sand, S	0.075 to 2.00		
Fine-grained or Fines	Silt, M	0.002 to 0.075	Liquid Limit and Plastic Limit	Mineralogy and geologic history
	Clay, C	< 0.002		

Figure 6-2. Information about soil classification using the Unified Soils Classification System (USCS), which is commonly applied in geotechnical reports. Well-graded coarse soils and low-compressibility fine soils are preferred for many construction purposes.

Symbol	Representation
G	Gravel
S	Sand
M	Silt
C	Clay
O	Organic
PT	Peat
W	Well graded
P	Poorly graded
L	Low liquid limit, low compressibility
H	High liquid limit, high compressibility
NP	Non-plastic

Figure 6-3. USCS symbols that are commonly used in geotechnical reports for building construction projects with their descriptions.

Combination Symbols	Representation
GP	Poorly graded gravel, <5% fines
SW	Well graded sand, <5% fines
GW-GM	Well graded, silty gravel, 5% to 12% fines
SP-SC	Poorly graded, clayey sand, 5% to 12% fines
GC	Clayey gravel, >12% fines
SM	Silty sand, >12% fines
ML	Low compressibility silt, >50% fines
CH	High compressibility clay, >50% fines

Figure 6-4. Examples of some USCS combination symbols with descriptions and %-weight fines. Such classifications are sufficiently differentiated to enable the builder to anticipate how the soil will behave during construction operations. The cost estimate and schedule might be affected.

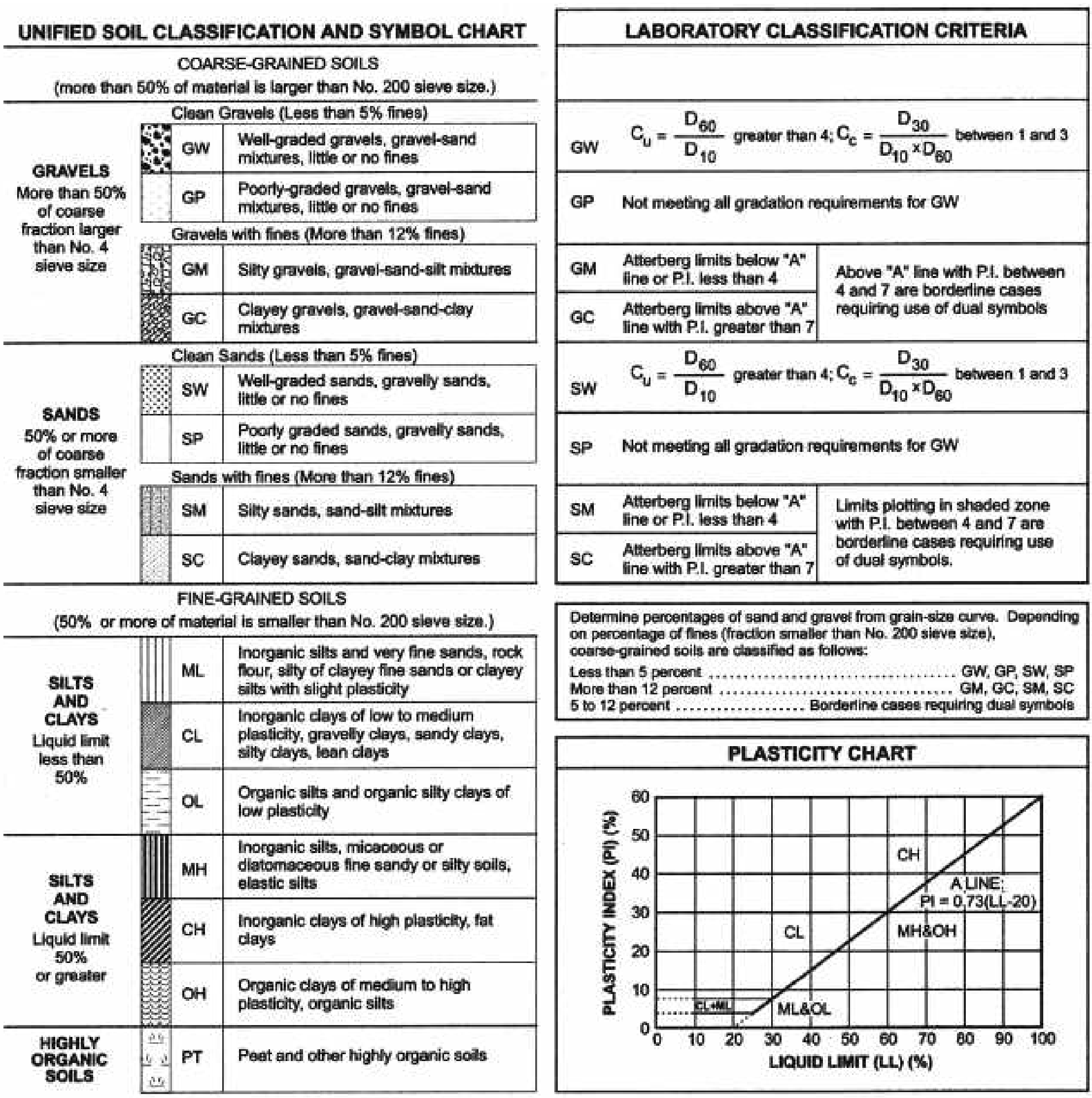

Figure 6-5. The Unified Soil Classification System, USCS (Matrix, the Virginia Transportation Research Council, 2012).

COMMON ISSUES OF SOILS IN CONSTRUCTION

General Properties of Soils

Different types of soils behave differently as construction materials. It is important to choose appropriate types of soils for specific purposes.

Granular soils, except for loose sands, generally possess good engineering properties with large bearing capacities and small settlement. The major uses and properties of granular soils are as follows:

- They are outstanding foundation materials for supporting roads and structures.
- They are excellent backfill materials for retaining walls because they are easily compacted and easily drained and exert less lateral pressure.
- They are excellent embankment materials because of their higher shear strength and ease of compaction.
- They are poor or unacceptable soils for use alone as earthen dikes and dams.

Cohesive soils include clays, silty clays, and clay-sand mixtures with relatively high clay content. When using cohesive soils as construction materials, the following properties should be considered:

- They tend to have lower shear strength and further lose shear strength upon wetting or exposure to other physical disturbances.
- They are plastic and compressible.
- They swell when wetted and shrink when dried. Some types swell or shrink greatly upon wetting and drying, which is a very undesirable feature for construction and engineering.
- They may creep (deform plastically) over time under a constant load, especially when the shear stress is approaching its shear strength, making clayey soils prone to landslides.
- They develop large lateral pressure because of low permeability, which makes them poor backfill materials for retaining walls or structures but better core materials for earthen dikes or dams.

Silty soils on the border between clayey and sandy soils are generally poor construction materials due to their high capillarity, which causes them to tend to draw water high above the water table. The capillary water can cause water problems in foundations. Additionally, in areas that experience deep freezing in the winter and relatively warm weather in the spring, silty soils are very susceptible to freeze-thaw movement (frost heaving) from any water present near the ground surface, which damages pavements.

Swell and Shrinkage

In construction, soils are removed from their original location, transported to the construction site, spread in layers, and compacted to specified densities. During earthwork in construction, as shown in figure 6-6, soil densities change because soil particles are disturbed from the relative locations into which they have settled over time. In construction operations, soils exist in one of the following three conditions or states:

1. **Bank state**. Soil is in its natural state before it is disturbed or removed. The unit of soil volume at bank state is bank cubic yards (bcy or BCY).
2. **Loose state**. Soil has been removed or excavated from its original location. The unit of soil volume at loose state is loose cubic yards (lcy or LCY).
3. **Compacted state**. Soil has been compacted to a specified density. The unit of soil volume at compacted state is compacted cubic yards (ccy or CCY).

Figure 6-6. Earthwork at a building construction site.

The soil densities at the three states are different because the arrangements of soil particles are different. After a soil is excavated from its natural location, the spaces between the soil particles generally increase. Consequently, the volume of the soil increases and the density of the soil decreases. The change in soil volume as the soil expands during excavation from the bank state to the loose state is called swell. Swell is defined as:

Swell (%) = [(Soil bank density ÷ Soil loose density) - 1] x 100%

Foundation or embankment soil must be compacted to increase its strength and stability. When compacting a soil to a specified density, the void spaces between the soil particles become smaller under the impact of compactors. Therefore, the volume of the soil decreases as the soil's state changes from loose to compacted. The decrease in the soil's volume as it changes from the bank state to the compacted state is called shrinkage. Shrinkage is defined as:

Shrinkage (%) = [1 - (Soil bank density ÷ Soil compacted density)] x 100%

It is often necessary to convert all soil volumes to a common unit of measure in construction in order to calculate the amount of work and the construction time needed for a given earthmoving project. All factors and terms in a computation are then in terms of lcy, bcy, or ccy. Any one of the three volume units may be used as the common measure, but the volume of soil at bank state is most widely used in practice. Also, pounds per cubic foot (lb/ft^3 or pcf) or pounds per cubic yard (lb/yd^3 or pcy) are common units of soil density measure. Two converting factors, load factor and shrinkage factor, are often used to do the conversions.

Material	Loose (Lbs. per Cu. Yd.)	Swell (Percent)	Load Factor	Bank (Lbs. per Cu. Yd.)
Cinders	800 to 1,200	40 to 55	0.65 to 0.72	1,100 to 1,860
Clay, dry	1,700 to 2,000	40	0.72	2,360 to 2,780
Clay, wet	2,400 to 3,000	40	0.72	3,360 to 4,200
Earth (loam, silt) dry	1,900 to 2,200	15 to 35	0.74 to 0.87	2,180 to 2,980
Earth (loam, silt) wet	2,800 to 3,200	25	0.80	3,500 to 4,000
Gravel dry	2,700 to 3,000	10 to 15	0.87 to 0.91	2,980 to 3,450
Gravel, wet	2,800 to 3,100	10 to 15	0.87 to 0.91	3,080 to 3,560
Sand, dry	2,600 to 2,900	10 to 15	0.87 to 0.91	2,860 to 3,340
Sand, wet	2,500 to 3,100	10 to 15	0.87 to 0.91	3,080 to 3,560
Shale (soft rock)	2,400 to 2,700	65	0.60	4,000 to 4,500
Trap rock	2,700 to 3,500	50	0.66	4,100 to 5,300
NOTE: The above numbers are ranges for common soils and rock. Weights and load factors vary with grain size, moisture content, and degree of compaction. If values must be applied in critical calculations, then a sample of the material should be tested.				

Figure 6-7. Weight-volume characteristics of common excavated materials (USAES, 1994).

The load factor (LF) converts between the loose volume and the bank volume. It is defined as:

LF = Soil density in loose state ÷ Soil density in bank state,

or

LF = 1 ÷ (1 + Swell)

The shrinkage factor (SF) is the conversion factor between the compacted volume and the bank volume. It is defined as:

SF = Soil density in bank state (lb/ft^3) ÷ Soil density in compacted state (lb/ft^3),

or

SF = 1 - Shrinkage

With the LF and SF factors determined, the volume conversions can be performed using the following formulas:

Bank volume = LF x Loose volume

Compacted volume = SF x Bank volume

Loose volume = Compacted volume ÷ (LF x SF)

The total weight of handled soil does not change; only the volume changes. Volume conversions are widely utilized to determine earthmoving quantities. The total soil volume handled by an operation affects the number of equipment operational cycles needed and therefore the time and cost to move the material. If the planner has no better reference for the shrink-swell factors, a rule of thumb, most accurate for common earth, is that 1 bcy = 1.25 lcy = 0.9 ccy.

Spoil Banks and Piles

Some of the soil from a building foundation excavation is almost always retained on-site for backfill into the excavation around the perimeter of the building, if there is area enough for stockpiling without hampering operations. Although it is in a loose state, it is often replaced in a compacted state, but carefully, so that the lateral forces against the structure are not excessive (see Earth Pressure). Appropriate computations will ensure that enough soil is stockpiled on the site to avoid the extra cost of return hauling soil to the site for backfill or other earthwork. The stockpiled volume should include a waste factor of a least a few percent.

Finding an area large enough to stockpile soil on a restricted site can be challenging. The planner can apply formulas to determine the dimensions of the stockpiled soil of a given loose volume in order to plan an area where the banks or piles can be located on the site that does not hamper site operations.

Spoil Bank Volume

Excavated soil is often stockpiled in a bank near the excavation from which it is cut, so that backfilling is quicker.

$$B = [(4 \text{ x } V) / (L \text{ x } \text{Tan } R)]^{0.5}$$

and

$$H = 0.5 \text{ x } B \text{ x } \text{Tan } R, \text{ where}$$

- B is the base width of the bank.
- V is the volume of the soil in the bank.
- L is the length of the bank.
- R is the angle of repose of the soil.
- H is the height of the bank.

It is essential to keep uniform dimensions for each factor. (A common mistake is to apply cubic yards of volume but linear dimensions in feet.) This formula applies for metric dimensions as well. The B and L values enable determination of the site area required to hold the loose soil. The H value combined with half of the B value lets the planner know if the equipment has the reach to build a bank of the planned size.

As an example of calculating the dimensions of a spoil bank, if a builder excavates 1,600 cy of moist clay (40% swell from figure 5-7) from a basement, then the loose volume of the 1,600 bcy can be estimated as 1,600 bcy x (1 + 40%) = 2,240 lcy. The site offers a 200-ft-long (66.7 yd) vacant space along its perimeter for soil stockpiling. The median angle of repose of moist clay is R = 37.5 deg (from figure 5-8). The base width of the bank would be

$$B = [(4 \text{ x } 2{,}240) / (66.7 \text{ x } 0.767)]^{0.5} = 175^{0.5} = 13.2 \text{ yd or } 39.7 \text{ ft},$$

and

$$H = 0.5 \text{ x } 39.7 \text{ ft x } 0.767 = 15.2 \text{ ft}$$

If the equipment cannot easily stockpile the soil into the calculated geometry, then the planner might extend the bank length or stockpile the spoil in multiple banks to reduce the dimensions to a geometry that matches the site and the equipment capabilities. Of course, soil would not be needed to backfill the volume within the constructed basement, so if not needed for other site earthwork, much of the excavated soil might be hauled away, leaving enough stockpiled for backfill, including a waste factor.

Soil	Angle of Repose, R
Clay, dry	30-deg
Clay, moist	35 to 40-deg
Silt, cohesionless	26 to 30-deg
Common earth	20 to 30-deg
Sand, dry, fine to medium	26 to 30-deg
Sand, dry, well-graded	30 to 34-deg
Sand-gravel mixture, dry	32 to 36-deg
Gravel, dry	40 to 45-deg

Figure 6-8. Common soils and approximate angles of repose.

Spoil Pile Volume

Akin to the spoil bank formula is that for a conical spoil pile.

$$D = [(7.64 \text{ x } V) / \text{Tan } R]^{0.333}$$

and

$$H = 0.5 \text{ x } D \text{ x Tan } R, \text{ where}$$

- D is the diameter of the pile base.
- Variables V, R, and H are as for the spoil bank formula.

This formula does not apply to metric dimensions.

Soil Stabilization

Stabilization methods are used to improve the physical properties of soil, such as increasing soil bearing capacity and shear strength, decreasing potential settlement, and reducing soil permeability, the flow or seepage of water through soil. The method categories include mechanical, chemical, or a combination of the two. Soil stabilizations are also applied to treat soils before construction to change soil conditions and provide a working platform for construction equipment. The methods of soil stabilization include soil densification by preloading, mixing granular material with the soil, blending soil with cementing materials or chemicals, and using geosynthetics. Stabilization of poor soil surfaces for construction operations can be cost-effective.

Preloading

Preloading before the structure construction starts applies a temporary load to a potential site where a structure shall be built. Preloading is utilized to consolidate soil into a denser state so that the settlement after a structure is built is minimized. Preloading is carried out by applying a fill or other heavy surcharge to the natural soil and allowing the added weight to sit on the soil for a period of time. Consolidation of soil is the result of constant pressure from loading above. The pressure squeezes water in soil voids away from the soil mass beneath the load and causes soil particles to get closer and bear the load without further settlement. Consolidation may happen over many years, although it is greatest when fine-grained soil is first loaded. Large or uneven consolidations may damage a structure and result in great loss. Consolidation is generally related to soft, silty clay and clay soils. Therefore, preloading is applicable only to fine-grained soils.

Mechanical Stabilization

Mechanical stabilization is carried out by changing the gradation through mixing with other soils, densification of soil by compaction, or removing the existing soils and replacing them with granular material. Mixing coarse aggregate and fine-grained soil adds internal friction and cohesion to the mixture and consequently makes the soil easier to compact to achieve maximum strength. Mechanical stabilization is widely used in highway construction. A common practice to stabilize wet and soft highway subgrade is to cover it with granular material or to partially remove and replace the wet soil with a granular material. The compacted granular layer distributes the wheel loads over a wider area and serves as a working platform.

Chemical Stabilization

Chemical stabilization is used to improve soil properties by adding chemicals such as cement, fly ash, lime, or a combination thereof. The chemical materials are mechanically mixed with the soil, and the mixture is compacted. Chemical reactions in the mixture of soil and added chemicals alter the physical and chemical properties of the soil. The main benefits of chemical stabilization include cementation of soil particles, increased internal friction among soil particles, greater shear strength, reduction in the plasticity index, and reduced shrink-and-swell potential. Many other chemicals, including sodium chloride and calcium chloride, can be used for chemical stabilization. Liquid asphalt is often used in highway construction to improve the strength and other properties of the subgrade.

Limes are often used to increase soil workability. When soil contains too much water, it is difficult for construction crews to work on it. High water content in soil often exists in many areas, especially in the early spring when snow and ice melt as the temperature increases. After mixing limes with soils, the chemical reactions among the lime, water, and soil will consume some water in the soil and thus improve the soil's workability and other properties. Therefore, adding limes to soils with high natural water content can be an effective way to advance a contractor's schedule.

Chemical stabilizations primarily result from the chemical reactions between the added chemicals and the clay particles in the soil. Therefore, the soils in chemical stabilization should contain more than 30% clay content in order to effectively improve the soil properties. Limes are commonly used for soil stabilization by adding 3% to 6% limes to soil. The content of Portland cement or asphalt cement in soil stabilizations typically ranges from 7% (for sandy soils) to 15% (for clayey soils). To assure thorough chemical reactions, the chemicals should be mixed with the soil when the temperature is above 45°F. Vegetation, organic soils, and soil particles larger than three inches should be removed from the soil for chemical stabilizations. For powdered chemicals, such as limes, fly ashes, and Portland cements, spreading the chemicals on the soil should not be performed under windy conditions. Appropriate moisture content should be maintained in the mixes of soil and chemicals for effective compaction. Compaction should start as soon as possible after mixing the chemicals with the soils for best results. Compacted soil must be protected from drying, at least for days and sometimes for a few weeks, to allow curing.

Geosynthetics Stabilization

Geosynthetics are a family of manufactured plastic materials in various forms. The commonly used geosynthetics for soil stabilization include geotextiles, geogrids, geonets, and geomembranes. Geosynthetics can be used to stabilize and reinforce soil masses. They can provide cost and time advantage over hauling and compacting additional fill. The main applications include reinforcing slopes and embankments, reinforcing backfills of retaining walls, erosion control of earth slopes, and separation of soil strata. Geosynthetics are widely used in highway construction to reinforce road sections, and the use of geosynthetics in road subgrades can provide tensile reinforcement, confinement, filtration, drainage, lateral spreading reduction, separation, construction uniformity, and reduction in strain.

With respect to construction, geogrids are often used in the muddy areas of building haul roads for construction equipment. Geogrids are placed between the mud and roadbed materials such as crushed rocks. This layer can not only improve structural support but also can significantly reduce the amount of roadbed materials needed.

DEWATERING

The presence of water in excavations may pose serious problems for construction. This problem normally occurs when excavations are carried below the groundwater level, which can fluctuate seasonally. There are three basic methods of controlling construction groundwater:

1. Open pumping: Permit the water to flow into an excavation, collect it in ditches and sumps, and then pump it away.
2. Predrain the soil before excavation using pumped wells, well points, ejectors, or drains.
3. Cut off or isolate the water with steel sheet pilings, diaphragm walls, ground freezing, tremie seals, or grout.

A combination of these methods may be necessary for specific situations. A dewatering operation might be carried out by the GC. However, dewatering operations in difficult situations usually require the services of a specialty subcontractor.

Open or surface pumping is used to remove slope seepage water. The water collects in a sump or a ditch along the perimeter of the excavation floor and then is removed by a pump. This method is also suitable for getting rid of collected rainwater and runoff. If much of the slope's soil solids also drain with the water and are pumped away, slope instability may result. Well-graded granular material, sometimes placed at the toe of the slope in sandbags, allows water to seep but holds soil fines in place.

Predrainage lowers the water table below the excavation floor and keeps it there during construction. One of the predrainage methods is a well-point system. A well-point is a hollow perforated tube extending below the desired water drawdown depth and covered with a filter screen that allows water to enter the well-point but keeps out soil particles. The bottom end is pointed or serrated to enable it to penetrate into the soil. A series of well-points are connected to a suction pump through a common header pipe. The header pipe is drained by the suction pump, which pulls water through the ground to the well-point system and to the pump. In a perfect system at sea level, a pump might draw water from about 34 ft below, but common energy losses in systems limit the depth for a well-point system stage to 15 ft to 20 ft. Multistage well-point systems may be used if deeper dewatering is needed.

Method	Suitable Soils	Applications	Notes
Sump pumping	Coarse-grained soils, except fine sands	Open, shallow excavations	Simplest pumps; beware discharging fine-grained soil with the water, or instability may occur
Well-points with suction pumps	Coarse-grained soils	Open excavations and trenches	Quickly installed; dependable suction lift to 15 ft per stage
Deep wells with submersible pumps	Coarse-grained soils to silty sands	Deep excavations near water-bearing formations	No drawdown depth limit; wells can draw water from several layers throughout its depth and be sited clear of excavation.
Jet eductors with high-pressure water	Sands to sandy silts	Deep excavations lacking room for multiple stages	No drawdown depth limit
Sheet piling cutoffs	All soils except boulders	Unrestricted	Steel piling can remain in the work or be recovered
Slurry trench cutoffs	Coarse-grained and silty soils	Unrestricted; common for curtain walls around excavations	Quickly installed; keys into impermeable layers, except hard bedrock
Freezing	All saturated soils and rock	Frozen water in voids stops seepage	Better for large applications of long duration; not so common
Diaphragm structural walls	All soils, even those containing boulders	Deep basements and shafts	Can be installed to key into impermeable layers
Contiguous bored piles	All soils, but boulders can be costly to penetrate	Deep basements and shafts	Can be installed to key into impermeable layers

Figure 6-9. Possible dewatering methods, their applications, and soil types for which they tend to be suitable (modified from NAVFAC).

Deep wells with submersible pumps also may be used to lower the water table. Compared to the well-point method, a deep well system can remove water to a greater depth and allows wider pump spacing. Vertical isolation or a lateral cutoff provides an impermeable wall around the excavation area so that groundwater cannot enter the excavation area. Some examples of isolation barriers are steel sheet piling, slurry wall, and tremie seal.

EARTH PRESSURES IN SHORING AND BRACING EXCAVATIONS

Depending on the space available for construction, excavation may be carried out vertically (90^{o} slope) or with an inclination. In many cases, excavation braced supports or trench shields are needed to assure excavation stability and safety. The OSHA excavation safety requirements are provided in chapter 10, but engineering principles that relate to the OSHA requirements follow. The design of an excavation support system largely depends on the forces acting on the support system. Four conditions in particular increase the risk of excavation slope or shore failure:

1. Surcharge loading by construction equipment or materials near the excavation.
2. Infiltration of recent precipitation.
3. Longer time that the excavation is open.
4. Vibration from nearby operating equipment or passing vehicles.

The stability and safety of an earth support system may be compromised by construction operations, especially if existing conditions change from the design assumptions. Such changes are not uncommon, because the soils encountered may differ from what the soil investigations lead one to expect. It is therefore helpful to understand some of the concepts and calculations of earth stress and forces.

Earth Pressure

At a point within a soil mass, stresses are developed from the weight of the soil lying above the point, plus any other vertical loading imposed. The safe bearing capacity of the soil and the settlements that develop under a given vertical loading are major items of concern. For such analysis, the significant stresses are considered to be those acting in the vertical direction.

The site professional should note that the vertical loads impose substantial horizontal force on structures such as retaining and basement walls, sheeting for braced excavations, and some types of pile foundations. For example, a heavy load imposed on soft backfill near a basement wall can cause the wall to fail. The contractor might not determine the magnitude of the earth pressures involved in these cases, but she should develop qualitative judgment about the general behavior of geotechnical structures and the effects of common construction operations on their behavior. This enables better assessment of possible risks.

Stresses Caused by the Soil Mass

There are three categories of earth pressure: earth pressure at rest, active earth pressure, and passive earth pressure (Liu & Evett). Basic knowledge of these soil pressures give the builder an idea of the behavior to expect from structures exposed to soil loads.

Earth Pressure at Rest

Figure 6-10 shows the concept of vertical and horizontal stresses on a small element of soil at a certain depth.

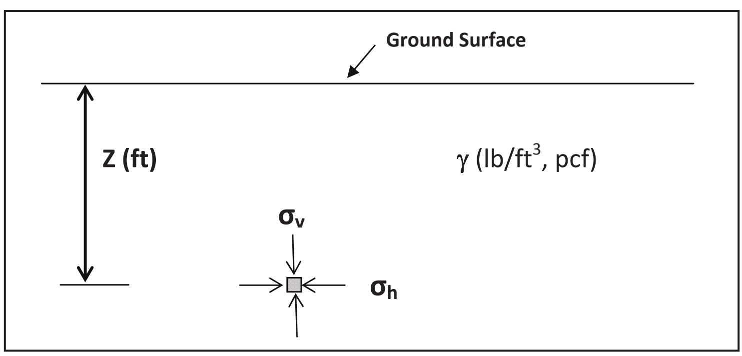

Figure 6-10. At depth Z, the weight of the soil of density, γ, above the small cubic element induces a vertical stress, $\sigma_v = Z \times \gamma$. A fraction of σ_v resolves into horizontal stress, σ_h, which depends on the properties of the soil. A stiffer soil transfers less vertical force in the horizontal direction than a softer or more plastic soil mass.

When the soil is in static equilibrium, the ratio of horizontal stress σ_h to vertical stress σ_v, K_0, is termed the coefficient of lateral earth pressure.

$$K_0 = \text{Horizontal stress} \div \text{Vertical stress} = \sigma_h \div \sigma_v$$

Soil Type	K_0
Granular, loose	0.5 to 0.6
Granular, dense	0.3 to 0.5
Clay, soft	0.9 to 1.1, undrained
Clay, hard	0.8 to 0.9, undrained

Figure 6-11. Typical K_0 values. The undrained condition refers to water in the voids being unable to quickly drain from the soil when a load is imposed and results in somewhat higher K_0 values.

When K_0 is known, the horizontal stress can be calculated as $\sigma_h = K_0\,\sigma_v$. For example, if the loose granular soil density is 105 pcf, then at a depth of 12 ft, the vertical stress is 105 pcf x 12 ft = 1,260 psf (lb/ft^2). Selecting the median K_0 value of 0.55 for that soil type, the horizontal stress is 1,260 psf x 0.55 = 693 psf at the 12-ft depth. This offers the builder some idea of the stress to which a subsurface structure might be exposed.

Active Earth Pressure

This horizontal pressure results from the soil pushing against a structure, and the structure can move slightly outward. A wall deflects outward, at least a small amount, from the horizontal force exerted by the soil it retains. That small, active movement allows the soil to shift slightly and begin to fail in shear along a plane of least resistance. The friction along the failure plane partly reduces the horizontal force that would otherwise be exerted. The reduced force results in active earth pressure against the wall. The active pressure is commonly somewhat less than the earth pressure at rest in a given soil mass.

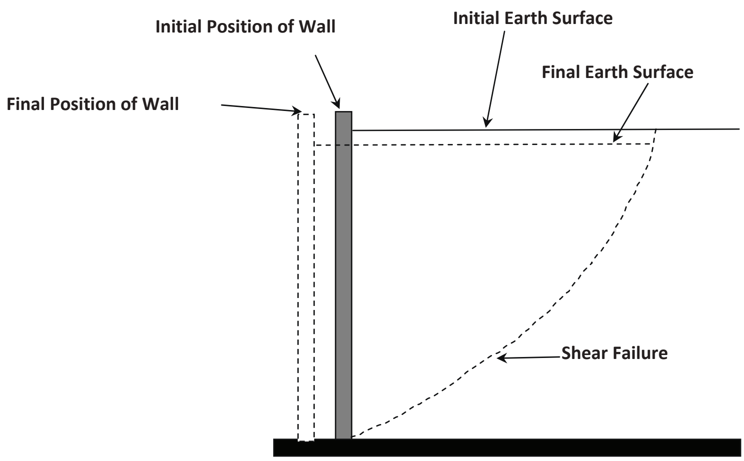

Figure 6-12. Active earth pressure against a wall. Friction along the shear failure surface reduces the horizontal force that the soil would otherwise exert. For smaller wall movements, the magnitudes of the outward and downward soil movements are approximately equal.

Passive Earth Pressure

If a wall is forced toward soil, the earth surface will tend to be raised, and lateral pressure on the wall will be increased. If the wall moves far enough against the soil, shear failure of the soil will occur, as shown in figure 6-13, and a sliding wedge will tend to move backward and upward. The earth pressure exerted on the wall at this state of failure is known as passive earth pressure.

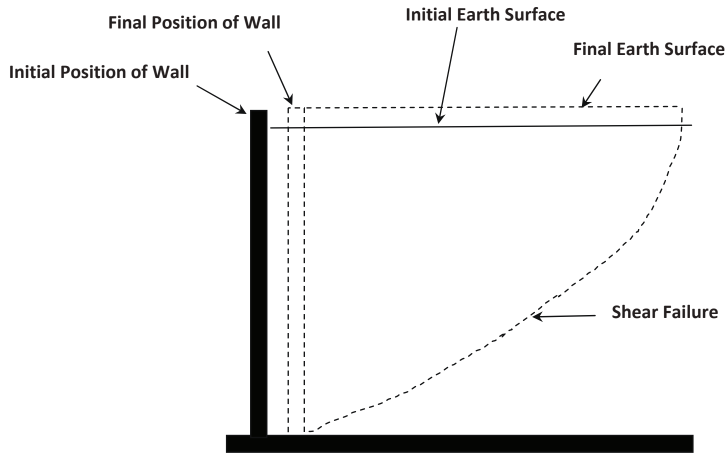

Figure 6-13. Passive earth pressure is commonly greater than earth pressure at rest due to the friction of soil sliding along the failure plane, adding to the resistance of the soil weight alone.

Lateral Earth Pressure on Bracing Structures

Excavations may be supported by bracing structures with some form of additional support rather than a rigid wall. A bracing structure contains two major elements: the part of the structure that is in direct contact with the soil and the bracing mechanism that supports it. Empirical diagrams of lateral pressure against bracing structures are applied for design and analysis (Schroeder, 2004).

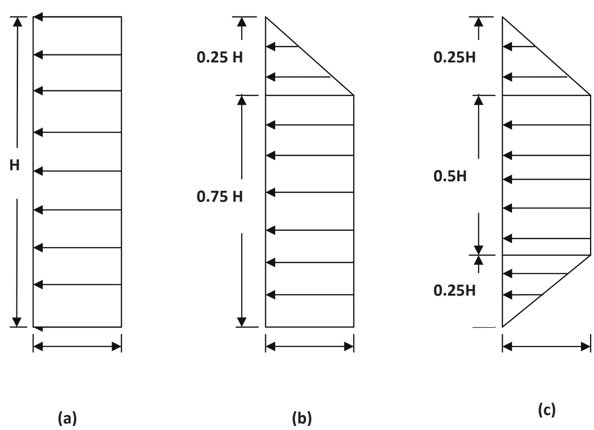

Figure 6-14. Lateral earth pressure distribution on braced excavation support: (a) sands, (b) medium to soft clays, and (c) stiff-fissured clays. The magnitude of the loads is a function of soil cohesion and internal friction. Geotechnical engineers might design the soil retaining structure, although installing contractors sometimes do so for excavation depths less than 20 ft. The builder should understand the loading in a qualitative sense to anticipate retaining structure behavior.

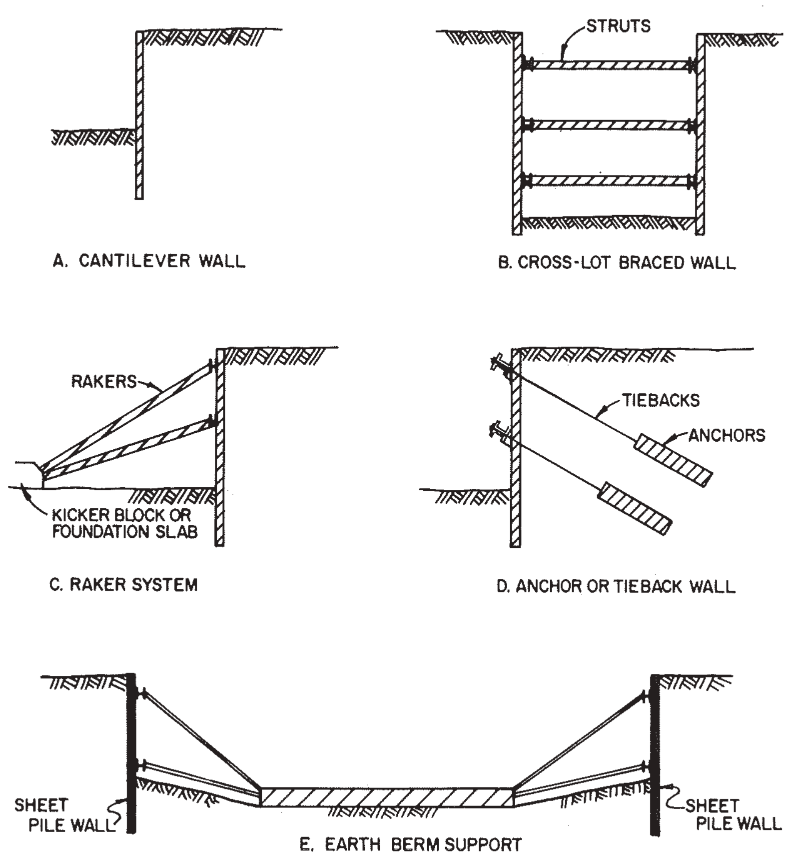

Figure 6-15. Common excavation support techniques, which can be preferred to the larger excavation footprint of sloped sides. Cantilevered walls and tiebacks provide greater freedom for material storage and crew movement in the excavation than the other methods (NAVFAC, 17).

Stability of Slopes

Whenever the soil has an inclined surface, the potential exists for part of the soil mass to slide from a higher location to a lower one because of the weight of the soil mass. Slope stability is important for construction excavation safety. The cohesion and internal friction of the soil provide a resistant force against the sliding of the soil mass. If the resistant force is considerably greater than the sliding force, the soil slope is stable. Otherwise, the slope is unsafe, and the soil mass will be prone to land sliding.

Slopes that are otherwise stable can be compromised if the soil becomes saturated. The greater weight of the water in the soil increases the weight of the slope soil, while the added water between the soil particles decreases their interlock and shear resistance against movement. This combination of adverse conditions can lead to sudden slope failure.

Figure 6-16. Welding bolts to hold wood lagging tightly to the driven H-piles. Encountering a layer of uncommonly plastic soil permits loads from the soil above to induce higher lateral pressures against the excavation supporting structure. Unexpected groundwater might also induce more pressure by increasing the weight of the soil mass while reducing its shear resistance. Not all subsurface conditions are discovered by common soil exploration procedures so builders must be observant.

Figure 6-17. Vertical excavation of clay. Despite the initial stability of steep slopes, they must be cut back for safety to at least 0.75H:1V, and maybe more, if a soil retaining structure is not built.

SOIL COMPACTION

Most construction materials can be specified in terms of composition, size, strength, and other properties to meet engineering and construction requirements. Strictly speaking, there are no established specifications for soils in construction because they are naturally given at construction sites. However, the properties of construction soils can be improved. The most important and common method for soil quality improvement is compaction. Compaction refers to the process of mechanically densifying a soil by reducing air voids. The voids between solid soil particles decrease in size; and the soil solids are brought into closer and more numerous interlocks, which increase resistance to movements within the soil mass. Increased soil density improves soil properties: more strength and durability and less permeability and settlement.

Laboratory Compaction Tests

Soil can be effectively compacted if it contains a certain amount of water. The water in soil acts as a lubricant and allows the soil particles to move more easily during compaction. However, too much water, which is incompressible, will fill the voids and prevent solids from moving into a denser state. Thus, for each soil, there should be a particular water content, w%, at which compaction is most effective.

Laboratory compaction, moisture-density, or Proctor tests are conducted to determine the water content of a soil at which the maximum soil density can be achieved. That amount of water is the optimum moisture content (OMC). The density, γ, and w% of each compacted laboratory specimen is measured. The dry density, γ_d, is obtained in terms of γ and w% by the following formula:

$$\gamma_d = \gamma \div (1 + w\%)$$

Figure 6-18 plots γ_d versus w% to identify the maximum γ_d and the OMC of the soil.

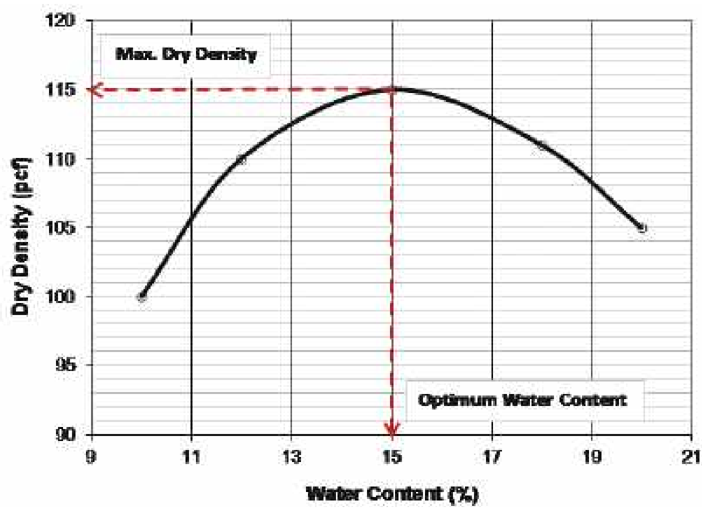

Figure 6-18. Here maximum dry density, $\gamma_{d,max}$, is 115 pcf and OMC is 15%, as located after plotting the Proctor compaction test results and drawing the curve. A compaction specification is commonly expressed as a percentage of $\gamma_{d,max}$. The subgrade of a structure might be at least 95% $\gamma_{d,max}$, while the backfill for a utility trench is often 90%. Compacting the soil near the OMC reduces cost. The contractor must achieve both the density and the moisture content specifications.

The reason for using dry rather than moist density in the Proctor test is that the former is independent of the water content of the compacted soil in the field. The solid particles of the soil, not the water in it, provide the structural matrix that supports loads, so dry density relates better to the load-bearing capacity of the soil. When the maximum dry density, $\gamma_{d,max}$, is determined for a given soil, the compaction of the soil in the field can be measured and assessed by comparing the actual dry density, γ_d, of the compacted soil with the $\gamma_{d,max}$ and without considering the soil's actual water content. Unless there is prior experience with a particular soil, one cannot confidently relate the compaction test results for the soil to a specific roller and number of passes; the contractor usually must perform a trial compaction in the field.

Compaction Equipment and Specifications

Many types of compaction equipment exist. Compaction devices densify soil through one of these actions or their combinations: kneading or tamping, static weight, vibration, and impact. Vibration is efficient for compacting granular soils. Compaction of clayey soils is mainly achieved through the static weight and kneading action of the compaction equipment. Selecting proper compaction equipment will result in a cost-effective process. Common compaction equipment includes the following:

- **Vibratory roller** (figure 6-19): Vibration rollers are those compactors that vibrate during compaction. They are effective for compaction of granular soils, such as sand and gravel.
- **Sheepsfoot roller** (figure 6-20): This equipment compacts soil through static weight and kneading actions. It is used for compaction of clayey soils. It cannot be used for granular soils, such as sands and gravels, because the roller feet will continue to penetrate into the granular soils. When soil is compacted as much as possible by the sheepsfoot, the soil will support the feet and the roller surface will not quite touch the soil.
- **Pneumatic or rubber-tired roller** (figure 6-21): This equipment compacts soil through static weight. It can be used for most soils. It works best for granular soils or soils containing a small amount of fines. It is also often used in asphalt pavement compaction.
- **Smooth-wheel roller** (figure 6-22): This equipment compacts soil through static weight. It is often used for fine-grained soils and for base course and paving mixtures.

There are two methods of specifying compaction. One of the methods is the work or descriptive method, which specifies the compaction equipment and the number of passes of compaction. The contractor need only follow the specifications for acceptance of the work. The work method is generally for compaction of coarse-grained materials such as rock fills. The other method is the performance method, which specifies a minimum density to achieve. The contractor selects the method by which to reach the density. The performance method is used for compaction of cohesive soils and fine aggregates.

The maximum dry density and optimum water content determined from the compaction tests are very important for compaction operations. Relative compaction and OMC are used in specifications to control compaction quality (Schroeder, Dickenson, & Warrington, 2004).

Figure 6-19. Compaction with smooth-wheel vibratory roller. This roller commonly compacts coarse-grained soils and rock fills.

Figure 6-20. Self-propelled sheepsfoot roller. A sheepsfoot roller is usually applied for fine-grained soils. A suitable weight and type of roller applied to fine-grained soil near the OMC usually compacts the fill to the specified percentage of $\gamma_{d,max}$ within six coverages. When a sheepsfoot roller "walks out" of the soil (i.e., when the compacted soil supports the roller without allowing the feet to penetrate the surface), it has reached the limit of its effectiveness for the conditions. The blade levels the surface of the loose fill so that the compaction effort is more evenly distributed.

Relative compaction (RC) is defined as the ratio of the measured dry density to the maximum dry density expressed as a percentage:

$$RC = (\text{field measured } \gamma_d \div \gamma_{d,max}) \text{ x } 100\%$$

The measured dry density is the actual dry density of the compacted soil. The field dry density may be measured by a nuclear gauge (figure 6-23) or other methods or devices.

Figure 6-21. Pneumatic-tired roller compacting asphalt. Tire pressure can be regulated to obtain optimum results. This roller type can often be the most flexible for varied compaction requirements.

Figure 6-22. Smooth-wheel roller. This roller compacts fine-grained soils and finishes the surface of asphalt pavement.

Depending on the design, the specifications will require a relative compaction range from 90% to 100%. The upper layers of an embankment are often specified with a higher relative compaction than the layers below. It is extremely important for a contractor to make the soil's water content as close to the OMC as possible so that compaction is effective. When the w% is far away from the OMC, it is almost impossible to achieve the required compaction. Each layer (or lift) of loose soil for compaction usually ranges from 6 to 12 in, with 8 in loose lifts

Figure 6-23. Measuring compacted soil density with a nuclear gauge. These devices can measure asphalt density as well as the soil moisture content. The project specifications will direct the required frequency of density testing, often per lift or per volume of compacted soil.

being typical for engineered soil embankments. The teeth of sheepsfoot or segmented foot rollers should penetrate slightly into the layer below that which is being compacted. This helps to "lock" the embankment layers together.

The following soil compaction guidelines are helpful for density control:

- The moisture content of clay shall be controlled within –2% and +1% of OMC, and the moisture content of silt should be –3% to optimum moisture.
- If the soil is too wet for compaction, the material shall be aerated or scarified to remove excess moisture.
- If the soil is too dry for optimum compaction, it shall be watered and disked to increase the moisture content.
- The soil shall be placed in uniform level layers and compacted with approved compacting equipment. Compacting equipment shall include at least one three-wheel roller or other compacting equipment capable of providing a smooth and even surface.
- Each lift of soil to be compacted shall be disked or treated by some other mechanical means to ensure that any existing lumps and clods are broken up.
- The loose depth of each lift shall be such that the required compaction can be obtained and shall not exceed 12 in.
- Field compaction tests shall be conducted on each lift, and the required compaction shall be obtained on each lift before the next lift is placed.

DRAINAGE

Surface Drainage

Surface drainage is often ignored or forgotten until after the first rainstorm. By then, the rainfall may have saturated wide portions of the site and degraded productivity, damaged installed work, and created unsafe working conditions. The well-prepared contractor should know expedient drainage design and installation measures in order to control precipitation runoff during construction. The risk from random storm runoff can be economically reduced where the cost to install the temporary structure is less than the expected cost of damage or delay if runoff is uncontrolled.

Permanent Drainage Structures

Permanent site drainage structures are designed by civil engineers on the basis of a design storm. Based on common practice, regulations, or specific owner needs, the acceptable risk of failure in any one year, say, a 2% or 4% chance of overflowing, determines the design storm for which permanent drainage might be installed. The design storm has a rainfall intensity (in/hr) for a selected period of storm duration. Depending on the geometry and other characteristics of the site and the location of the structure, the design storm results in a peak rate of flow that must be carried. The structure is designed to carry that flow of stormwater runoff.

CMs might install the permanent site drainage structures early in the construction phase so they can drain the project, even during construction. Designers may recommend against this if they think that the drainage structure will be damaged during construction, but this alternative should always be considered. Early installation of permanent subsurface drainage frequently has less risk of inadvertent damage than do surface structures.

Expedient Drainage Design

Expedient drainage construction and its routine maintenance throughout the work should be factored into the project overhead of the cost estimate. It might be a critical part of the Stormwater Pollution Protection Plan (SWPPP), which is covered later in this chapter. Naturally, where the contractor can utilize on-hand materials rather than purchasing new, the drainage costs will decrease.

A common expedient structure is a culvert. Expedient culverts might be built to provide cross-drainage or otherwise pass stormwater runoff through a site access road embankment or continue side ditches at construction road intersections.

Design Flow

The expedient design procedure for a surface drainage structure is based on the equation

$$Q = 2 \text{ x } A \text{ x } R \text{ x } C, \text{ where}$$

Q = peak volume of runoff, in ft^3/sec (cfs). As will be seen, the formula results in dimensions of acre-in/hr, where 1-ac-in/hr = 1.008 cfs; so approximately 1-ac-in/hr = 1 cfs.

Constant, 2. The origin of this factor is uncertain, but an anecdote from one engineer provides a clue. He served in New Guinea during World War II, and the drainage structures they designed there with an earlier technique kept washing out during the monsoon. The military designers then empirically decided to routinely double the design capacity of all of their structures, and the problems nearly disappeared, using the same construction materials and techniques.

A = the drainage area of the basin, in acres (1 ac = 43,560 ft^2). The drainage basin comprises the area that feeds stormwater runoff to a culvert or ditch. The basin draining to the planned expedient structure may include more or less area than the construction site. The expedient procedure becomes progressively less reliable when the basin exceeds 100 acres due to the greater chance of spatial variations of rainfall intensity. To reduce this possibility, the procedure limits the applicable drainage basin area to 100 acres.

R = rainfall intensity for the design storm, in in/hr. The intensity is commonly determined from the data of many storms, as recorded by the U.S. Weather Bureau and shown in the *Rainfall Frequency Atlas of the United States*, Technical Paper (TP) 40 (U.S. Dept. of Commerce, 1961). Rainfall intensity is displayed on special maps by isohyets for a storm of one-hour duration and a return period of some number of years, usually two years but maybe five or 10 years for expedient design (Tech. Paper 40, pp. 16–18). Isohyets are the lines connecting the locations of the same expected rainfall intensity for a storm of a stated duration and return period. The longer the storm return period (lower the frequency) and duration are, the greater the peak rainfall intensity will be. The design for a site located between two isohyets, even if close to a lower value isohyet, uses the rainfall intensity of the higher value isohyet.

During a one-year construction period, the probability of the flow from a properly designed structure exceeding what it is designed to carry is the reciprocal of the storm return period. That is, a culvert or drainage ditch designed for a two-year return period storm has a ½ = 50% likelihood during any one-year period of being subjected to flows at *or above* that for which it is designed. A 10-year return period provides a design that has a 1/10 = 10% chance of being subjected to runoff at *or above* the design capacity during any one year.

For most building construction projects, the one-hour duration for two-, five-, and 10-year return period storms offers enough alternatives to reduce the risk of the structure washing out to 50%, 20%, and 10%, respectively, during any year. For a construction period exceeding one year, one can select a TP 40 isohyet plot with a storm return period closer to the duration of the project. However, as project circumstances move further from the simple conditions of the expedient procedure, a civil engineer should be consulted.

C = the coefficient representing the ratio of runoff to rainfall, dimensionless. The basin soil type determines rainfall infiltration into the soil, and the vegetation of the basin affects the interception of rainfall to keep it from reaching the ground surface. The coefficient, C, is found from combining their effects. The expedient designer should be able to obtain the predominant USCS soil type from a project geotechnical report or from a field sample of soil during a site visit. The vegetation causes the site to be classified with turf or without turf; much grass cover over most of the site would lead to the former, while minimal cover would lead to the latter. The values of C are obtained from figure 6-24. Applying a coefficient derived by the area-weighted average for substantial variations of soils and vegetation is sensible. However, the site planner should keep this expedient procedure quick and simple. As will be seen, the procedure often leads to installation of structures with substantial safety factors.

Soil Runoff, C, Coefficient Determination						
Major Soil Divisions		USCS Classification		Drainage Characteristics	C-value	
					Turf	No Turf
Coarse-Grained Soils	Gravelly Soils	GW		Pervious	0.10	0.20
		GP		Pervious	0.10	0.20
		GM	d*	Slightly Pervious	0.30	0.40
			u*	Impervious	0.55	0.65
		GC		Impervious	0.55	0.65
	Sandy Soils	SW		Pervious	0.10	0.20
		SP		Pervious	0.10	0.20
		SM	d	Slightly Pervious	0.30	0.40
			u	Impervious	0.55	0.65
		SC		Impervious	0.55	0.65
Fine-Grained Soils	LL< 50	ML		Slightly Pervious	0.30	0.40
		CL		Impervious	0.55	0.65
		CL		Impervious	0.55	0.65
	LL > 50	MH		Slightly Pervious	0.30	0.40
		CH		Impervious	0.55	0.65
		OH		Impervious	0.55	0.65
Highly Organic		P_t		Slightly Pervious	0.30	0.40
Asphalt Pavements and Roof Surfaces						0.95
Concrete Pavements						0.90
Gravel or Macadam Pavements						0.70
Wooded Areas						0.20
* The GM and SM subclasses d and u represent soils that are desirable or undesirable as road subbase materials.						

Figure 6-24. Values for coefficient C in the Q = 2 x A x R x C formula. Although the expedient method design should remain quick and simple, an area-weighted average might be applied for larger sites (modified from USACE, 4–3).

Culvert Design

By continuity,

$$Q = V \times A_{wet}, \text{ where}$$

- V = the velocity of flow, in ft/sec.
- A_{wet} = the vertical cross-sectional area of the flowing water, in ft^2 (sf).

One assumes that V = 4 ft/sec (fps). If water flows too fast, it scours the ground surface of a ditch or culvert outlet. If water flows too slowly, it deposits the soil particles that are suspended in the flow and clogs the structure. The 4-fps value helps to preclude both of these conditions.

Given Q and the assumed velocity,

$$A_{wet} = Q \div 4 \text{ fps}$$

Where a ditch exists on-site, one can sometimes observe the peak flow that seems to have washed through it, and A_{wet} can be estimated. Assuming the ditch has been in place over time, this can provide the best estimate of A_{wet} for an expedient structure.

The cross-sectional area of the designed structure results from applying a safety factor to A_{wet}:

$$A_{des} = 2 \text{ x } A_{wet}$$

The site professional then selects a culvert or multiple culverts, so that the area sum of all installed cross-sections is greater than or equal to A_{des}:

$$\sum \text{culvert cross-sectional areas} \geq A_{des}$$

Corrugated metal pipe (CMP) is often installed, due to its light weight and ease of handling. Common CMP culvert cross-sectional areas are listed in figure 6-25. The round cross-sections are found in diameters from 6 in to tens of feet, with the smaller diameters in 6-in increments. Besides round cross-sections, horizontal and vertical elliptical shapes are produced. The horizontal elliptical shape is useful when the depth of the fill is restricted, and the vertical ellipse better resists the overhead loads if the compacted fill provides less load-bearing capacity.

CMP demands special care to ensure that it will not be crushed by overhead traffic. To dissipate the loads from traffic, the top of the culvert is always installed below the compacted cover, which is at least 1 ft or one-half of its diameter, whichever is greater. Note figure 6-26.

Uncommonly heavy traffic increases this requirement. The builder provides sufficient fill to achieve the necessary cover above the culvert pipes.

Cover thickness, C + Diameter of pipe, D = Fill height, F ≥ ½ D or 1 ft, whichever is greater

Just as important as compacted fill beneath the traveled way is adequate compaction of the rest of the fill, especially under the culvert shoulders, the lower arc of the pipe below the horizontal diameter. If stronger pipe material, such as reinforced concrete or cast or ductile iron, happens to be on hand, then the cover requirements might be reduced slightly if necessary.

One usually selects the largest diameter culvert that maintains the cover requirements. It is easier to install one pipe that carries the flow instead of multiple pipes of smaller diameter, but one uses what is most readily available. Another constraint is that pipes must be separated by ½ D from one another and from the sides of an existing ditch into which they are installed. This may lead to an alternative of a different diameter. See figure 6-26.

The diameters of multiple culverts should be the same and installed at the same depth, or there is greater risk of washing out the smaller pipe(s). Stepwise increments for the culvert selection process often lead to greater installed cross-sectional area than called for by design. If so, then this design step increases the factor of safety.

In some cases, the available pipe may yield a cross-section that is moderately less than A_{des}. If a culvert area of at least A_{des} is not installed, then one notes the higher risk of washout or overtopping. Engineering judgment must be applied in the context of cost-benefit. Installing a slightly inadequate cross-section by using available materials instead of purchasing more would be more tolerable for a shorter than a longer project.

CMP Culvert Diameters and Cross-Sectional Areas	
Diameter (in)	Area (sf)
12	0.79
18	1.77
24	3.14
30	4.91
36	7.07
42	9.62
48	12.6
60	19.6
72	28.3

Figure 6-25. Round CMP cross-sections yield these areas to satisfy A_{des} (USACE, 4–6). Larger diameters than shown are produced, but the above usually satisfy expedient culvert applications. The CMP is galvanized for durability. High-density polyethylene (HDPE) pipe varieties from 1 to 5 ft in diameter are common as well.

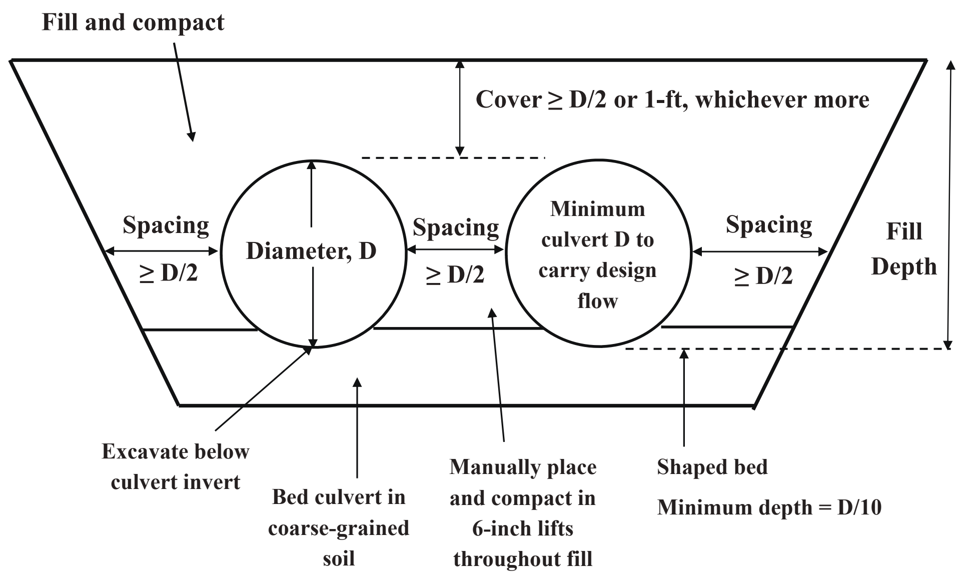

Figure 6-26. Expedient culvert construction diagram (USACE, 7–15).

After the culvert diameter is fixed, the pipe length must be calculated. The length extends from upstream to downstream through the fill cross-section. If no downstream headwall is built, then the culvert must extend at least 2 ft beyond the toe of the slope to reduce erosion at the outlet.

Enough sections of pipe must be obtained for the culvert length. CMP is commonly produced in 10- and 20-ft sections. If manufactured CMP connecting joints are not available, then upstream sections nest at least 1 ft into the downstream sections. When inserting one pipe end into another is difficult, three or four longitudinal cuts of length slightly less than the overlap enable easier assembly without crushing the ends to restrict flow. The joints should be tight enough that water does not easily leak into the surrounding soil to undermine the pipe bedding and that soil cannot infiltrate the joints to clog the flow. The extra foot of length per overlap must be added to the total pipe length to find the number of sections that must be ordered. For an installation with multiple pipes, the required number of sections increases accordingly.

For example, say there are two side-by-side pipes in a culvert that runs through an embankment, and the bottom of the embankment is 32-ft wide in the direction of flow, including embankment side slopes. The available CMP is in 20-ft sections. A 2-ft downstream extension is needed for each pipe. If the upstream section of a pipe nests 1 ft into the downstream section, then the total length needed per pipe is

32 ft through the embankment + 1-ft overlap + 2-ft extension = 35 ft of CMP

Then one section might have some of the extra 5 ft (2 x 20 ft – 35 ft) cut off, or the pipe would extend much further than required downstream. The downstream toe extension of the culvert should not extend much beyond 2 ft. At two sections per pipe, the culvert installation would require four 20-ft sections.

For another example, if 10-ft lengths are used, four sections are required per pipe for a total of eight sections. The four sections of a pipe require three overlaps and might be increased to 2 ft per overlap:

$$(4 \times 10 \text{ ft}) - (32 \text{ ft} + 2 \text{ ft}) = 6 \text{ ft, then}$$
$$6 \text{ ft} \div 3 \text{ joints} = 2 \text{ ft per overlap}$$

The sections should be kept intact, if possible, for flexibility of use in later installations after the temporary drainage structures are removed. Depending on the ease of nesting the sections, they might require cutting, as in the first example, to preclude very deep overlapping of sections.

The pipe bottom should be embedded in coarse-grained soil to a depth of at least 0.1 x D. The fill within distance D of the pipe should be compacted carefully so as not to damage the pipes. For longer construction periods, if no headwalls are built at the inlet or outlet, then suitable gravel or cobbles of a larger size might be spread as rip-rap on both embankment slopes to reduce erosion. A boulder-lined discharge pool at the outlet can be useful, too. If many elaborate features are added, however, then the expedient design strays from its economical purpose.

Even for shorter periods of usage, both the surface of the traveled way that spans the culvert and the pipe interior must be maintained. Traffic tends to displace the compacted surface of the cover so the compensating traveled way fill should be added and compacted from time to time. Pipes should be periodically cleared of blockages, especially before and after a storm. Reliable drainage structures during construction are a critical part of a SWPPP.

Example:

Permanent drainage structures at a new project site located in the southwest corner of Missouri will not be built until the work is almost complete. Therefore, the contractor decides to plan for expedient drainage. The drainage basin area that encompasses the construction site is estimated to be 620,000 sf. The flow path for all runoff leads to a ditch, which is dry except during storms and blocks the planned site entrance. A haul road embankment will be constructed over the existing ditch at the temporary site entrance. The builder must install a culvert to carry drainage through the site haul road embankment. She will accept no more than a 20% chance of exceeding the capacity of the CMP culvert during the year before a permanent embankment and concrete culvert will be constructed nearby. From the geotechnical report, she notes that the surface soil in the basin is predominantly low-compressibility silt (ML). She sees that the site is sparsely vegetated and wide areas are exposed soil. The elevation of the top of the planned road embankment is 849.00 ft. The bottom of the existing ditch that the haul road shall span is at an elevation of 842.50 ft. The road embankment will be 18-ft wide on top, allowing for the widest expected traffic axle width, plus 2 ft on both sides. Embankment side slopes both upstream and downstream will be 2.5H:1V. The width of the existing ditch is 10 ft at the bottom, and the sides of the ditch slope are at 1.5H:1V to the top edges. The builder does not want the added expense of headwalls.

Requirement:
By expedient methods, determine the size and length of culvert pipe(s) that are needed through the road embankment. How many 10-ft lengths of culvert pipe must be obtained?

Solution:

$$A = 620{,}000 \text{ sf and at } 43{,}560 \text{ sf/ac} = 14.2 \text{ ac.}$$

The five-year storm offers a 1/5 = 20% chance of being exceeded. Page 17 of Technical Paper 40 displays R for a five-year, one-hour storm. The southwest corner of Missouri lies between the 2.2 in/hr and 2.4 in/hr isohyets, so the higher value is used: R = 2.4 in/hr.

From figure 5-24, ML soil and sparse vegetation (basically no turf): C = 0.40.

Then,

$$Q = 2 \times A \times R \times C = 2 \times 14.2 \text{ ac} \times 2.4 \text{ in/hr} \times 0.40 = 27.3 \text{ cfs}$$

Assuming that V = 4 fps,

$$A_{wet} = Q \div 4 \text{ fps} = 27.3 \text{ cfs}/4 \text{ fps} = 6.8 \text{ sf.}$$

Then,

$$A_{des} = 2 \times A_{wet} = 2 \times 6.8 \text{ sf} = 13.6 \text{ sf.}$$

From figure 6-25, a 48-in pipe of 12.6 sf does not quite provide the required 13.6 sf. A 60-in pipe amply provides 19.6 sf, but does it fit vertically within the fill?

The fill, F = 849.00 ft–842.50 ft = 6.50 ft. The cover requirement, C, is at least 1 ft or 0.5 x pipe diameter, D = 5 ft, whichever is greater. Half of the 5-ft diameter is 2.5 ft, which when added to the 5-ft diameter is 7.5 ft > F = 6.5 ft. Therefore, a smaller diameter than 60 in must be selected, and multiple pipes should all be of the same diameter.

Two 42-in pipes provide 2 x 9.62 sf = 19.2 sf, which is more than enough. Their cover requirement is 0.5 x 42 in = 21 in, for

$$C + D = 21 \text{ in} + 42 \text{ in} = 63 \text{ in},$$

which is less than the 6.5 ft x 12 in/ft = 78 in. This design would work. Another possibility is to construct the structure with three 30-in pipes of 4.91 sf each:

$$3 \times 4.91 \text{ sf} = 14.7 \text{ sf},$$

which is closer to the desired design area. Fewer pipes are preferred, but the builder uses what is available or can be easiest obtained. In any case, the stepwise increments for the pipe diameter selection tend to add to the factor of safety of the expedient A_{des}.

The required horizontal separation must be checked. The two 42-in pipes, plus the ½ D = 21 in between them, plus 2 x 21 in to their exterior sides is the width, W, needed for separation:

$$W = 2 \times 42 \text{ in} + 21 \text{ in} + 2 \times 21 \text{ in} = 147 \text{ in} = 12.25 \text{ ft}$$

This dimension must be satisfied at the ditch height of the horizontal diameter. The height is 0.5 x D = 21 in, plus the depth of the culvert bedding, at least 0.1 x D = 4.2 in (say, 5 in) above the ditch bottom. At that combined height of 26 in, the 1.5H:1V slope extends the width of the ditch by 1.5 x 26 in x 2 = 78 in = 6.5 ft. The width of the ditch at a height of 26 in is a total of 10 ft + 6.5 ft = 16.5 ft. Therefore, the 12.25 ft requirement is attained.

The builder must determine the required number of pipe sections. The next step examines the cross-section of the embankment through which the pipes run in order to find the bottom width of the embankment. The bottom width includes the top width, plus the horizontal component of the 2.5H:1V side slopes (vertical F = 6.5 ft). In addition, the pipes should extend at least 2 ft beyond the toe of the downstream slope:

$$\text{Pipe length, } L = 18 \text{ ft} + 2 \times (2.5 \times 6.5 \text{ ft}) + 2 \text{ ft} = 52.5 \text{ ft}$$

Six 10-ft sections must be installed for both pipes. Since the six sections require five joints, the sections must total at least 52.5 ft + 5 x 1 ft = 57.5 ft, which is less than the 60 ft of the six sections. The pipes can be cut off 2.5 ft downstream, or each of the five joints might overlap 1.5 ft, if nesting them deeper than 1 ft is not too difficult.

Therefore, obtain 12 10-ft sections of 42-in CMP for the two culvert pipes.

Subsurface Drainage

An earlier chapter section discussed dewatering, which is the provision for disposal of undesirable groundwater on a building site. Subsurface drains draw away water that infiltrates from the site surface. Although more involved than cutting a surface drainage ditch, subsurface drains might be part of the plan since they do not restrict surface operations as open ditches sometimes do. If the completed project is required to have subsurface drains, the contractor may be able to install them in the first phase of construction so that they drain the site while the builder works.

STORMWATER POLLUTION PREVENTION PLANS (SWPPP)

The U.S. Environmental Protection Agency (EPA) demands that an SWPPP be prepared and implemented throughout the course of a construction project in order to obtain a National Pollutant Discharge Elimination System (NPDES) permit. Templates are provided on the EPA website and will likely change from time to time. The superintendent must ensure that the plan meets environmental specifications and can be implemented. Both the site owner and operator, commonly the contractor, determine any effect that site runoff may have on endangered species and special habitats such as wetlands. In particular, the prevention of sediment flow from the site is imperative, although pollutants of many types demand control.

The estimate for project overhead costs must include all activities and preparation that ensure the project meets EPA stipulations. Maintenance often costs more than the initial control feature installation. Inspections must be performed to ensure erosion and sediment controls remain fully functional. The inspection frequency varies with project site conditions, but weekly or biweekly inspections may be prescribed, as well as within 24 hours of 0.25 in or more precipitation. Some SWPPP maintenance activities might be formally scheduled to ensure compliance.

The serious nature of the plan should never be understated. The construction site operator or authorized representative, who has direct responsibility for implementing the SWPPP, must sign the plan and all reports.

The EPA SWPPP Guide is comprehensive and offers useful advice to site managers. Best management practices (BMPs) include appropriate contract language to ensure that subcontractors comply with the requirements and that the installed stormwater control features are inspected before, during, and after precipitation. A successful SWPPP hinges on implementation of BMPs, which in addition to the inspections and maintenance of control structures require that:

- The construction site is kept clean, especially of spills and trash that might contaminate the area
- Exposure of bare soils to rain is minimized
- Diversion of runoff from exposed areas is maximized
- Sediments do not wash from the site
- Pollutant spills are remediated
- Provisions of the plan are modified if an inspection shows that any are ineffective

Ditches and culverts of permanent or expedient design and with sufficient capacity may be important components of the SWPPP.

Superintendents must be sure that all of their personnel are trained to (a) prevent spills and apply sound cleanup measures; (b) understand the purpose of the various BMPs on site; and (c) know the penalties for noncompliance with the SWPPP.

CONCLUSION

Construction field professionals' knowledge of soils and drainage is sometimes limited. For some, only seat-of-the-pants experience guides their decision-making when it comes to those subjects, so their understanding of resulting risks and opportunities is similarly constrained. Field professionals do not have time to consult a civil engineer before deciding all actions to take on-site. And they should have some idea of when the owner's representative should be apprised of unusual ground conditions that might affect the work. With much concern about the safety of people and property and strict environmental demands on construction sites, competent construction supervisors often need to learn more of geotechnical and drainage practices in order to be more effective at site planning and task execution.

QUESTIONS, PROBLEMS, AND EXERCISES

1. Explain how gap-graded and uniformly graded gravels might be improved as construction materials.
2. A rectangular parking lot, 500 ft x 300 ft, will be constructed. Select soil from a local borrow pit shall be spread below the base course. The select material must be compacted in two lifts to a 12-in depth at RC = 100% and γ_{dry} = 110 pcf with OMC = 15%. In bank, the select soil γ = 106 pcf with w = 9%. Assume that minimal soil moisture is lost from evaporation upon excavation and transport. How much water must be brought to the site and mixed with the loose, select material to reach the OMC? (Hint: The weight of the compacted dry soil solids in the 12-in select layer is the same as the weight of the dry soil solids in bank.)
3. A 10-ft-deep foundation wall will be backfilled with loose sand of density γ = 110 pcf and no compaction. Using K_0, approximate the lateral pressure at the bottom of the wall.
4. An asphalt access road must be built to a remote building. This will require compaction of the clay subgrade, the gravel base course, and the asphalt. What compaction rollers will you select for each, and why?
5. A total of 4,500 bcy of moist clay shall be excavated for a building basement and stored on-site for backfill and other applications. Since the site is moderately restricted, the builder wishes to use as little site area for stockpiling as possible. However, the construction equipment characteristics require that the soil be banked no higher than 12 ft. What minimum length and width should the builder expect that the soil bank will require?
6. Permanent drainage structures at your new project site, located near the northernmost reach of Mobile Bay in Alabama, will not be finished until a year after NTP. The flow path for all runoff leads to a ditch, which carries little flow except during storms, but blocks the planned site entrance. A haul road will be constructed over the existing ditch at the temporary site entrance. You must install a culvert to carry drainage through the site haul road embankment that you will build across the ditch. You plan to use round CMP for the culvert. The basin area that drains to the planned site entrance is 15 ac. You will accept no more than a 10% chance of exceeding the capacity of the expedient drainage structure.

From the geotechnical report, you note that the surface soil in the basin is predominantly high-compressibility clay (CH). You also see that the site is grassy. The elevation of the top of the planned road embankment will be at 82.00 ft above datum. The bottom of the existing ditch that the haul road shall span will be at 75.60 ft. The road embankment crossing the ditch must allow for the widest expected axle width of 12 ft, plus 2 ft on both sides. The side slopes of the new embankment both upstream and down will be 3H:1V. The bottom width of the existing ditch is 12 ft, and its sides slope 1.5H:1V to the top edge. You do not want to build any headwalls. By expedient methods, determine the size and length of the culvert pipe(s) needed through the road embankment. How many 20-ft lengths of CMP must be obtained?

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SECTION III

SITE LOGISTICS

As a superintendent, understanding site logistics is critical to the success of the job and will dictate the efficiency of the project. It is far more than marking a plan with the locations of the fence, crane, and trailer. Logistics planning is the ever-constant process of getting the resources (material, labor, and equipment) to the right place, at the right time, in a safe manner, and for the least amount of money. Logistics planning is a daily task that must be done by all members of the construction team to maximize project success.

From the start of the job, earthmoving is one of the most costly, time-consuming, and unpredictable tasks on the project. Massive machinery costs combined with the unpredictability of the weather and unforeseen conditions can make for expensive down time. This section will explore the planning and management of earthmoving equipment and the procedures required to do it in a cost-effective manner.

As a project begins to build, the orchestration of material movement from the concrete to the finishes can often take on the complexity of a chess game. Understanding the machinery and efficiencies is critical to maximizing profitability at the job level. Cranes, lifts, and hoists are just some of the equipment this section will delve into.

The results of a solid understanding of the movement of labor, material, and equipment will make any superintendent successful.

CHAPTER 7

SITE LOGISTICAL PROCEDURES AND ADMINISTRATION

Daphene C. Koch, PhD

INTRODUCTION

The logistics of a jobsite is a major influence on the profitability of a construction project. A good logistics plan, which also creates a safer, more productive work environment, begins with a preplanning process for the site, project scope, and schedule. The integration of information from design, estimating, accounting, and procurement representatives as well as the vendors and subcontractors, the project owner, and all the other major players is required to increase the success of a process. It is commonly believed that the efficiency of the materials specified increases the productivity of a project. As an example, figure 7-1, a pie chart of the typical day for craft workers on a construction project, assigns 24% of a worker's daily time to materials-related issues. Many construction professionals cringe at the thought of only 54% productive time for a worker's day, but challenging projects create problems that often cause downtime. We know that we cannot work 100% of the time, but when the logistical areas were planned in advance, productivity can increase. Waiting on materials, waiting on directions, and multiple material handling make up 28% of time that could be more productive. This chapter provides the reader assistance for planning to continuously improve logistical productivity, to increase profits.

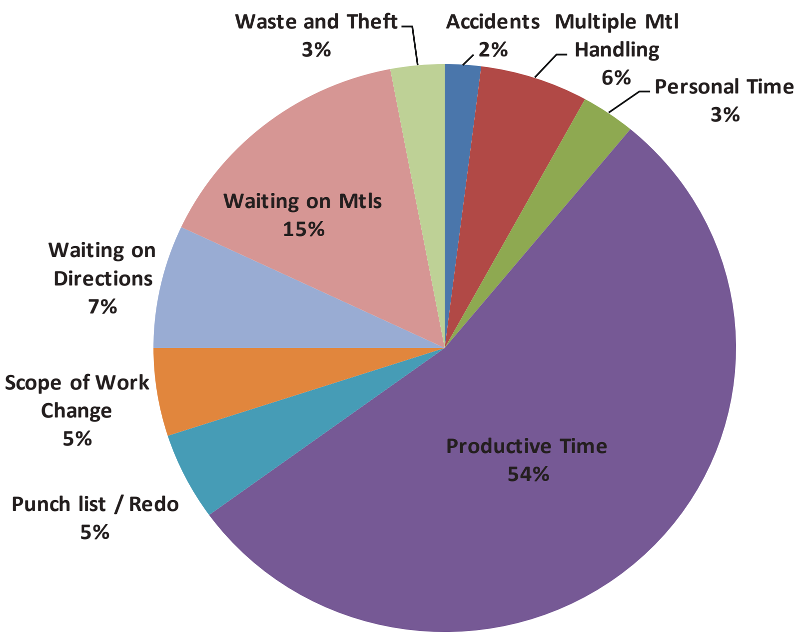


Figure 7-1. Typical use of construction worker's daily time.

Materials management on a construction site includes ordering, planning, and controlling the procurement and safe storage of the correct quantity of materials ready for use, as well as assuring that they are obtained within a specified budget and that the materials received are correct and undamaged (Bell & Stukhart 1986; Stukhart 1995). Research has shown that material-related issues (handling, waiting, moving, etc.) account for much of the nonproductive time during the installation phase of a construction project. Construction materials generally consume about 40%–60% of the total budget of a project (Agapiou et al., 1998; Kini, 1999; Polat & Arditi, 2005; Wong & Norman, 1997). Therefore, it is necessary and important to properly manage and control construction materials. As such, several unneeded expenses could be substantially reduced (Hendrickson & Horvath 2000).

Supply chain has become a common term and a part of the preplanning of construction projects. Since 2020, many specific construction materials have had longer lead items. The lead time for construction materials is the time from order to the delivery to site. Figure 7-2 shows a sample of materials that have been consistently changing lead times. Being aware of the major items on the project and the supply chain limitations are critical as part of the preplanning on every project. That gap might be built into a CPM network for a more reliable schedule.

Item	Lead Time 2020	Lead Time 2023
Steel Joist	3–5 Months	9–12 Months
Electrical Switchgear	3–6 Months	10–14 Months
Roofing Membrane	3–6 Months	9–12 Months
Roof Insulation	3–6 Months	9–12 Months
Precast Concrete	6–10 Months	14–18 Months
Overhead Doors	10–12 Months	16–20 Months
Wood Doors	6–10 Months	12–14 Months

Figure 7-2. Construction lead time examples.

On a construction site, sound administration of logistics demands not just the storage of materials, but that they are purchase ordered to be delivered to site with labeling, rigging, or anything that is needed to increase productivity. Logistics also requires preplanning, proper purchasing, packaging, shipping, and the persons and equipment related to these functions for efficient movement on site.

What are the steps for preplanning on the project? Do we need to order materials early? Do we need to propose a change to how the project is built? An example of this situation might be the reviewing of a precast panel versus a cast in place concrete. Communication with the precast manufacturing company revealed that the panels for a project would not be available for six months but the project was to be completed in three months. Once a conflict of materials availability is revealed, alternatives can be devised and the options communicated. In this situation, the design team opted to place cast in place concrete that would function for the design intent.

Poor materials management creates hours of unproductive use of resources—which leads to waste and surplus materials, delays, decreased productivity, and lack of up-to-date, real-time information regarding the status of purchase orders (PO)—the levels of inventory, and the actual versus planned usage of materials. The following section outlines a good model for site logistics including the following areas:

- Prejobsite: Preplanning and purchasing.
- Jobsite: Working the plan, tool tracking, material receipt, storage, and issues.
- Postjob: Clean up, surplus, and lessons learned.

PREMOBILIZATION: PREPLANNING AND PURCHASING

Prior to beginning a project, a plan should be discussed, which should happen during the bidding or proposal stages of a project. The planning affects expected costs and, therefore, the bid price of the work. A preliminary schedule that ties materials delivery items as resources in the schedule. The logistics plan then could be part of the presentation to the owner even during a proposal process. Other considerations to this plan could include the following: haul road, parking, jobsite trailer, storage area, security, water runoff, erosion control, and so forth. Figure 7-3 shows a sampling of the items that need to be reviewed before a project begins. Special considerations must also be addressed. For example, a project in the Chesapeake Bay area of the United States had the requirement of a fence around the jobsite that would keep an endangered turtle off the jobsite. The temporary fencing was to be installed and maintained for the duration of the project. No work could begin until the fence was inspected.

Construction Project Logistics Checklist	
Environmental Assessments	**Areas of Concern**
	Air
	Water
	Runoff
	Noise
	Waste
	Recycle
	Ecological
	Natural Habitats
Security	
Material Delivery Route	
Parking	
Office/Trailers	
Inspection	
Quality Control Needs	
Special Equipment	
	Dust Control
	Cranes
	Large Delivery
	Special Lifts

Figure 7-3. Sample of a Construction Project Logistics Checklist. Of course, this and other administrative forms are commonly fully automated for easy, accurate entry by electronic tablet.

The logistics specifics should be discussed with the entire project team, and the resulting plan must align with local code and owner restrictions as required. Some examples of items that may incur extra costs are dust control, limited delivery times, noise ordinances, flight plans, and traffic patterns, among others. Projects in major metropolitan areas may restrict deliveries to early morning or late evening and not during normal working hours, especially if oversized and slow-moving loads requiring special traffic control, while unique projects in residential areas may require work to begin after 8:00 a.m. All of these items are logistical details that should be explored as soon as a project is reviewed in the prebid stage as part of due diligence (see chapter 3) and may even be a reason not to pursue a project.

Special circumstances on projects could make the biggest impact on a project. For example, a project near an airport was delayed due to flight patterns of aircraft limiting the movement of a crane needed to install the HVAC equipment. Special scheduling and lifting considerations had to be developed to complete the project.

Visualization of the project area is very important for planning. Tools in technology, such as aerial maps (available free on the Internet), can be very helpful in determining a logistics plan (see chapter 4). Another tool is 3-D visualization software, which can allow a model to be developed so that all interested parties can more easily understand the plan and also identify the best plan. Figure 7-4 illustrates using a building information model (BIM) to demonstrate how a street configuration would look during a concrete pour. In this particular example, the BIM was helpful for the municipality representatives, who initially could not visualize if it was going to be safe to shut down the street. This visualization also could have been animated to illustrate where the workers would be in relation to cars and pedestrians passing and was also used to successfully obtain a permit to shut down a city street to make the process safe and more productive.

Figure 7-4. Sample BIM to show logistics plan.

Once contracts have been signed and the big picture for the project has been outlined, the purchasing procedures begin. These procedures also can be reviewed with subcontractors as necessary, along with constant communication and up-to-date scheduling information. Weekly meetings should include any information about material deliveries, especially long-lead items. Long-lead items are those materials that are not readily available (e.g., products that require special finishes or must be manufactured for the project, such as HVAC equipment, or specialty items such as explosion-proof electrical boxes).

The materials for a project are purchased in many different ways. Some companies have purchasing departments or one person may oversee purchasing. Other companies may have project managers or someone who was involved in the estimating process complete the purchasing as well. It is common that purchasing personnel do not always understand the needs in the field—especially the best packaging to help crews and the time they require to prepare materials for installation—so open communication among all persons involved is important. In some cases, construction supervisors review sensitive purchase orders for accuracy before the company transmits them to the vendor. All stipulated delivery dates must be synchronized with planned installation per the CPM schedule. These actions are essential for quality control and operational feasibility.

Purchase Orders (POs)

A purchase order is a legally binding contract that acts as an acceptance of a supplier's offer or quotation. It must contain a date of issue and a purchase order number for tracking and identification; the name and address of the vendor; the quantity, description, and price of the item(s) purchased; approval signatures; and the conditions and terms that will govern the purchase. Additional information often includes tracking (barcode, radio frequency identification [RFID], etc.); shipping instructions; packing instructions; delivery notification; status reports; specific delivery dates; and specific delivery requirements.

Figure 7-5 shows a generic purchase order, which can be developed in a MS Office Word template and set up for tracking in an Excel spreadsheet. It is very important to develop a consistent format that provides appropriate space to detail the necessary requirements for each specific project. It can be helpful to review purchase orders that have been used by others to learn more about the legal terminology that must be included.

<table>
<tr><td colspan="3">PURCHASE ORDER</td><td colspan="3">PO #: 6203-N2-M200-00</td></tr>
<tr><td colspan="6">All related correspondence, shipping papers, and invoices must include PO #</td></tr>
<tr><td colspan="3">To:</td><td colspan="3">Ship To:</td></tr>
<tr><td>P.O. DATE</td><td>REQUISITIONER</td><td colspan="2">SHIPPED VIA</td><td>F.O.B. POINT</td><td>TERMS</td></tr>
<tr><td></td><td>DLO</td><td colspan="2">ABF Freight</td><td>Job</td><td>Net 30 days</td></tr>
<tr><td>QTY</td><td>UNIT</td><td colspan="2">DESCRIPTION</td><td>UNIT PRICE</td><td>TOTAL</td></tr>
<tr><td></td><td></td><td colspan="2"></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="2"></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="2"></td><td></td><td></td></tr>
<tr><td colspan="3" rowspan="3"></td><td colspan="2">SUBTOTAL</td><td></td></tr>
<tr><td colspan="2">SALES TAX</td><td>$0.00</td></tr>
<tr><td colspan="2">SHIPPING & HANDLING</td><td>$0.00</td></tr>
</table>

Figure 7-5. Sample purchase order (PO).

Material Classification	Definition	Example	Type of Purchase Order
Bulk	A material that is not tied to one location	Concrete, soil	Blanket order
Commodity	Commercially available items that are identical but used in different areas	Pipe, wood, shingles	Specific quantity, size, specification
Capital Tools	Tools that are purchased with the intention of becoming company assets	Saws, welding machine, special tools	One-time purchase order
Consumable	A material that is consumed or becomes worthless due to its use in construction	Ear plugs, gloves	Purchase order with max-min quantities for reorder
Engineering Item	A material for which its function or requirements are defined for a specific project location	HVAC equipment, custom door	Purchase order includes info on design review, material delivery, storage, etc.
Tag Item	A material component that is identified for a specific function and unique project location	Toilet WC-1, Door 123-A	Specific purchase order including tagged ID with each item
Loose	Items that are shipped individually	Electrical or plumbing fixtures	Specific quantity, size, specification
Specialty Subcontracts	Contracts with contractors	Structural steel, detailing and erection	Contract that outlines all project requirements

Figure 7-6. Common material classifications.

The most important part of the purchasing process is to have the ability to track the materials and purchase order information. A job number can be used as identification on a purchase order. The numbering system is commonly standardized for the company to yield a unique array of P.O. numbers for every project. To reduce confusion, the system is different from the numbering system of the architect, engineer, or owner, unless sharing the number array is required in the project contract. A detailed example of a purchase order system usually identifies the type of materials included in the purchase order. For example, 6203-N2-C600-00 is a purchase order for Job #6203, with a classification of material as bulk N2; C600 is Civil/ Concrete, and 00 indicates this is the first revision of the purchase order. Material can be classified as bulk, commodity, tag, engineered, or consumable. Figure 7-6 outlines different classifications of materials along with their definitions and examples, as well as the types of purchase orders that might be included.

The correct ordering of materials during the planning stages greatly influences the ability to conduct a safe project that generates a profit. Ordering the materials during the purchasing process also includes arranging the appropriate packaging of the materials to be shipped. On a multistory structure, for example, electrical fixtures can be palletized by floor and scheduled for delivery in accordance with the installation schedule, or bagged items, such as door hardware, can be labeled to be delivered to the correct location of the door, as needed. The main

Figure 7-7. Palletized materials not stacked to withstand load or movement.

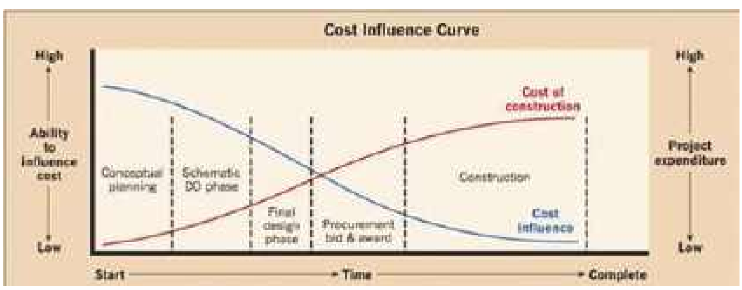


Figure 7-8. The life cycle of a project: Cost increases but influence of decisionmakers on reducing costs decreases as time progresses.

idea is to have the materials available when and where they are needed, and having materials arrive on-site ready for use is even better. Typically materials can be delivered in the following handling methods:

1. **Bagged**: packaged in manageable quantities for use
2. **Palletized**: allows for use of a forklift to easily move materials on jobsite (figure 7-7)
3. **Packaged**: boxes with protective covering like shrink-wrap to keep all parts together
4. **Loose/Tagged**: sealed per pallet or standalone item
5. **Bulk**: sand, gravel, and so on may be off-loaded on the ground in a designated area

Packaging requirements can be outlined in the purchase agreement to make it a legal requirement. Material delivery is best if brought to site JIT for use, which is not always possible, especially for materials such as roofing shingles, brick, or concrete masonry units. In these cases, the requirements of the purchase order might be that the packaging be durable enough for exterior storage. The preplanning and purchasing stages have a huge impact on the success of the overall project. The cost of fixing the problem in the field is substantially more than in the preplanning stage. Figure 7-8 shows the typical influence of cost during the project. It is important to get input from the field early in the project.

Information for the purchasing of materials can come from the design areas (client, architect, and engineer) or from the field (supervisors, field engineers, and foremen). Purchasing information that originates from design professionals is usually accompanied by detailed information that is attached to the purchase order (specifications, cut sheets). The process for acquiring materials may require approval from the client, in which case the words "Purchase order contingent upon approval of submittals" may be required to protect the contractor.

The process of ordering materials is very specific and tends to follow specific procedures. The general requirements are as follows:

1. **What is needed?** This information can be obtained from the project estimate, field identification, design drawings, and so forth.
2. **What is the description of the material?** Size, quantity, type, model number, and so forth aligned with project drawings and specifications.
3. **Where can it be purchased?** Selection of possible sources/vendors.
4. **How much will it cost?** Review quote for cost analysis and delivery.

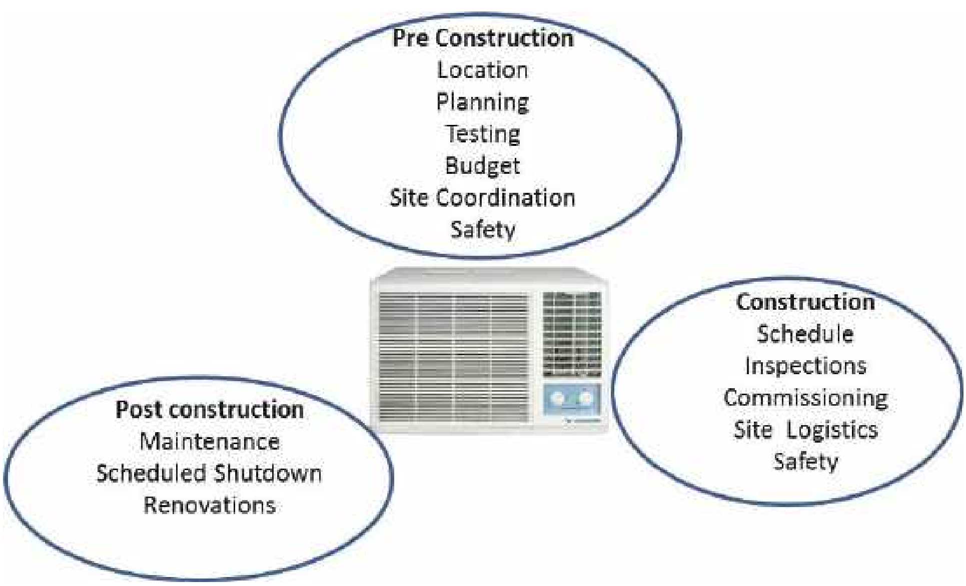


Figure 7-9. Information needed during project phases using visual example of furnace.

5. **What does the purchase order look like?** Place order with detailed purchase order agreement that includes all required information: include tagging (bar code, RFID), certifications and warranties, delivery requirements, submittal approval process, return requirements, restocking fees, and so forth (figure 7-5).
6. **When will it arrive?** Expedite delivery and follow up with order status.
7. **Is it the right material/approved material?** Verification of submittal process or other clearance requirements, inspection, quality, and so forth.
8. **Is it all here?** Completion of delivery and payment process.
9. **How do I take care of it?** Provide operation and maintenance files as necessary.
10. **How is it documented electronically?** Integration into BIM model for project.

As the implementation of a BIM is common practice on a jobsite, it is also important to align all of the information in the purchase order to the information that will be used on the project. The checklist and equipment diagram shown in figure 7-7 is an example of information that would be necessary for the project and can be imbedded in the BIM. During the procurement process, the model/shop drawings/submittals are approved by the owner/architect/engineer. Information is needed for the preconstruction, construction, and postconstruction phases.

The purchase order should also include information about the delivery and marking of materials. How are the materials going to be tracked before, during, and after delivery? One example of tracking would be the barcoding of structural steel members that aligns with the erection drawings submitted by the fabricator. The cost of a tracking tag is very minimal compared to the cost of time lost in looking for materials or the cost of labor or equipment standing idle during the search.

Tracking shipments is a very common practice for big logistics companies. United Parcel Service (UPS) developed a very sophisticated Delivery Information Acquisition Device (DIAD). This technology uses a barcode on a package in conjunction with the handheld DIAD, which collects the signature and delivery information at one time and transfers data to allow real-time tracking. Another common tracking system seen today is the Radio Frequency Identification (RFID), which is the technology in smart cards and toll road passes and included in most supply chain processes to track products for manufacturing. This technology advanced in the late 1990s due to a significant decrease in the cost of producing the computer chip.

The most common and familiar tracking is still the barcode. The first barcode was the Uniform Product Code (UPC), scanned in 1974. The RFID tag does not require a line of sight to the reader and may be embedded in the tracked object, while a barcode is visible and must be scanned by a reader to transfer data. If tracking requirements are included in a purchase agreement, the efficiency of the tracking, receiving, issuing, installing, and even maintenance of the materials and equipment will increase. If materials are identified throughout their life, then materials can be tracked "from cradle to grave," as some would say. Figure 7-10 illustrates the data tracking used to follow the fabrication, delivery, receipt, and installation of materials, thereby connecting the schedule and cost models to real-time data.

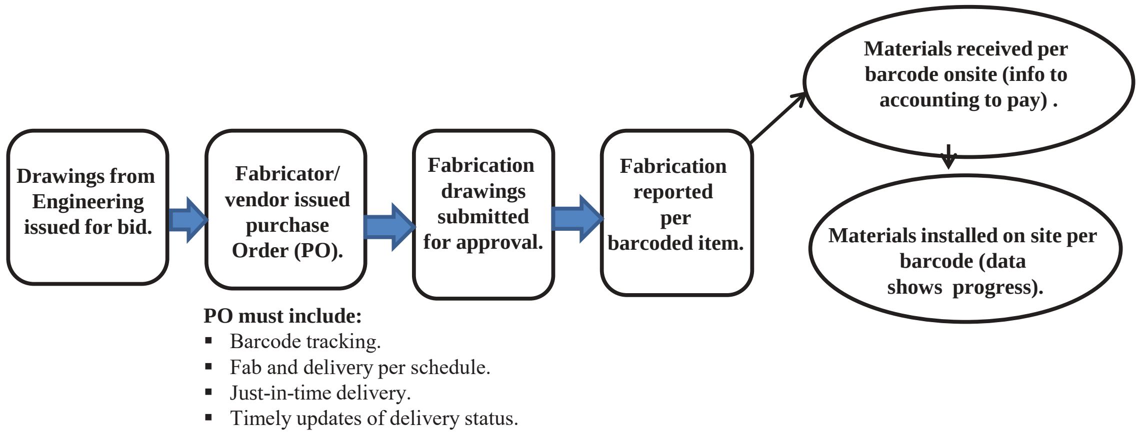


Figure 7-10. Life of materials and application of tracking.

JOBSITE: WORK THE PLAN, TOOL TRACKING, MATERIAL RECEIPT, STORAGE, AND ISSUE

All of the planning that has been done on a project will need to be put into action. Everyone with responsibilities for materials on a project needs to work together for success and profit. Common safety, housekeeping, and site logistics procedures are developed. A site superintendent, for example, may have a daily checklist, which should include notes of the following materials-related items to be transferred to a daily log or diary.

1. Weather report: What equipment will be needed today?
   - Other considerations: dust, water removal, mud clearing, wind/storm readiness
2. Site walk-through: What is the status of the site today related to material?
   - Water standing, housekeeping needs, material issues, progress issues, clash/ work flow issues
3. What are the major events today?
   - Short interval scheduling related to materials, expediting information, long-lead items, owner-furnished materials
4. What material deliveries are due today?
   - Bulk items, large loads, special equipment, and so forth

At the beginning of every day, material and site information updates need to be integrated into jobsite meetings. There is nothing worse than sending a crew of men out to complete a task to find they have no materials, the wrong materials, or insufficient materials to finish the task. Working with the scheduling information available, field supervisors must be kept up-to-date on a daily and weekly basis, which should include a long-lead items timeline, in order to keep everyone aware of the logistics and material status on a jobsite. This responsibility can be a part of the daily tasks for a project superintendent or an assistant. Computer software programs exist that can track the material received against the drawings on large projects.

Tool Tracking

Construction firms have many methods for handling and tracking tools on project sites. Some firms require that all workers provide their own tools, and if specialty equipment is needed for a project, it is provided by the firm—many times by a rental company. Larger firms own a rental company that competes with outside vendors.

As technology advances and mobile devices become commonplace on construction sites, better systems are being developed to track tools. During the 1980s, companies began using barcodes to track tool access by individuals or crews. Some of the current technologies include the use of cloud-based data collection, Global Positioning System (GPS) tracking, and RFID tags. There are many providers and a lot of information available from vendors to assist any size company in saving money on lost tools. ToolWatch (www.toolwatch.com), for example, has apps for this purpose for iOS and Android systems. These new technologies also allow the real-time tracking of when, where, and who is using the equipment, thereby enabling better monitoring of jobsite productivity and early detection of any variance in the scheduled activity. Even with this level of accountability, up to 30% of tools can be missing by the end of a project.

Material Receipt, Storage, and Issue

A clear materials management plan, part of the project logistics plan, is crucial to successful projects. This plan must be understood by all parties involved in the project, from the client/designer to the project and field management personnel. Vendors also are included in materials management via purchase orders. Ways to increase profit as it pertains to materials management include:

1. Reduce materials waste, as with prefabrication, to increase efficiency of installation.
2. Control damage to materials, as with JIT delivery, to minimize storage on-site.
3. Proper storage and handling of materials on-site.
4. Stop the waiting, reaching, and searching for materials by workers.

The objectives for a materials management plan include the following guidelines, some of which will be discussed in detail:

1. Determine the controls that are used in the receiving and issuing of materials.
    a. How are materials going to be tracked for storage?
    b. How will this information be communicated with others on a jobsite?
    c. Who is the person responsible for these activities?
2. Follow common practices used in the industry.
    a. Use JIT delivery, especially for large items with special lifting procedures.
    b. Continue to follow best practices in the industry.
3. Analyze issues that are important on each project.
    a. Location, location, location! Where is the project?
    b. Who is the owner?
    c. What are the major items included on this project?
    d. What are the local codes and restrictions?

4. Develop management tools that include forms and standard operating procedures (SOPs) that can be used for every project related to site logistics.
    a. How can this be done electronically?
5. Follow proper material storage and controls.
    a. Are materials being stored outside that will be damaged? For example, PVC pipe is damaged by ultraviolet light (UV).
6. Develop checklists for the project to assist in the implementation of SOPs.

Every project has its own challenges. A *restricted* storage site might only have space enough to store materials installed during the next day or two. A *limited* storage site might offer space enough to store materials for a week or two. A clean grassroots project in the middle of a large field allows for lots of space for material storage, jobsite trailers, and no city ordinances for traffic. This type of project can be classified as a site with *unlimited* storage; but when there is more space, there is more chance of losing materials. Large projects therefore also require the same organization of laydown areas as do projects with limited storage space. For example, if there are large shipments being delivered to a remote location, an area may be aligned in a grid pattern to identify small areas where material would be stored that would allow for locating the materials at the time of installation. Figure 7-9 shows a grid developed to assign material locations.

A specific material would be stored in each of the grids, which can be marked with posts or signs at the end of each section. Row A could be wood products, B could be masonry items, and so forth. With technology, we can now use a GPS system to track the location of materials. Upon receipt of materials, the packing list would be stamped with the location of the materials (see figure 7-10), and this information then would be loaded into an inventory database, which could track the location of the materials. It is important to also remember that when any materials are moved they must be relocated in the system; for example, if structural steel is RFID-tagged, that number can be referenced for its initial location when received. That data would then be transferred to the accounting department to pay the vendor. When the field personnel retrieve the piece for installation, the field engineer has a record that it has been installed and can update the project schedule—and even a BIM—to show progress in real time.

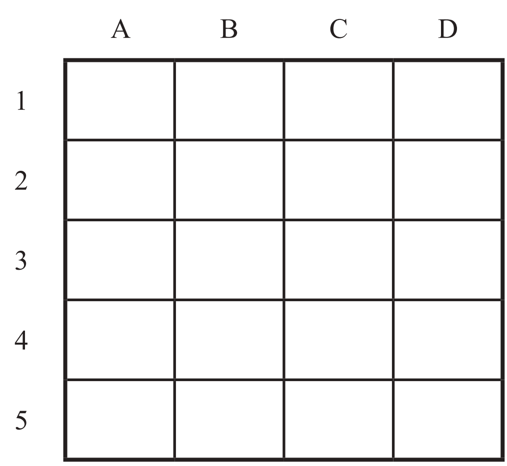


Figure 7-11. Sample grid layout for large storage area.

Receipt documentation is necessary for the accounting department to pay invoices from vendors and also in order to submit invoices to the client. Project control also can use this type of information to show progress payments and assist with cash flow on a project. The sample receiving stamp shows the information that needs to be recorded on the paperwork when a shipment is received. It is also very important to document the condition status of materials upon arrival. The boxes may look great on the outside, but damage may be found upon opening the boxes. This documentation can help with any questions or concerns in the future.

Shipment Receiving Stamp
P.O. #: ______ Vendor: ____________
Carrier: ____________________
Bill of Lading #: ______ Date: _______
Received By: ____________________
Storage Location: _________________
Condition upon receipt: _____________
Photo documentation: ______________

Figure 7-12. Sample receiving stamp.

Technology is available to handle this process and allow for immediate update of the project records; cell phones or iPad applications can be utilized for real-time data updating. A program also could be used to send a digital copy of all documentation to the correct departments. Photos of all packages with the GPS location can be attached for location purposes.

If the design team and scheduling team work together, the materials can be assigned to specific grids before delivery, creating less stress to establish a storage location when large shipments arrive. Most sites have limited storage areas, so planning the exact storage area for materials well in advance also will assist in following the efficiency steps for material management. Best practices and past project experience are usually the most reliable means to creating successful plans.

A knowledgeable person should always inspect the receipt of a load. The "Received By" line of the receiving stamp on the bill of lading or packing list could become a legal matter if there are problems with the materials. Some bill of lading forms have small print that say, "By signing here you have accepted the load." All employees should be trained in the proper procedures for a damaged load. Rejecting a load is not always a solution for a product that is needed immediately. Some scratches and dents can be fixed or the product can be installed for initial startup to be replaced at a later date.

When handling materials, it is always wise to remember that actions add to or reduce the productivity of the project. Material movement does not make money for the company. The number one rule, as stated before, is to have the right materials where needed, when needed, with nothing left over. That is a challenge, but some general rules to follow include:

1. **No double handling of materials**. When materials arrive, try to minimize moving them again because every move is an unproductive cost incurred.

2. **Have the right amount of material in the right location exactly when it is needed**. Too much material at a work location has to be removed after the work is done, and material too far away from the work area causes waiting and wasted time.
3. **Use gravity**. It is easier to walk downhill than uphill.
4. **Clearly mark all boxes of materials for the location**. There is nothing worse than having to open 10 boxes to find the one you want.

The next type of project would be one that has *limited* storage area. In this case, more of the materials must be delivered JIT for installation. This requires more preplanning and critical communication with the different levels of field supervision. The worst case scenario on a project with very limited storage space is that it cannot be secured or controlled. It needs to be considered a restricted space, and the best case scenario is a warehouse or vendor storage area that can store, track, and issue all the materials for a project. A plan should be reviewed even before the project has been acquired. The movement of materials could be critical to the profit of a project. One example would be the installation of a rooftop unit on the top of a high-rise in the middle of a busy downtown city center. In this case, there are no storage areas near the project site, and streets may need to be closed and permits received from local authorities for the delivery to occur.

Special agreements with vendors may need to be established for sites with limited or no storage. JIT delivery has been a long-time established policy for not only concrete mixes but also large beams, girder, or precast concrete components. There can be agreements for other commodity-type items (wood, pipe, and conduit) to be delivered in stages as needed. This type of agreement might be utilized by the field personnel by sending an email at the end of the day to request delivery the next afternoon, which is a very common practice with lumberyards that have customers who have materials delivered as progress is made on a project.

All materials need to be marked as received, the packing slip needs to be checked against the purchase order, and the accounting department needs to be notified. The purchase order number, location, project number, tag number, and so on need to be marked on the material so that it is easily identifiable. If materials are being received at a central location, it is a good practice to have one area for each project. For small contractors, a shelf might be identified for each project. On a large project, a materials receipt log may be completed to identify materials that have been delivered. Figure 7-11 shows some of the information that would be important.

Daily Receiving Log

Date:

Purchase Order No.	Vendor	Description	Storage Location	Carrier	Bill of Lading No.	Remarks

Figure 7-13. Daily Receiving Log example.

It is critical for the field personnel to know the following:

1. When materials have arrived for planning the scheduling of work

2. Where materials are stored for retrieval
3. Actual delivery dates in case of work delays due to delivery problems
4. Carrier and freight bill number in case of damage found during unpacking
5. Status remarks such as “contacted vendor about damage” or “contacted roofing crew about delivery”

Bulk items are more difficult to track. They become more of a maximum-minimum quantities to be stored on-site or JIT delivery. Concrete is a great example of a material that must be tracked for receipt, location, and installation to know progress, but it also must align with a tight quality-control system. A material management system can align well with the quality control of a project in that purchase orders generally align with the project specifications or have been approved by the owner or design professional. The use of a 3-D model on a project can enhance the tracking of bulk materials. A spreadsheet can be developed to track the receipt of each item and could include all the necessary information (truck number, quantity, test number, area of project, etc.). The field personnel in charge of the receipt of bulk items can keep track manually or electronically on a log or spreadsheet to record all the necessary information.

This type of documentation is also critical with projects requiring “built in America” standards. This type of project requires one person to be responsible for receiving all the products for a jobsite and validating their *manufactured* status. Just because a product is bought from a U.S. company does not mean it is American-made.

A good jobsite will require that all trucks check in, and a log is kept for everyone entering or exiting. Jobsites now have the ability to electronically send this information in real time to smartphones or other electronic devices. A project in a busy city with multiple tower cranes, for example, used an electronic load schedule that updated all involved individuals as the lifts were being completed. This feature created a communication tool that could increase productivity by allowing one area to move ahead if another area had a load that was delayed. For example, if the door installation foreman had scheduled to lift his shipment to the 10th floor at noon on Tuesday only to find out at 9 a.m. that the shipment was delayed due to an accident on the

Figure 7-14. Labeling and organized storage of bulk common items and max-min levels.

highway, the painting foreman got a notice of this change and now could utilize the lift time for his crew to begin work on the 12th floor. These concepts can be implemented for any part of the site plan.

Concrete trucks are usually tracked by each load with a load ticket. When there is an intelligent BIM, the field superintendent can click on the area of the concrete pour in the model and verify the specification mix design for that area before the truck pours. Batch plants now use computerized systems to mix each truck to the correct specification. This is a vast improvement over the manual ticket deliveries that had to be tracked with a piece of paper given to the field personnel by the driver.

In the past, it was easy to hijack a concrete truck from a busy jobsite. This was done by having a gate checker collect the load tickets to assist the pour foreman, so the foreman would not have to hold that paperwork. If the gate person checked in the trucks and his buddy needed a new driveway, he could have the truck drive through the gate, then turn around and deliver the load to an alternate location. Maybe the driver would question this, but the gate person could just say that the pour location was not ready for this load so it was going to a small project that needed to be completed today. This is a true story of how one lucky guy got a new concrete driveway for free. Many mixing trucks now have intelligent GPS locating and tracking systems, so vendors can watch the routes of the trucks and record where the pour occurred.

Other bulk materials may need to be stored in a warehouse on-site or in an off-site location. Nuts, bolts, and washers are examples of items that can be purchased much cheaper in bulk. Figure 7-14 shows a storage drawer system where items are clearly labeled for quick access. This kind of drawer system can be installed in a field storage trailer. The shelving system could be used for flat items like gaskets.

Other examples are storage where items need to be hanged, and an outline of that item can be shown to know when it is missing. In the case of a tool, someone can see that it is not there and save time looking around for the tool. In the case of commonly used materials, the empty space would indicate the need to reorder. Figure 7-15 (left) shows belts stored in a clear fashion so they are not hidden when needed. The photo on the right shows the concept of taking a photo of what will be placed on the shelf.

On smaller projects, coffee cans can be used for storing materials and mounted in a rack that can be stored in the back of a truck. Every hardware store now has sections with organizational products to assist in keeping everything in the same place. The organization of materials must become a habit for all employees in a company. There is nothing worse than using workers to clean up after other workers. A more common site is the situation in figure 7-16. This photo shows the materials of a plumber who might be done with a project, but there is no way to identify what is used and what is new.

All materials, tools, and equipment for projects should have an organized way to begin and end a day. Buckets can be used for the recycling or collection of waste materials. Daily worksheets, which can be manual or electronic, should track the use of materials. If the materials for each project are tracked daily, the time needed to do so is limited. A good supervisor will know what work is complete and what is planned to be completed as well as the status of the materials and future work. The information on materials received shows where they are stored and when they will be issued for installation.

Figure 7-15. Exact and open locations for materials to avoid searching and assist in reordering.

Figure 7-16. Typical example of bad material storage for small projects.

On a large construction project, the major contractor could have a materials manager with a crew that oversees all procedures related to materials. A $150 million petrochemical grassroots project could have the following personnel:

- **Materials manager**: Reports daily to jobsite superintendent and approves all material reports. Routinely interacts with project manager and superintendent and maybe owner.
- **Warehouse manager**: Reports to the materials manager and oversees a crew who receives and issues materials to the field.

Figure 7-17. Prefabrication of commercial bathroom piping and supports.

- **Field material control specialist**: Project engineer who verifies that the materials are in accordance with the specifications for the project and issues them to the field as required. This person also might have the responsibility of inspecting every shipment before off-loading and accepting it.

Traditionally, the materials management of a project is thought to be wasted money, but remember from figure 7-1 that the typical craft worker spends a lot of time waiting on materials. Even for a small contractor, the practice of purchasing materials that are received on-site in the order and organization for erection is possible. The following are generally accepted principles of materials handling that are really common sense and increase the productivity of a project:

1. **Move over short distances**: This applies to delivery to the site and within the project for less time and cost.
2. **Minimize cycle time**: Plan equipment operation to move as efficiently as possible to increase productivity.
3. **Avoid partial loads**: Choose the right equipment for the project. For example, one should not use a huge tri-axle truck if a three-quarter-ton dump truck can do the job.
4. **Limit manual handling**: Reduce handling to improve safety and productivity.

Figure 7-18. Low bridge issues (https://www.nhregister.com/connecticut/article/Truck-carrying-cooking-oil-cheese-crashes-into-11348987.php).

Highway	Effective Date	Expiration Date	Counties	Restriction Type	Start	End	Direction	Comment
I69	X/X/XX	X/X/XX	Steuben	width <= 168	SR 4	US 20	SB	I69 will be intermittently restricted btw US20 & SR4 beginning today until Wednesday, June 26th. 45MPH speed limit, 14 wide load restriction. Watch out for bridge work. J Campbell # 711.
I69	X/X/XX	X/X/XX	Pike	width <= 144	SR 56	SR 257	Both	Restriction on I69 near Petersburg due to joint sealing. Information provided by Barry Mueller, 812-354-9898.

Figure 7-19. Sample report of road restrictions from State of Indiana database.

Overall vehicle length	No federal length limit is imposed on most truck tractor-semitrailers operation on the National Network.
Trailer length	Federal law provides that no state may impose a length limitation of less than 48 feet (or longer if provided for by grandfather rights) on a semitrailer operating in any truck tractor-semitrailer combination on the National Network. (Note: A state may permit longer trailers to operate on its National Network highways.) Similarly, federal law provides that no state may impose a length limitation of less than 28 feet on a semitrailer or trailer operating in a truck tractor-semitrailer-trailer (twin-trailer) combination on the National Network.
Vehicle width	On the National Network, no state may impose a width limitation of *more or less* than 102 inches. Safety devices (e.g., mirrors, handholds) necessary for the safe and efficient operation of motor vehicles may not be included in the calculation of width.
Vehicle height	No federal vehicle height limit is imposed. State standards range from 13.6 feet to 14.6 feet.

Figure 7-20. Federal Oversize Load Guidelines from the U.S. Department of Transportation website (http://ops.fhwa.dot.gov/freight/sw/index.htm).

Prefabrication or module building is a very smart way to achieve high quality control in a controlled environment and minimize the amount of materials that have to be stored on-site. Figure 7-17 is an example of the drain, waste, vent, supply, and carriers for a commercial bathroom made in a controlled fabrication shop to be delivered to the jobsite and set in place.

When prefabrication is utilized, a major challenge for construction projects is the oversized loads often required. It is important to understand the permitting issues for the project location and possibly even verify the paperwork ahead of time. Some examples of why verifying the routes to the construction site is in the best interest of the project are as follows. Figure 7-18 shows a warning sign that was missed when a custom-built HVAC unit was being delivered to a major project, and the load ended up as shown in figure 7-18 when the load hit the deck of the bridge. The permits were approved for the road, which had a low bridge height, but no one verified the route. Another example of poor planning is a long-distance load that did not have a permit for the state to which it was delivered and, therefore, was not permitted to cross the border until the issue was resolved. This problem delayed the shipment for one week.

In the state of Indiana, road restrictions are posted on the www.in.gov website when there are changes to original road designs. This is very helpful, especially during the busy summer road construction months, to verify the logistics of shipments to a jobsite. The Indiana website allows for a user to search by road or restriction type on the route. A time reference can be set for the past three, 30, or 60 days. Figure 7-19 shows a sample of a report that was generated through the site. Other states have similar systems that can be used to determine possible safe routes for construction deliveries. In some cases, a project manager or logistics manager may want to verify all of the construction road issues near a jobsite and begin communication with all the vendors as soon as possible to ensure that deliveries will be possible and undamaged.

Oversize loads also have restrictions related to the time of day of travel and permitting with which they must comply in order to pass inspections along the transportation route. These are areas that should be verified with the transportation company as part of the purchasing process. Federal restrictions can be reviewed at http://ops.fhwa.dot.gov/freight/sw/index.htm and some references are shown in figure 7-20. The federal restrictions would be the minima for any state.

Materials are received on a jobsite or in an office and then transferred to a jobsite. If purchase orders are developed with the proper instructions, all materials will be properly marked and identified for a project. Unfortunately, this does not always occur, especially on smaller items or items that are picked up on the way to a jobsite. The size of the object does not matter; there are still costs related to the movement, storage, and installation of that item.

If a warehouse-type facility is used on the project, procedures for the issuing of materials are required. Technology, such as those used in manufacturing or retail, can be used to determine what is on the jobsite and what areas can be worked. Tracking software, such as Smart Plant Materials (SPM) by Intergraph (formerly known as Marian), now can be purchased to manage the materials for a construction project. Its key features include quantification, supplier management, inquiry cycle and purchasing, expediting, inspection, logistics, progress tracking, inventory and warehouse management, and planning and subcontractor management. Another major software supplier is AVEVA (www.aveva.com), who aligns more with the marine and plant engineering side, using materials as a module of design engineering. Many larger engineering, procurement, and construction (EPC) firms are developing their own products as well: Fluor uses their home-grown software, Mat Man, and Kellogg, Brown & Root (KBR) uses their own software, IPMS (Oracle based like SPM).

These practices have been used since the 1990s to provide the field with control tools for receiving, warehousing, and issuing materials. As the BIM technology expands, data are more available to integrate the tracking of materials from design through lifelong maintenance. Other resources for expanded use on large projects include publications available through the Construction Industry Institute (CII, http://www.construction-institute.org) and Fiatech (http://www.fiatech.org).

POSTJOB: CLEANUP, SURPLUS, AND LESSONS LEARNED

The last contractor person remaining on the jobsite is usually someone related to materials management. All temporary structures need to be removed, and laydown areas often need to be landscaped or paved. Many of the final cleanup details of the project are included in the contract documents per the owner's expectations. (See chapter 16 for details about project closeout.)

The objectives for materials that are left after the project is complete should be carefully considered. The following guiding questions may assist with the process:

1. **What materials are considered as surplus?** Some contracts require that a certain amount of materials are left for the owner (e.g., brick that may be used for damage in the future, filters for testing, and so on).

2. **Is there a need to differentiate the types of surplus materials?** Clarify if they are hazardous, recyclable, reusable, or scrap.
3. **What project requirements have already been determined?** Follow client-defined specifications, city ordinances, and common practices.
4. **Who is responsible for the surplus issues?** Determine if the owner already has taken ownership of the materials.
5. **What checklists exist for typical surplus materials?** Vendors sometimes leave instructions about disposal.

Sometimes materials that have been used for temporary structures can be sold with an advertisement in newspapers or online. For example, a project that utilized rail ties for dividing the areas of the laydown yard placed a sales advertisement at the end of the project, and a very happy landscape contractor bought all of them at a great price. The money was returned to the construction contractor as part of the profits for the project. Common items often can be returned to the vendor as part of the terms of the original purchase order, which may include a restocking fee, if necessary. In addition, depending on the owner and terms of the contract, surplus materials may be left for future maintenance use.

Specialized items may be more difficult to timely procure in required numbers. They might be fairly common on projects but are not produced in mass on a regular basis. For example, a contractor working in the petrochemical industry had a buyer for explosion-proof electrical fixtures with rigorous performance certifications. The manufacturer had none in stock, but by employing a specialized buyer the contractor timely located a source with some in stock. Creativity and innovation can be as critical for logistical actions as it is for engineering design.

With many years of experience come many lessons learned. One expert in materials management made a list of lessons at the end of every project, which he then used as the starting point for the next project. The goal is to continually improve with each project and increase productivity to make more money. Practices related to logistics and materials have a large capacity for increasing profit on a construction project.

CONCLUSION

Site material logistics sometimes fails to draw the willing attention that construction professionals devote to crew operations. Yet, logistics is directly linked to what the crews can accomplish and is a critical part of all project dimensions: schedule, budget, quality, and safety. Quality-control procedures for materials are discussed in chapter 13. Whether sound project materials management principles are routinely applied from a company's standard materials procedures or directed in the project-specific materials management plan, wise construction site professionals devote a significant part of their planning time to optimizing the procedures and plan to surely deliver the right items, in the right number, to the right place, and at the right time.

QUESTIONS, PROBLEMS, AND EXERCISES

1. What information would need to be included on a purchase order for the following sample item?

   Specification P-1A:

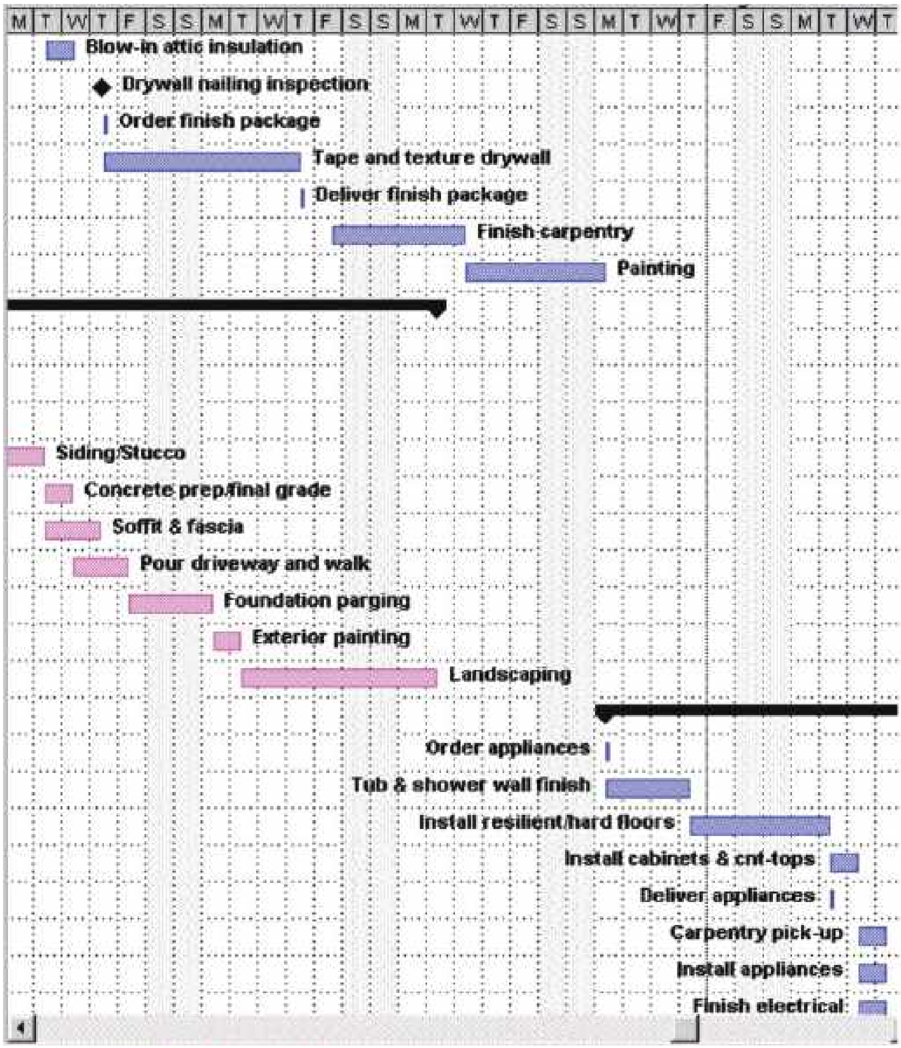
   1. Wall hung, white, vitreous china, siphon jet, elongated bowl, 1-1/2-in top spud. Mount with rim height 15 in above floor. 1.6 gallon flush. Kohler Kingston K-4330 or approved equal.
   2. Elongated, black, solid plastic, open front seat, less cover with check. Extra heavy duty. Kohler K-4667-C, Beneke 533, Olsonite 95 or approved equal.
   3. Flush valve with dual filtered diaphragm, skirted high back pressure vacuum breaker, 1-in screwdriver angle stop with vandal-resistant cap, rubber bumper, sweat solder adapter, cast wall flange with set screw. 1.6-gal/flush. Nonhold open ADA compliant handle with triple seal packing. Sloan Royal 111 or approved equal.
   4. Carrier: Josam or approved equal.

2. Using the structural steel example, outline how another material item can be tracked. Answer the following questions as you develop a flow chart and plan for purchasing, approving, expediting, and all steps through installation of materials.

   1. Where does the design information originate?
   2. Who approves the purchase?
   3. How is the material packaged, delivered, installed, and so on?
   4. How is the material tracked before, during, and after construction?
   5. Where are the materials stored?
   6. How is the information updated in the project schedule?
   7. What is the connection to cost, schedule, and field management?

3. Given a sample project schedule, outline which of the items need to be detailed into the material management plan. Produce a purchase order and develop a flow chart showing this information. Include answers to these questions: What types of materials are being used? Who is responsible for the information? What information is missing? What kind of information needs to be tracked?

4. Given a case study of a project, which includes an outline of the project, an estimate of selected materials, a schedule for the project, and so on, produce administrative tools that could be used to receive, track, and issue those project materials.



5. Explain which is better: to order bulk materials for a lower price, store the materials, and move them a number of times *or* to only order for a particular project or day. Pick a type of material (drywall, piping, wood, etc.) and analyze types of options for the delivery of that material. What are the pros and cons for different types of contracts and vendor agreements? What type of projects might be better suited for the different types of material management options?

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CHAPTER 8

EARTHMOVING OPERATIONS

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INTRODUCTION

This chapter describes earthmoving operations and related items, including the clearing of right-of-way or construction limits, various types of excavation, and excavation construction requirements. The types and methods of embankment construction and the application of various types of equipment are specially discussed, and in those sections, the supervisor will learn the components and procedures to excavate and build earth embankments. Additionally, the supervisor will learn to apply these skills to properly estimate and manage construction earthwork operations.

RIGHT-OF-WAY PREPARATION

Preliminary Investigation Terms and Procedure

Certain preliminary investigations are required whether a project is the widening of an existing pavement section, the construction of a new roadway section through a new undisturbed right-of-way, or the erection of a new building on an existing parcel. The owner will need to obtain right-of-way grants for all the parcels of property purchased for the new work as well as grants for temporary right-of-way during the construction. All right-of-way is staked according to the construction plans so that the limits of ownership and the areas of temporary ownership for construction are clearly visible. It is important that all employees of the contractor are aware of the property limits so that no disputes arise over work activities outside the property or destroying or disturbing private property. Any work in the right-of-way will have some involvement with public or private utilities as well.

During completion of the plans, the designer notifies all public utilities and all pipeline owners or other parties affected so that they may plan to move and relocate their existing facilities. It is important that all utilities be moved so that there is no involvement or conflict between the public utility companies and the new construction. Public utility delays to the construction schedule are justifiable reasons for time extensions, but they can cause contracts to be extended into another construction season.

Existing survey section comers and other survey-controlled points and benchmarks must be referenced for reestablishment when the contract is completed. The county surveyor having jurisdiction of the site should be contacted to obtain the proper location of all section survey references.

Another area of importance when starting a contract is the investigation of existing underground drainage. Farm field tiles placed by farmers must be perpetuated or continued across the project limits so the drainage is uninterrupted, and legal county tiles and ditches must be maintained and preserved. The contractor should coordinate with the county surveyor or county engineer to assure that all legal county drainage has been located. If the contractor is required to assist in the investigation of underground drainage by excavation, this excavation is paid for as set out in the standard specifications.

Figure 8-1. Trenching machine for pipe tile.

When the contractor arrives at the jobsite, one of the first orders of business is to clear the right-of-way or property limits in preparation for construction. This will consist of the removal and disposal of all vegetation and debris within the limits of the construction site that are obstructing the construction work. Any items within the building property boundaries that are designated to remain in place will not be disturbed or damaged by the contractor. Trees, shrubs, and other items outside the construction limits must be preserved. The contractor will repair any damage to these items and pay all costs to do so.

The following comments about clearing and grubbing may or may not apply to building construction, but it may apply to road construction. It is important to become familiar with your contract documents to determine what is allowed relative to these activities and how you get paid (e.g., a lump sum, by the acre, a unit price, etc.). Trees that are encountered within the construction limits may be removed. If trees are completely removed, the roots from the stump must be grubbed from the ground around the old stump. Any holes created in an embankment area must be backfilled satisfactorily up to the level of the existing ground prior to starting a new embankment. Burning perishable items may only be done if local laws, ordinances, and the contract permit burning. Perishable materials, such as brush, stumps, and sod, must be removed from the right-of-way and disposed of at a location approved in advance by the owner. This approval includes a plan for site restoration after the contract and a plan for prevention of stream sedimentation. Written permission to dispose of perishable materials must also be obtained from the property owner before disposal operations commence.

Sod and topsoil must be removed from inside the embankment limits as well as the excavation limits and should be stockpiled on-site for future use. No longer is it permissible to remove the sod and place it outside the limits of construction. The measurement and payment for clearing right-of-way is a somewhat complicated area. It may be paid for by the acre, by a lump sum payment, by length, or by individual units. If payment for tree removal is per individual unit, the tree is to be measured a height of 24 inches above the ground. Any tree less than 4 inches in diameter is classified as brush and no payment is made.

TYPES OF EXCAVATION

During the construction of a highway, bridge, or building, it may be necessary to remove existing materials that occupy the space in which the new structure is planned. Therefore, they must be removed or excavated. Some materials excavated may be suitable for use in embankment construction, and those that are not must be disposed of completely. There are three types of excavation and a discussion of each type follows.

COMMON EXCAVATION

Common excavation is the most frequently encountered type of excavation in construction. Most standard specifications state that common excavation shall consist of all excavation not included as rock excavation or excavation that is otherwise classified and paid for (e.g., flexible pavements and all rippable materials). Common excavation therefore is the excavation of soil materials from within the project's limits but is not limited to soil materials only. It can include existing flexible type pavements, which consist of bituminous mixtures, macadam, crushed stone, bricks, cinders, among others. A rule of thumb is that if it is shown on the plans and is not a concrete pavement or another defined excavation, then it is considered common excavation.

This work shall consist of excavation, hauling, and disposal or compaction of all the material. However, because compaction of the material is included in common excavation, it will be necessary to obtain soil samples. These samples are submitted to an appropriate testing laboratory for determining maximum density at optimum moisture if the materials are later used as embankment soil.

Rock Excavation

Rock Excavation

This is excavation and disposal of igneous, metamorphic, and sedimentary rock. It also includes boulders or detached stones having a volume of 1½ cy or greater. The material for this type of excavation is removed by blasting, power shovel with a 1-cy minimum bucket capacity, or by other equivalent-powered equipment.

The contractor must restrict the amount of explosives used near structures, rock formations, and other property that may be damaged. Adequate seismograph readings for regulated ground vibrations shall be obtained if commercial buildings are within the affected vicinity at no additional cost. These readings and preblast measurements and images document that the blasting operations have not altered the existing commercial building foundations.

Unclassified Excavation

This is excavation and proper disposal of any type of material that is encountered during the progress of the work. This is the riskiest type of excavation.

EARTHMOVING MATERIALS

It is appropriate to begin an earthmoving discussion by describing common material types. Material characteristics directly affect the way a machine performs. For example, a wheel loader is a good choice to load loose material, but if underfoot conditions are poor, it may not have enough crowding force, so a track loader is a better choice. A bank may be packed so tightly that a track-type tractor must be used to rip the material and then doze it to the loader. Materials fall into three broad classes with respect to earthmoving operations: rock, soil, and mixture.

EXCAVATION CONSTRUCTION REQUIREMENTS

General Preparation

Prior to beginning excavation, grading, or embankment operations in any area, the following items must be completed:

- Clearing and grubbing includes the removal of all perishable materials, such as tree roots, stumps, sod, weeds, agricultural debris, and so on.
- After the clearing items have been completed, the contractor will proceed with scalping in areas where excavations are to be made or embankments are to be placed. Another common term for scalping is stripping. Scalping is the removal of the upper 4 inches of soil. Removal is necessary to insure that vegetation is not incorporated into an embankment. Although 4 inches is a maximum, topsoil containing large quantities of humus to a depth greater than 4 inches is removed until suitable materials are exposed. Scalping is completed to the limits of the building footprint or roadway. The grading operations are inspected closely for unsuitable material, and roots and other large perishable objects should be removed and piled outside the construction limits for later disposal.
- All pronounced depressions left in the original ground surface by removal of objectionable material from within the limits of an embankment are filled with acceptable material and compacted to the density required for the embankment.
- The final step before embankment placement is proof rolling. This step subjects the embankment to stress at least as high as any later expected traffic. When proof rolling is specified, the work is performed with a pneumatic tire roller as shown in figure 8-3. There usually are one or two complete passes, as directed. Roller marks, irregularities, or failures are corrected. This procedure will also reveal all spongy and yielding materials that are not properly compacted. These materials are then removed. The locations of spongy and yielding material may be detected visually. During proof rolling, the pneumatic tire roller will often leave severe ruts in the grade indicating either yielding areas or unstable material. These locations must also be detected audibly. During proof rolling, the engine of the roller will have a consistent sound if it is rolling solid grade. When an unstable area is encountered, the engine will labor in order to pull the roller through the spongy area. This proof rolling procedure can be accomplished with a loaded tri-axle truck instead of a

Figure 8-2. Dozer with root rake blade.

Figure 8-3. A typical pneumatic tire roller. Tire pressure can be adjusted by the operator to optimally compact the lift of the material.

pneumatic tire roller. After proof rolling has been completed and all soft or unstable areas have been replaced, the area is ready for placement of the embankment. (See chapter 5 for more information about compaction.)

- The weight of scrapers and haulers on the soil they spread sometimes can provide enough compaction if the specifications for the embankment are not very stringent. The kneading action of the tires compacts the lift from the bottom up to create more uniform density, while steel rollers compact the lift from the surface. While uncommon, occasionally a vibratory pneumatic roller is used for this work.

General Requirements

Excavated material that is suitable for embankment construction is placed in the embankment before placing any borrow material, which means that ditches should be excavated first since a great deal of common excavation is derived from ditch cuts. Construction of ditches also provides drainage for the embankment area. The embankment should be maintained higher at the center to provide drainage. Once the ditches have been completed, the contractor begins placement of erosion control devices as soon as possible. Failure to do so may cause pollution to drainage ditches, streams, and rivers adjacent to the project. When necessary for the prevention of pollution due to erosion, temporary berms, dikes, dams, ditches, or sediment basins are constructed. These erosion-control features are maintained until permanent erosion control features are placed. The need for erosion-control devices is determined in the planning stages of a project. Erosion control devices are outlined and detailed on the construction plans, and additional controls may be required to meet field conditions. The contractor is responsible for ensuring that these devices are maintained as well. Inspection of control devices is especially important during and after periods of rainfall that may cause damage to the devices, and if damage reduces the effectiveness of these devices, the contractor must take corrective actions (e.g., sediment basins need to be cleaned, dikes or dams reconstructed, straw bales replaced, etc.). Failure to comply with Rule 5 can delay the schedule, and fines can be levied. Rule 5 is a state and federal law that regulates pollutants from construction or land disturbances.

During the construction of an embankment, each lift being placed has certain factors that must be considered:

- Lifts should extend transversely over the entire embankment area between slopes.
- Staking ensures that the outside slopes of the embankment as well as the middle of the embankment are compacted. The higher the fill, the more critical this becomes.
- The fill width should be checked as the fill progresses. Failure to do so may cause fat or bellied slopes. Fat slopes are slopes that contain excess material or exceed the planned slope that results in extra work in computing pay volumes.
- Bellied slopes are slopes that do not contain enough material, which is detected by viewing the slopes longitudinally. Bellied slopes need to be corrected as the embankment is being built. Side casting should be avoided as a solution because a fill slough or slide usually develops at a future date.

EQUIPMENT

The equipment required for placing embankment consist of basically three types: hauling equipment, spreading equipment, and compacting equipment. The contractor determines the hauling method for embankment material, which is based upon the following construction factors:

- Type of material
- Source of material
- Conditions or obstacles between the source and area of placement
- Availability of equipment

The most frequently used equipment for hauling includes dump trucks, earthmovers, and off-road trucks. There are various sizes and models, some of which are self-loading and more convenient for smaller projects. Earthmovers are used in the excavating, hauling, and placement of soil materials that are adjacent to or on the project. When common excavation must be hauled across a bridge structure, or when borrow material is obtained from a remote source, dump trucks are used. Quarry trucks are normally used in rock excavation when the borrow pit is close to the embankment site, and the use of public roads can be avoided. Here are rules of thumb for selecting earthmoving equipment versus distance between cut and dump:

- Tracked dozers to 300 yds
- Towed scrapers to 800 yds
- Self-propelled scrapers to 1 mi
- Loader and haulers beyond 1 mi

Figure 8-4. Dump trucks can be used on public roads.

Figure 8-5. A 21-cy capacity elevating self-propelled scraper.

Figure 8-6. Off-road articulating truck loaded onto a “low-boy” trailer for street travel.

Figure 8-7. Motor grader. Note the light-duty ripper-scarifier mounted on the back end.

Because embankments are to be constructed in uniform layers, spreading equipment is necessary. Placing uniform layers can be done with several types of equipment or groups of equipment. The most common are the motor grader (figure 8-7) and the bulldozer. If soil conditions are suitable, earthmovers also may be considered as spreading equipment. This is accomplished by the earthmover operator controlling the discharge of materials in a manner that creates a uniform layer, which saves significant spreader time. Because soil conditions can change dramatically, the earthmover should not be considered the only spreading device necessary. Another method of leveling layers uses a sheepsfoot compactor with a blade. This piece can be used in lieu of a motor grader. This is especially true on small grading projects.

A piece of equipment that also may be used during the spreading operation is the disk. Although it does not level, the disk is helpful in creating a uniform layer and is used for the following work:

- Breaking up lumps, slabs, and clods
- Aerating material to remove excess moisture
- Incorporating water to increase moisture
- Mixing stabilizing agents spread atop the soil

The requirements for compacting equipment (figures 8-8 and 8-9) vary from project to project. The most commonly used compactors include:

- Three-wheel roller
- Smooth-drum vibrator roller
- Vibratory tamping roller
- Static tamping roller or sheepsfoot
- Crawler-tread equipment or bulldozer
- Mechanical tamps or vibrators

The compactor will be used and that decision is dependent upon several factors:

- Size of embankment
- Type of materials being compacted
- Conditions of materials being compacted
- Availability of equipment
- Contractor’s preference

Figure 8-8. Self-propelled sheepsfoot roller; no roll-over protective system (ROPS) yet mounted.

Figure 8-9. Smooth-drum tandem vibratory roller.

For placement of granular embankment material, three-wheel and smooth-drum vibrator rollers are preferred over tamping rollers. A dozer may be used in areas not accessible to conventional rollers, in building surcharges for peat excavation, or for rock embankments. Tamping vibratory rollers are preferable for shale embankment.

For the placement of clay soil as embankment material, large slabs, lumps, or clods in the soil must be broken up before compacting. Breaking may be accomplished by disking, but often a sheepsfoot roller will work clods and low-moisture lumps.

Equipment, Power, and Cost

When a contractor needs equipment for an existing project but is not on the jobsite or is selecting equipment for a proposed project, it is difficult to determine if a machine will meet the needs of a task. For example, the contractor may need to find the right type of track loader to carry a load out of a basement excavation in wet conditions. The following are some general guidelines for equipment decisions using the track loader example. The first consideration should be the *power required* to move the loader up the ramp, and then does the machine have enough *power available*? If the power available is sufficient, is all the *power usable* for the ground surface condition? A contractor also needs to know the equipment cost in order to bid the construction work. The equipment cost for construction is estimated in terms of ownership and operating (O&O) cost.

Equipment Power

Power required is an important measure when considering a machine because it measures the power needed to overcome Total Resistance (TR). TR is the sum of Rolling Resistance (RR) and Grade Resistance (GR).

$$\text{Total Resistance} = \text{Rolling Resistance} + \text{Grade Resistance, or}$$
$$TR = RR + GR$$

Rolling resistance (RR) is the force that must be overcome for a machine to move on level ground. A number of forces affect RR, but the most significant are internal friction (IF), tire flexing (TF) and tire penetration (TP).

Internal friction (IF) measures the resistance of the drive line components from the engine flywheel to the final drives. Tire flexing (TF) accounts for the resistance when the sidewall and tread are distorted as the tire turns. In a properly maintained machine, IF and TF are considered a constant of 40 lb/ton. Therefore, regardless of any other factors, 40 lb of pull or push are needed for each ton of gross vehicle weight (GVW). Therefore, if a construction vehicle with conventional tires is on hard, smooth, and level surface; then:

$$IF + TF = 40 \text{ lb/ton}$$

Haul road conditions also affect rolling resistance (RR). There is less RR on well-maintained roads than on severely deteriorated roads. On average, for everyone inch of tire penetration, a machine must overcome an additional 30 lbs/ton of RR. TP = 30 lb/ton per inch penetration

$$\text{Thus, } RR = 40 + 30 \text{ x inches of penetration}$$

RR can vary considerably because of great differences in ground conditions. Figure 8-10 provides typical rolling resistances.

Ground Conditions	**Rolling Resistance (lb/ton)**	**Effective Grade (%)**
Hard, smooth roadway, without tire penetration under load.	40	2
Firm, smooth rolling roadway with dirt or light surfacing, flexing slightly under load, regularly maintained and watered.	70	3.5
Dirt roadway, rutted, flexing under load; little, if any, maintenance; no water; 1/2-in tire penetration.	100	5
Rutted dirt roadway, soft undertravel, no maintenance, no stablization; 4- to 6-in tire penetration.	150	7.5

Figure 8-10. Typical rolling resistances for surface conditions.

The effect of RR on track-type vehicles is negligible. Although there is some undercarriage penetration, it is slight, and under normal conditions, not significant. Grade resistance (GR) is gravity's force that must be overcome when going up (or down) a grade. It works against both track and wheel-type machines. Grades are measured in percent slope, which the rise (or fall) is divided by the horizontal distance in which the rise or fall occurs. For example, a rise of 10 ft in a horizontal distance of 100 ft is a 10% grade. If the grade is downhill, or favorable, the effect is a helping force, and is expressed as a negative grade or –10%. GR can be converted from a percentage to an equivalent RR in lb/ton as follows:

$$1\% \text{ GR} = 20 \text{ lbs/ton RR, and } 20 \text{ lb/ton RR} = 1\% \text{ grade GR}$$

Total resistance (TR) expressed as a percentage is called effective grade. Therefore, the following formulas can be used for TR:

Effective grade (%) = GR (%) + RR (lb/ton) ÷ 20
TR (lb/ton) = GR (%) x 20 + RR (lb/ton)
TR (lb/ton) = effective grade (%) x 20

Power required (PR) is the product of the TR and the GVW in tons:

PR (lb) = TR (lb/ton) x GVW (ton)

Alternatively:

PR (lb) = effective grade (%) x 20 x GVM (tons)

Once PR is determined, the next step is to find the power available (PA). PA can be found from the performance curve in the equipment specifications. The PA for a track-type tractor is expressed as the *drawbar pull.* From the manufacturer's performance curve, one can determine PA, ground speed, and gear ranges. These combinations range from low speed and high pull to high speed and low pull. Selecting an operating gear will give certain speed and pull combinations. In the case of a wheel vehicle, the PA is measured between the tire and the ground and is referred to as the ***rim pull.***

Another factor that affects PA is *altitude.* As altitude increases, the air is less dense; and above 3,000 ft., the oxygen loss will reduce engine power. The higher the altitude is, the greater is the power reduction. The power required will remain the same at any altitude; but as the altitude increases, PA will decrease**.** Derating factors for equipment can be found in a manufacturer's performance handbook. Derating factors also can be estimated. Generally, engine power decreases approximately 3% for each 1,000 ft above the maximum altitude of 100% efficiency of the machine, usually 3,000 ft. A derating factor can be calculated as:

Derating factor (%) = 3 x [(altitude (ft) – 3,000 ft) ÷ 1,000 ft]

Example: At sea level, the power required for a tractor is 15,000 lbs. What should the tractor's power be in order to work at an altitude of 10,000 ft?

Solution: Derating factor (%) = 3 x [(10,000 ft – 3,000 ft) ÷ 1,000 ft] = 21%.

Percent rated PA = 100% – 21% = 79%. At 10,000 ft. altitude, for the tractor to work, it should have a power = 15,000 ÷ 79% = 18,987 lbs.

After finding the PA, the ***power usable*** must be determined to take into account the ground surface conditions. At the moment an object is slippery on a surface, the ***coefficient of traction*** (COT) is the ratio of the horizontal force on the object (P) to the weight of the object (W) (i.e., COT = P/W). Figure 8-11 presents typical coefficients of traction for various types of ground surface conditions. Power usable can be calculated by the following formula:

Power usable = COT x Weight

Surface	Rubber Tires	Tracks
Concrete	0.9	0.45
Clay Loam, Dry	0.55	0.9
Clay Loam, Wet	0.45	0.7
Rutted Clay Loam	0.4	0.7
Dry Sand	0.2	0.3
Wet Sand	0.4	0.5
Quarry Pit	0.65	0.55
Gravel Road	0.35	0.5
Fine Earth	0.55	0.9
Loose Earth	0.45	0.6

Figure 8-11. Coefficients of traction on various surfaces.

Estimated Bulldozer Production

Recall information about the load factor, LF, and loose, bank, and compacted soil volumes from Chapter 5.

Production loose cubic yards (lcy/hr) = maximum production x correction factors

bcy/hr = lcy/hr x LF

Maximum production assumptions:

1. 100% efficiency (a 60 min/hr).
2. Power shift machines with 0.05-min fixed times.
3. Machine cuts for 50 ft, then drifts blade load to dump over a high wall. (Dump time = 0 sec.)
4. Soil density of 2,300 lb/lcy = 85 lbs/cf.
5. Coefficient of traction:
   A. Tracked machines: 0.5 or better.
   B. Wheel machines: 0.4 or better.
6. Hydraulic controlled blades used.
7. Gear sequence: dig-IF, carry-2F, return-2R.

Job condition correction factors:

- **Operator**: Excellent, average, or poor
- **Material**: Type of soil
- **Slot dozing**: The operator makes use of the sidewalls from previous passes to hold material in front of the dozer blade in order to limit side spillage.
- **Side-by-side (blade-to-blade or buddy) dozing**: two dozers work side-by-side to reduce the side spillage of each machine by 50%.

- **Visibility**: dust, rain, snow, fog, or darkness
- **Job efficiency**: 50 min/hr; 50/60 = 0.83, or 40 min/hr = 40/60 = 0.67
- **Bulldozer**: blade used relative to the base blade

Earthmoving Production Cycle Times

A cycle time is the total time, in minutes, that it takes for a machine to make one complete trip or cycle (from cut to fill and return to cut). The five components of the earthmoving cycle:

1. Excavate/load
2. Haul
3. Dump/spread/compact
4. Return haul
5. Spot/delay

On any job, a machine moves in a pattern or cycle: loading, hauling, dumping, and returning for another load. The time to complete one round trip is the *cycle time.* Once a job is laid out and operating, it is fairly simple to determine a machine's cycle time by timing several cycles and taking an average. But how can the cycle time be determined for a job that has not started? Historical data from the company is the typical method to estimate. It is also possible to get an accurate estimate of a machine's cycle time by dividing it into two parts: fixed times (FT) and variable times (VT).

Fixed times are those segments that are fairly constant and do not change with loading, dumping, and maneuvering times. Most manufacturers publish typical fixed times for their equipment. There are many ways to reduce fixed times, including:

- In scraper operations, borrow pits should be located for downhill loading.
- Wait time in the cut can be eliminated by matching the number of scrapers and pushers. To keep the machines moving, the load times should be adjusted as haul distances and job conditions change.
- Excessive time should not be spent in the cut heaping a load; maximum production is more important than big loads. Moving dirt makes money. The extra cost is more than offset by the increased production.
- Push tractors can be equipped with rippers to break up hardpan.
- In loader/truck operations, the material should be easy to dig whether natural or conditioned (whether ripped or drilled and blasted).
- The truck should be angled to the face to shorten swing or articulation time. The floor of the load area should be kept clear and dry to improve loader travel times.
- If possible, trucks should be loaded on the left side so the operators can see each other and to reduce truck positioning and startup times.
- The truck should be matched to the loader for easy dumping.

Variable time (VT), often referred as travel time, is the time spent traveling from loading to dumping and returning. These times vary with the distance, grade, and condition of the haul roads.

Caterpillar Model	Load by	Loaded Time (min)	Maneuver and Dump (min)
613	Self-loading	0.9	0.7
621	One D8	0.7	0.7
623	Self-loading	0.9	0.7
627	One D8	0.6	0.6
627IPP	Self-loading	0.8	0.7
631	One D9	0.7	0.7
633	Self-loading	0.9	0.7
637	One D9	0.6	0.6
637IPP	Self-loading	0.9	0.7
651	One DI0	0.7	0.7
657	One DI0	0.6	0.6
657IPP		1	0.7
PP denotes push-pull scrapers or two scrapers used in tandem. The times shown are per pair, including transfer time.			

Figure 8-12. Typical fixed times for scrapers.

Earthmoving Production

Earthmoving rate of production per hour

production (cy/hr) = cycles per hour x volume per cycle

Questions to determine the production rate include these:

- What is the measure of payment—cut, haul unit, or embankment? (bcy, lcy, or ccy)
- What is the shrink-swell factor for the payment location?
- What is the capacity of the pusher/loader, and how long to load? A preferred method is to base all production on "cut" or "bank."
- What is the nature of the material?
- Will job conditions allow a full load consistently?
- What controls the rate of production?
- What happens if the haul distances changes?
- What are the critical machines?

The total equipment cost per hour is the sum of these:

- Machine O&O cost/hour
- Operating engineer cost/hour
- Spread foreman cost/hour

Then, the earthmoving cost of production is

cost ($/cy) = total equipment cost ($/hr) ÷ production (cy/hr)

Mass Excavation

The following pictures show techniques for mass excavation using a track excavator, dozer, and dump trucks.

Figure 8-13. The site for mass excavation of a side slope in a rail yard incorporating a track excavator and dump trucks.

Figure 8-14. Track excavator loading trucks.

Figure 8-14 shows that the excavator has a short stick on the boom and a large bucket. This configuration allows the excavator to replace boom weight for a larger bucket filled with earth. Additionally, the excavator is sitting above the top of the truck bed, which will reduce swing and hoist cycle time. Therefore, the number of dump trucks required for this operation depends on the total cycle time for the trucks to be loaded, travel time to dump the load, and return time to be loaded again. If the trucks hold approximately 12 lcy per load, then the total output of the excavator can be divided by the truck load cycle time. Say that excavator production = 400 lcy/hr. One truck can make

$$3 \text{ cycles/hr} \times 12 \text{ lcy/cycle} = 36 \text{ lcy/hr}$$

Then,

$$400 \text{ lcy/hr} \div 36 \text{ lcy/hr} = 11 \text{ trucks}$$

Figure 8-15 shows that the excavator can use a heaped bucket capacity due to less boom weight. Therefore, the bucket capacity is increased over the nominal capacity.

Haul road conditions are critical to the total travel time of the haul units. Figure 8-16 shows deep haul road ruts, which need to be leveled. Haul road maintenance will greatly increase overall production. If the haul road is not constantly maintained, the trucks will become stuck, and production is halted until the truck is extracted.

A wide-tracked dozer fine grades the side slope and maintains the haul road for the trucks, and it can extract a stuck vehicle. Figure 8-17 shows the dozer fine grading the slope to the designed percentage. On board the dozer is a spirit level that measures the degrees of slope and equivalent percentage.

Figure 8-15. Heaped bucket capacity.

Figure 8-16. Haul roads.

Figure 8-17. Dozer fine grading slope.

Figure 8-18. The finished product of a mass excavation that employed one track excavator set up to perform mass excavation, several haul units, a dozer designed to grade slopes, a dozer at the dump site (often forgotten in the estimate), and a foreman to manage to process.

To maximize the production of the mass excavation, one truck should be waiting to be loaded. The excavator should never wait for haul units. Time waiting is zero production.

Many factors mentioned previously can reduce production, and the CM needs to recognize detractors and try to eliminate as many as possible.

CONCLUSION

Considering the time and expense that earthwork operations can demand, carefully planned equipment operations are critical to the success of many building construction projects. Although it is common for the GC to subcontract such work for a firm-fixed price, the best site professionals will nevertheless understand enough of such work to estimate their cost with reasonable accuracy. They should be able to satisfy themselves that the bids are reasonable and the work methods are appropriate.

QUESTIONS, PROBLEMS, AND EXERCISES

1. In reference to clearing, explain the different ways that payment quantities might be measured.
2. What diameter of a tree trunk determines brush?

3. How many general types of excavation are listed? What are they?
4. Which type of excavation is considered to have the most risk? Why?
5. What does the term *scalping* mean? What is considered to be the typical depth of *scalping*?
6. What is proof rolling? What is the purpose of proof rolling?
7. What is Rule 5?
8. What is the rule of thumb for earthmoving equipment versus distance?
9. Why are agricultural discs used in embankment operations?
10. How many types of compactors are listed in the chapter? What are they?
11. What is a sheepsfoot?
12. What does the term *O&O* mean?
13. Define the abbreviations TR, RR, and GR.
14. What effect does RR have on track-type vehicles?
15. What are the five components of an earthmoving cycle time?
16. Cycle times have two major parts. What are they?
17. In what cycle time component is *travel time*?
18. There are several ways to reduce *fixed time*. List three.
19. When using dump trucks on public streets, what is considered to be the greatest potential time loss?
20. While performing mass excavation, should the excavator tracks be at the same elevation as the wheels of the haul truck? Explain.

CHAPTER 9

CRANES AND HOISTING EQUIPMENT

Bryan Hubbard

INTRODUCTION

A crane is a critical piece of construction equipment that is needed to lift and move large and heavy objects on a construction site. The strategic use of a crane can help control job productivity, scheduling, cost, and safety on a construction site. The selection and use of a crane requires knowledge of crane types, their placement, loading, and load rigging, as well as the potential hazards. This chapter will provide an overview of basic crane operations on a construction jobsite. However, it is not possible to provide detailed information on all aspects of cranes here, so additional information may be found in the references noted at the end of the chapter, which include crane textbooks, crane and rigging handbooks, and crane manufacturers' information. In addition to the information in this chapter and the references, it should be noted that the crane equipment discussed in this chapter requires an experienced operator in order to ensure safe and efficient material movement.

There are many crane choices for hoisting and moving materials on the jobsite. When comparing all the different types of cranes, they may seem very different, but on close inspection, there are many similarities between them. The majority of cranes use a hoisting system of wire rope routed through blocks (with pulleys or sheaves) that is attached to a winding drum (see figure 9-1). The system of pulleys provides the crane with a mechanical advantage to lift the load. The winding drum rotates to either raise or lower a load. The operation of the winding drum is much like a simple winch system used for pulling or lifting that is commonly installed on the front of a pickup truck or utility vehicle.

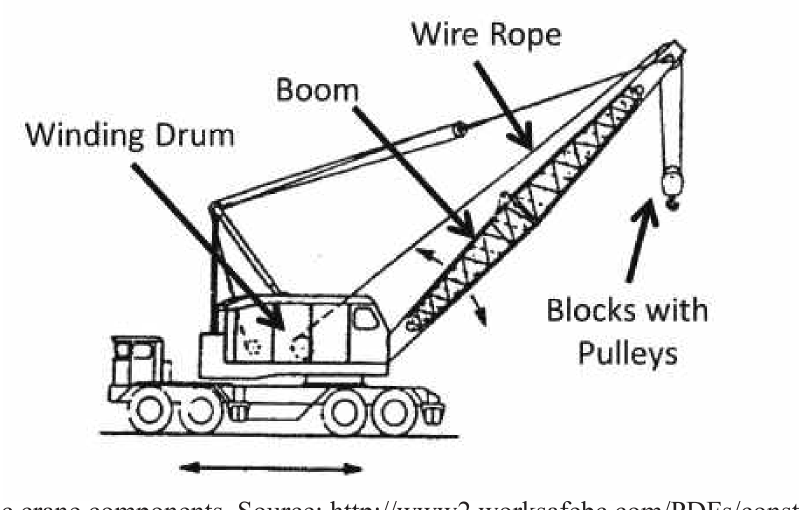


Figure 9-1. Basic crane components. Source: http://www2.worksafebc.com/PDFs/construction/types_of_cranes.pdf.

Another element common to all construction cranes is that the system of wire ropes and pulleys are attached to a boom (figure 9-1). The boom is often a steel truss structure that is strong and lightweight and may resemble a lattice; hence, it is called a lattice boom. The crane in figure 9-1 depicts a lattice boom. Another type of boom includes a steel box structure that can telescope in and out and operates on a hydraulic system (figure 9-2). The hydraulic telescoping boom option is a heavier boom, but it provides additional flexibility in moving the load.

CRANE TYPES

Construction crane types are generally divided into two categories: those that are mobile on the jobsite and those that are fixed. Mobile cranes are typically self-powered and can be set up in multiple locations on the jobsite. Fixed cranes are placed at the beginning of the job and typically do not move for the entirety of the project. The most common fixed crane is the tower crane.

Mobile Cranes

There are numerous types of mobile cranes, and the type designated is based on the system used to move the crane and the type of boom. The common methods for the crane to move are wheel-mounted or crawler-mounted. Crawler cranes ride on a set of tracks rather than directly on wheels. The use of either a wheel-mounted crane or a crawler crane depends on a number of factors, and, often, either one will work for a construction site. The guiding factor may be the availability of equipment or the kind of equipment that the contractor owns. Some attributes of wheel-mounted cranes include (Shapiro, 2001):

- Lower cost
- Quick setup
- Numerous attachments for flexibility
- Easily maneuverable on the jobsite and to other jobsites

Some attributes of crawler-mounted cranes include:

- Heavy lift capacity
- Tracks are advantageous for mobility on uneven terrain
- Tracks provide good support on many types of ground conditions

Even though mobile cranes can be moved to various locations on the jobsite, moving a crane is a substantial endeavor. There is significant preplanning required to ensure correct placement based on the crane specifications, the adequacy of the foundation, and the potential hazards in the vicinity. Six types of common mobile cranes are discussed in the following sections.

Crawler-Mounted Crane with Lattice Boom

The crawler crane with a lattice boom is one of the most commonly used cranes and is seen on a variety of construction and work sites. The crawler crane is very stable and tends to not move under a load. It has a 360-degree operating radius. It requires a level and firm surface underneath it, which may require earthwork or other stabilizing measures prior to placing the crane; this is discussed in greater detail later in the chapter. The crawler crane with a lattice boom is

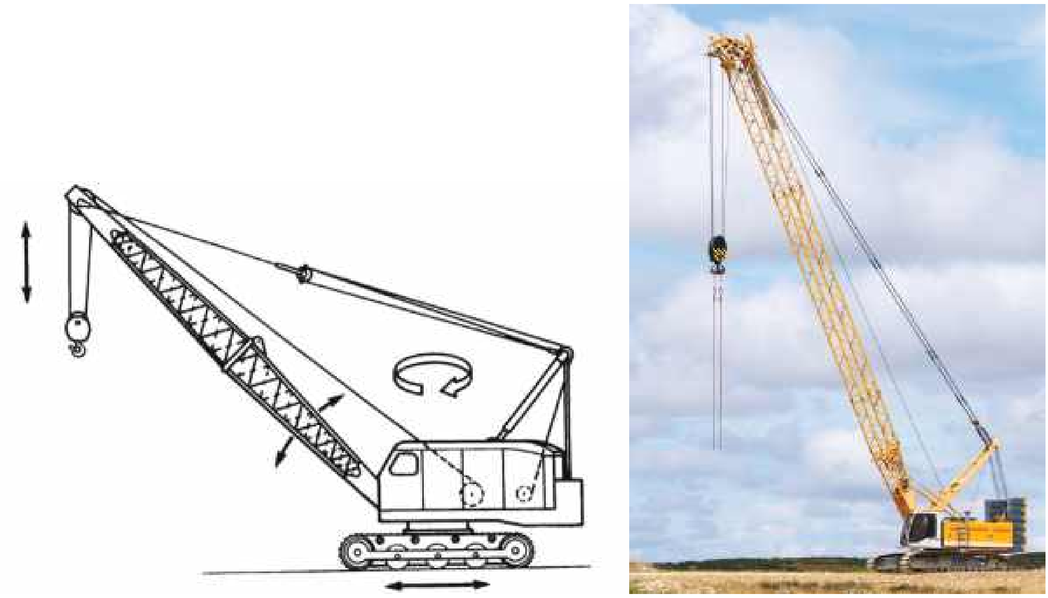


Figure 9-2. Crawler crane with lattice boom. Source: http://www2.worksafebc.com/PDFs/construction/types_of_cranes.pdf and www.photos.com.

illustrated in figure 9-2. The tracks on a crawler-mounted crane distribute the load more evenly due to the greater surface area of the tracks.

Crawler-Mounted Crane with Lattice Boom and Jib

An attachment often used on a crane to increase the reach of the crane is a jib. A jib is attached to the end of the boom as shown in figure 9-3. There are different types of jibs that can either be fixed or move under the control of the operator. A jib that can be moved and controlled by the operator is a luffing jib.

Crawler-Mounted Crane with Telescoping Boom

A crawler crane with a telescoping boom is shown in figure 9-4. The telescoping boom provides for increased flexibility in maneuvering a load. The crane can also be used for picking and carrying the load. The crawler tracks provide significant stability in this operation.

Wheel-Mounted Mobile Cranes

Wheel-mounted cranes come in many configurations as well. They have become very popular because they are easy to move around a jobsite that has rough terrain. The cranes can also pick up and carry lighter loads and often are set up with the outriggers as shown in figure 9-5. The outriggers are required for stability when the crane is picking up and moving loads.

Truck-Mounted Crane

A truck-mounted crane, like the one shown in figure 9-6, is often used for smaller lifts, such as lifting materials from a truck bed. It is easily set up and transported since it can be moved at highway speeds. Larger truck cranes are available and can be mounted with a luffing jib to extend its capabilities.

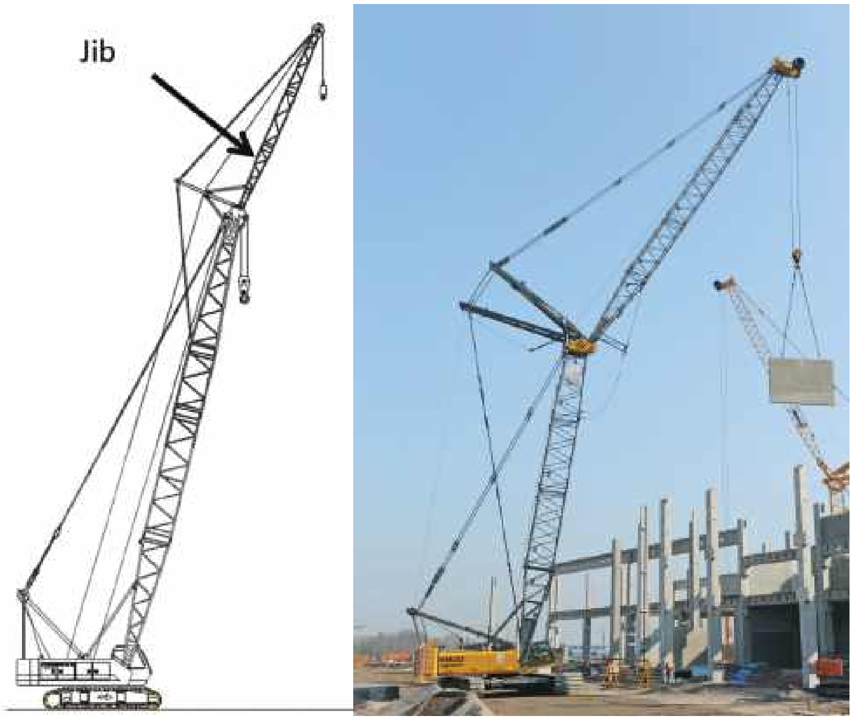


Figure 9-3. Crawler-mounted crane with lattice boom and luffing jib. Source: http://www.truckcrane.cn/Crawler_Mobile_Crane/images/Crawler_Crane_QUY50-9.jpg and http://sennebogen.com/download/C64f7f5c1X1350ee45daaXY3b69/SENNEBOGEN_5500_Crawler_Crane.jpg.

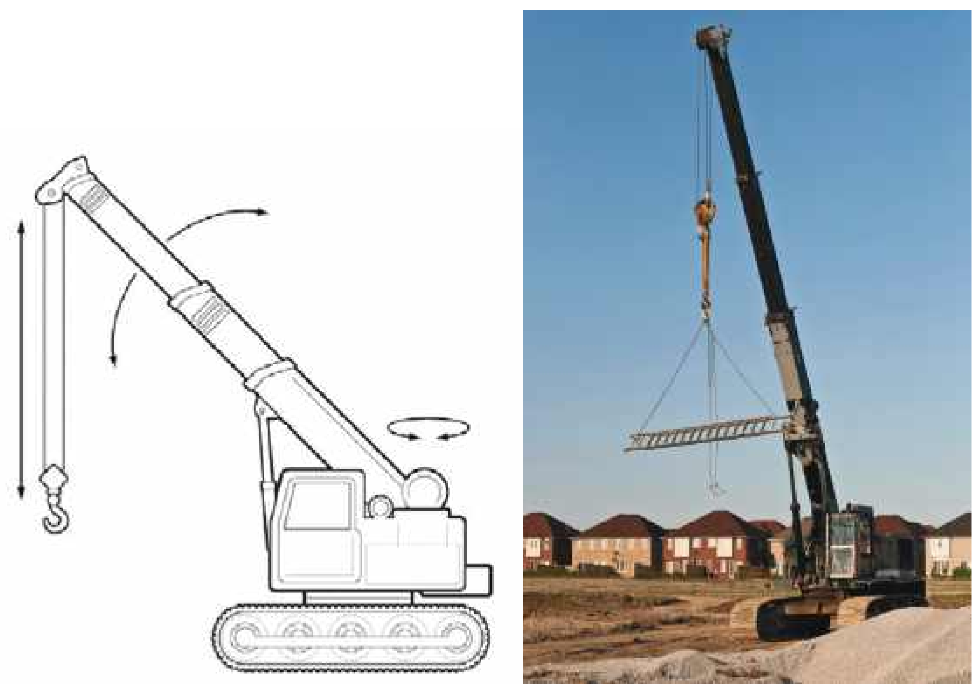


Figure 9-4. Crawler-mounted crane with telescoping boom. Source: http://www2.worksafebc.com/PDFs/construction/types_of_cranes.pdf and www.photos.com.

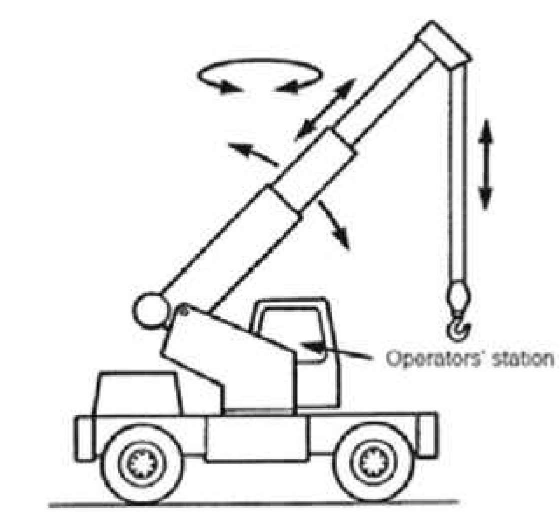


Figure 9-5. Wheel-mounted mobile crane with telescopic boom. Source: http://www2.worksafebc.com/PDFs/construction/types_of_cranes.pdf and www.photos.com.

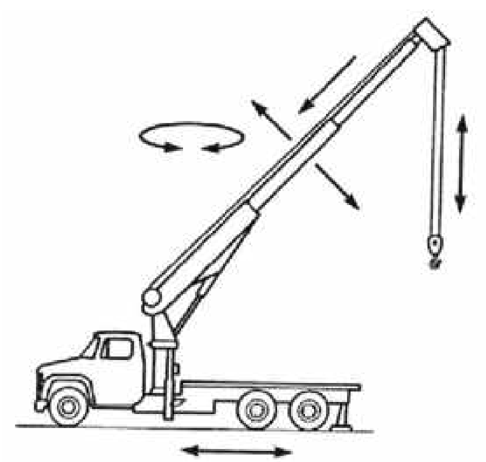


Figure 9-6. Truck-mounted crane. Source: http://www2.worksafebc.com/PDFs/construction/types_of_cranes.pdf and http://overtonsafetystore.com/images/Sheetrock%20Boom%20Truck.jpg.

Tower Cranes

Tower cranes have a fixed tower that is attached to a jib. In the United States, they are used most frequently on high-rise buildings. In other parts of the world, such as Europe and Asia, they are used for many different types of commercial construction. Tower cranes need to be erected on the construction site and arrive on the jobsite in multiple pieces. The installation cost is typically much higher than for mobile cranes. These additional costs must be accounted for and can include building the base foundation, erection of the unit, and increasing the height of the crane during the construction process as the structure being built rises in height. There are numerous ways to increase the height of a tower crane. A method of jacking up the tower and inserting tower extension pieces is shown in the video located at http://www.youtube.com/watch?v=vx5Qt7_ECEE&feature=em-share_video_user.

Tower Crane with Saddle Jib

A tower crane with a saddle jib is shown in figure 9-7. This type of tower crane has a trolley on one of the jibs, known as the load jib. The trolley can move the material closer or farther from the tower. The side opposite the load jib is another jib called the counterweight jib, which has counterweights to balance out the load being hoisted and keep the crane stable.

Tower Crane with Luffing Jib

A tower crane also may be outfitted with a luffing jib. The luffing jib is an extension at the top of the crane that pivots and can be raised or lowered, which provides a significant amount of

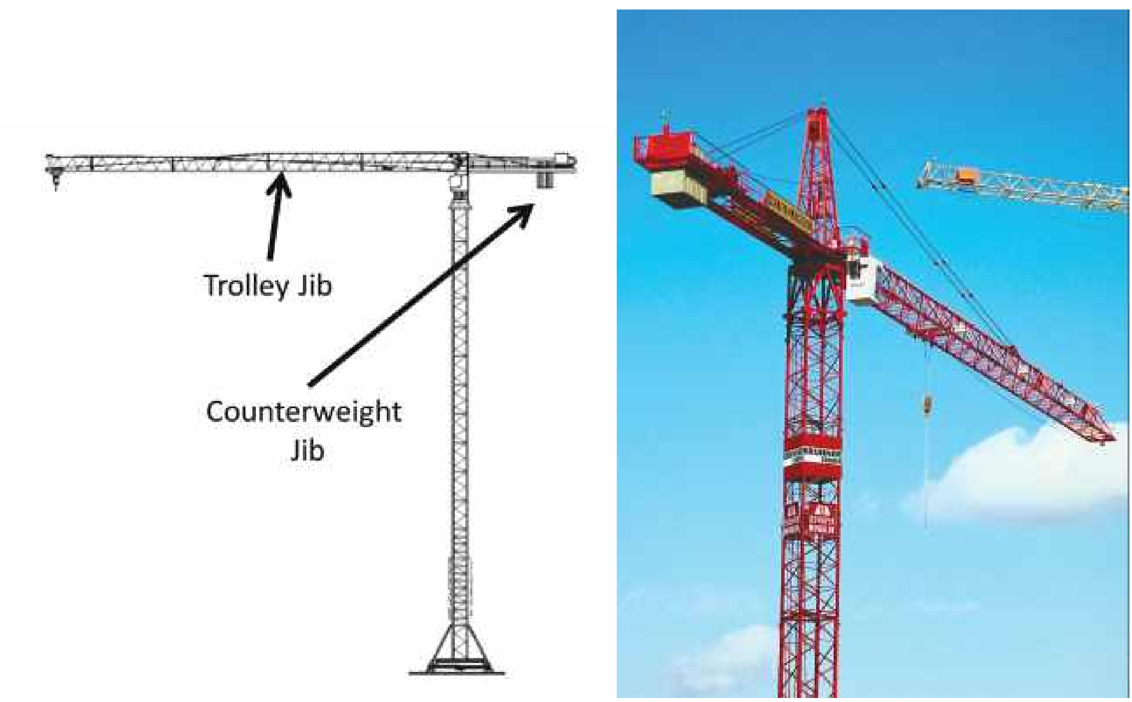


Figure 9-7. Tower crane with saddle jib. Source: http://www2.worksafebc.com/PDFs/construction/types_of_cranes.pdf and www.photos.com.

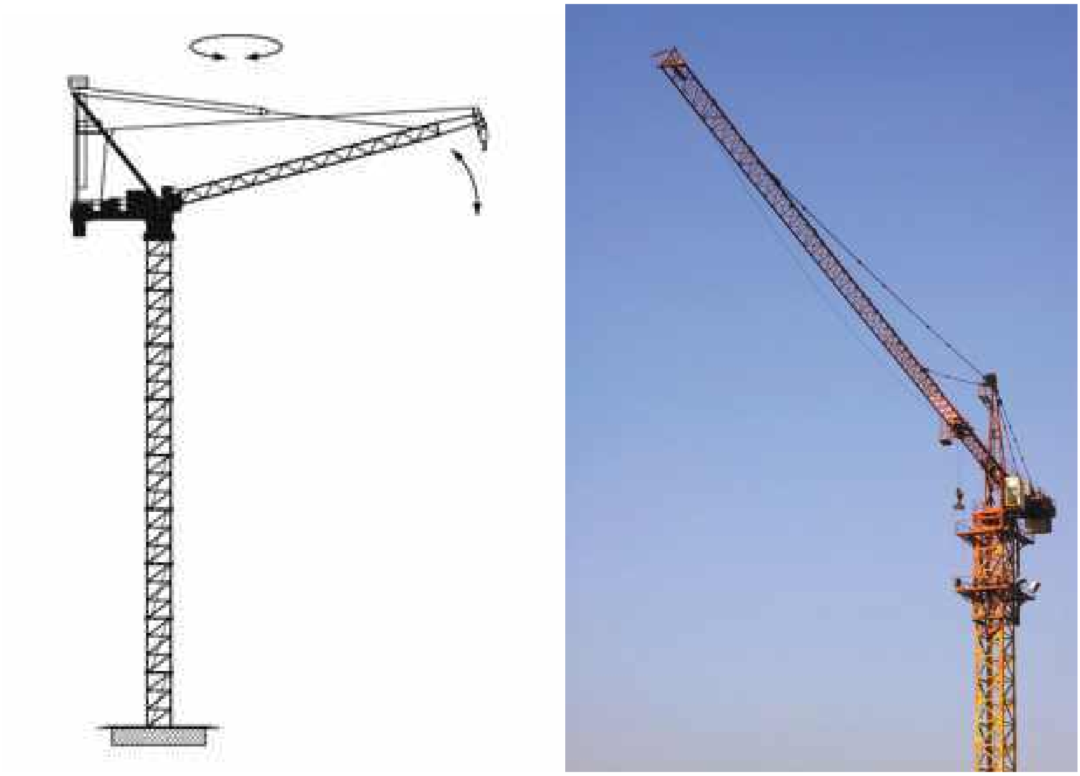


Figure 9-8. Tower crane with luffing jib. Source: http://www2.worksafebc.com/PDFs/construction/types_of_cranes.pdf and www.photos.com.

flexibility over the tower crane with a saddle jib. This type of crane can be used for very large jobs. An example of a tower crane with a luffing jib is shown in figure 9-8.

ADDITIONAL MATERIAL HANDLING EQUIPMENT

In addition to the cranes discussed in this chapter, there are other important pieces of construction equipment to move materials throughout the construction site. In a manufacturing environment, the movement of material using forklifts, conveyers, on-rail transfer carts, and automated systems is a carefully planned and orchestrated operation day in and day out. In the construction environment, material handling equipment must be versatile and operate effectively in the harsh construction environment. Two pieces of construction equipment commonly used for material handling are forklift trucks and telescopic material handlers.

Forklift Trucks

A standard forklift truck, as shown in figure 9-9 (left), can be used for unloading materials from trucks and moving them around the jobsite. This type of standard forklift can hoist a load vertically. A common safety issue with forklifts is overturning, which may occur due to equipment overloading and/or if the forklift is not on an even surface. As with a crane, forklifts have load limits based on their configuration, and the load limit can depend on many factors, including the configuration with the ballast weights. Forklifts for the construction site are modified to compensate for the rough terrain, as shown in figure 9-9 (right), which in this case is a small skid steer loader with a fork truck attachment. It can lift a load vertically and navigate uneven terrain; however, similar to the standard forklift, significant safety issues remain that must be considered to avoid overturning, and hoisting must be performed on even terrain.

Figure 9-9. Standard fork truck (left). Skid steer loader with forklift attachment (right) Source: www .photos.com.

Figure 9-10. Telescopic Material Handler. Source: www.photos.com.

Telescopic Material Handlers

A commonly utilized forklift-type piece of equipment is a telescopic material handler (also known as a telehandler), which is shown in figure 9-10 and is typically equipped to manage rough construction terrain. It is similar to a forklift truck in that it can hoist material vertically; however, it has more capabilities because it is also able to move the load in a horizontal direction. Just as with a crane, a telehandler has a rated lift capacity, it must be level on a firm surface when a lift is performed, and its operation must be in compliance with the manufacturer's instructions to avoid common safety issues such as overturning. The load chart for a telehandler is similar to the load chart for a crane, which is discussed in the following sections. Telehandlers have many different types of attachments that can be utilized for various construction operations, such as a grapple bucket, a work platform, and a concrete bucket.

CRANE SELECTION

Selection of the proper crane for a specific task is difficult and requires an understanding of all the lift conditions. In this section, an overview of how to properly select a crane for a lift is provided. All cranes have different lift capacities in various configurations. Cranes will often be named for their maximum capacity. For example, a Manitowoc 10000 has a 100-ton capacity. It is important to note that the maximum capacity is typically the crane outfitted with a short boom and the load close to the crane (small operating radius). A majority of the time, the operating conditions reduce the crane's lift capacity, causing the capacity to be significantly below its maximum lift capacity.

In addition to the boom length and operating radius, there are a number of other operating conditions that affect the capacity of a crane. Examples of conditions that may affect the capacity include:

- Setup of the crane (e.g., jibs and rigging attached to the crane)
- Position and weight of counterweights
- Outrigger placement
- Operational area of the crane, for example, whether the crane moves the load in an arc around the crane or simply lifts it off the ground, which will affect the capacity

The manufacturer's information regarding the maximum allowable loads, operating conditions, and other safety information are provided with the crane. It is important to note that although reference material can be obtained via the Internet and from suppliers for a specific crane model, the information obtained from those sources should be for reference only and should not be used for a final lift plan. Only the load charts associated with a specific crane should be used to plan a lift as there can be variations in the capacity for different cranes with the same crane model designation, and there may be changes to the load rating for a crane due to its maintenance and repair record.

Reading a Load Chart

In order to determine the maximum capacity of a crane, the working range diagram and the lift capacity charts for that crane must be consulted. These documents are provided with each individual crane. Sample charts for a rough terrain crane are shown in figures 9-11 and 9-12.

Figure 9-11 is a working range diagram that provides a visual image of where the load can be lifted based on the boom length. The shaded region is an area to which the load can be moved if the boom is set to one of the seven lengths shown at the right of the graph.

In order to determine if the load is within the capacity of the crane, the lift capacity chart must be reviewed. Figure 9-12 shows a lift capacity chart for the rough terrain crane. Lift capacity charts are different based on the manufacturer and the model; however, many charts show the boom length in the columns across the top of the graph (x-axis) and the distance from the load to the center of the crane (center pin) in the rows (y-axis). As an example, if the boom is extended 57 ft and the load is 50 ft from the center pin, the maximum capacity for the load is 12,400 lbs. It is important to note that this load is based on a certain configuration of the crane, as noted at the top of the diagram. In this example, the following crane configuration is required: 6.5 tons of counterweight, with outriggers fully extended at 22 ft x 22.3 ft, and for this configuration, the load can be moved in an arc around the crane of 360 degrees. The swinging of the load around the center pin of the crane is called slewing.

Another important consideration when evaluating a crane's operational information is the angle of the boom, which is directly related to the distance to the load from the center pin (radius from center of rotation). This may be determined from diagrams like the one shown in figure 9-13. As the boom becomes more horizontal, the boom angle becomes smaller, and the capacity of the crane severely diminishes as the boom moves into a more horizontal position.

When determining whether the crane is capable of lifting a load in a certain configuration, all of the possible weights must be accounted for—not just the weight of the load. Many times,

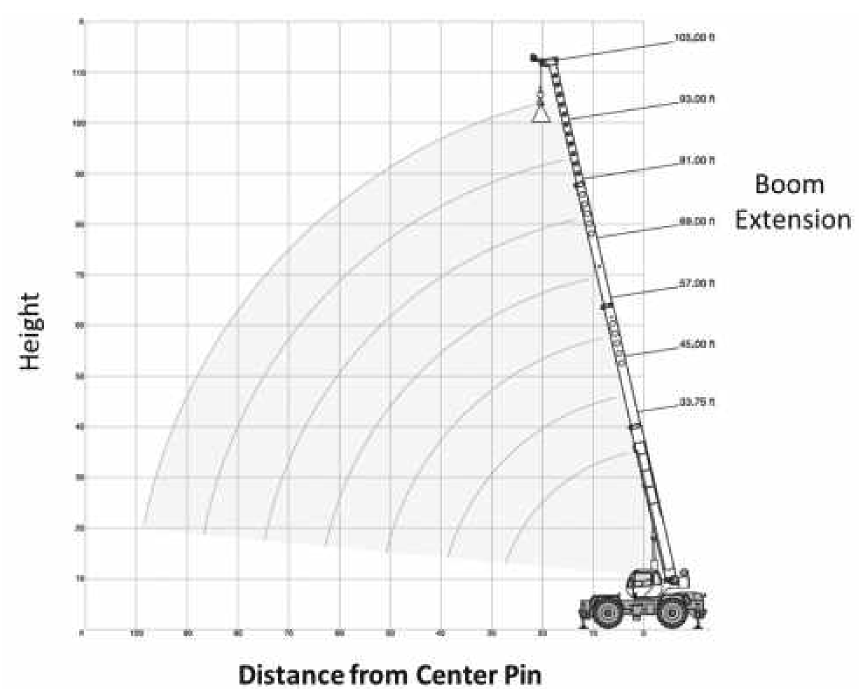
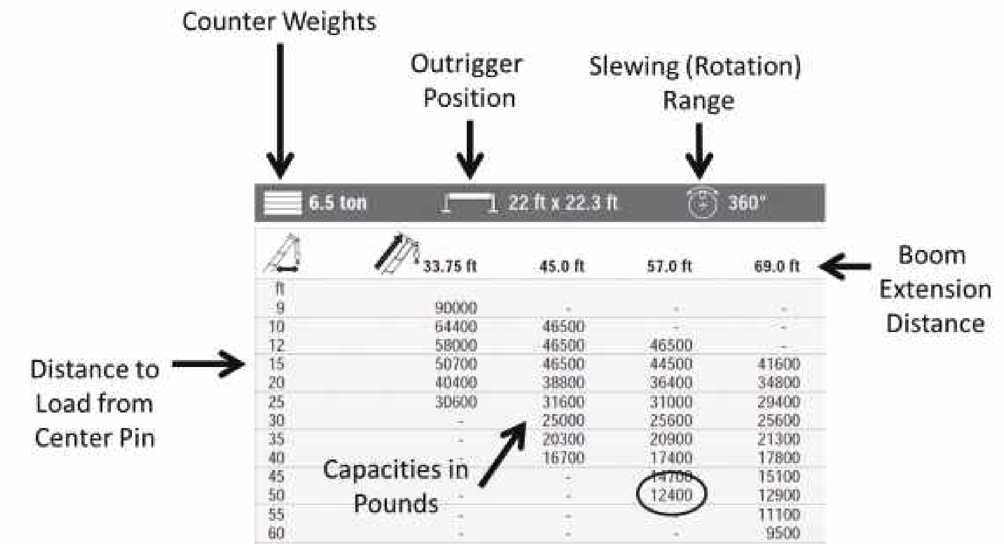


Figure 9-11. Working range diagram for rough terrain crane (illustration only; Terex RT 345XL specifications).



ft	33.75 ft	45.0 ft	57.0 ft	69.0 ft
9	90000	-	-	-
10	64400	46500	-	-
12	58000	46500	46500	-
15	50700	46500	44500	41600
20	40400	38800	36400	34800
25	30600	31600	31000	29400
30	-	25000	25600	25600
35	-	20300	20900	21300
40	-	16700	17400	17800
45	-	-	14700	15100
50	-	-	12400	12900
55	-	-		11100
60	-	-	-	9500

Figure 9-12. Lift capacity for rough terrain crane (illustration only; Terex RT 345XL specifications).

the weight of the rigging required to lift the load and the extra wire rope are not accounted for when reading the crane charts. These elements must be considered and can significantly reduce the amount of actual material a crane can hoist. Examples of charts for sizing a crane are provided in figures 9-13 and 9-15.

Reading Crane Charts: Example Problem

An American HC 80 Hydraulic Crawler Crane is being used on a job (figures 9-13, 9-14, and 9-15). It has a maximum capacity of 80 tons (160,000 lbs). The crane configuration is:

- Main boom length = 100 ft
- Distance to the load = 60 ft (boom angle 56.1 degrees)
- 100-ton capacity crane block = 1,200 lbs
- Three additional hoist lines used for the 100-ton crane block = 1.5 lb/ft
- Rigging = 150 lbs

Using the information provided, what is the maximum load weight that the crane can hoist?

- **Step 1**: Determine the lift capacity from figure 9-15.
  Based on a 100-ft boom and a distance of 60 ft to the load, the lift capacity is 19,720 lbs.
- **Step 2**: Determine the weight of the crane block and rigging.
  Based on the problem description, the crane block weighs 1,200 lbs and the rigging provides an additional 150 lbs, for a total of 1,350 lbs.
- **Step 3**: Determine the wire rope weight (the weight of extra wire rope not included in the crane configuration). The maximum height from the boom tip to the ground is 88 ft. The maximum weight of the three lines would be:

  88 ft x 1.5 lb/ft x 3 lines = 396 lbs of additional weight

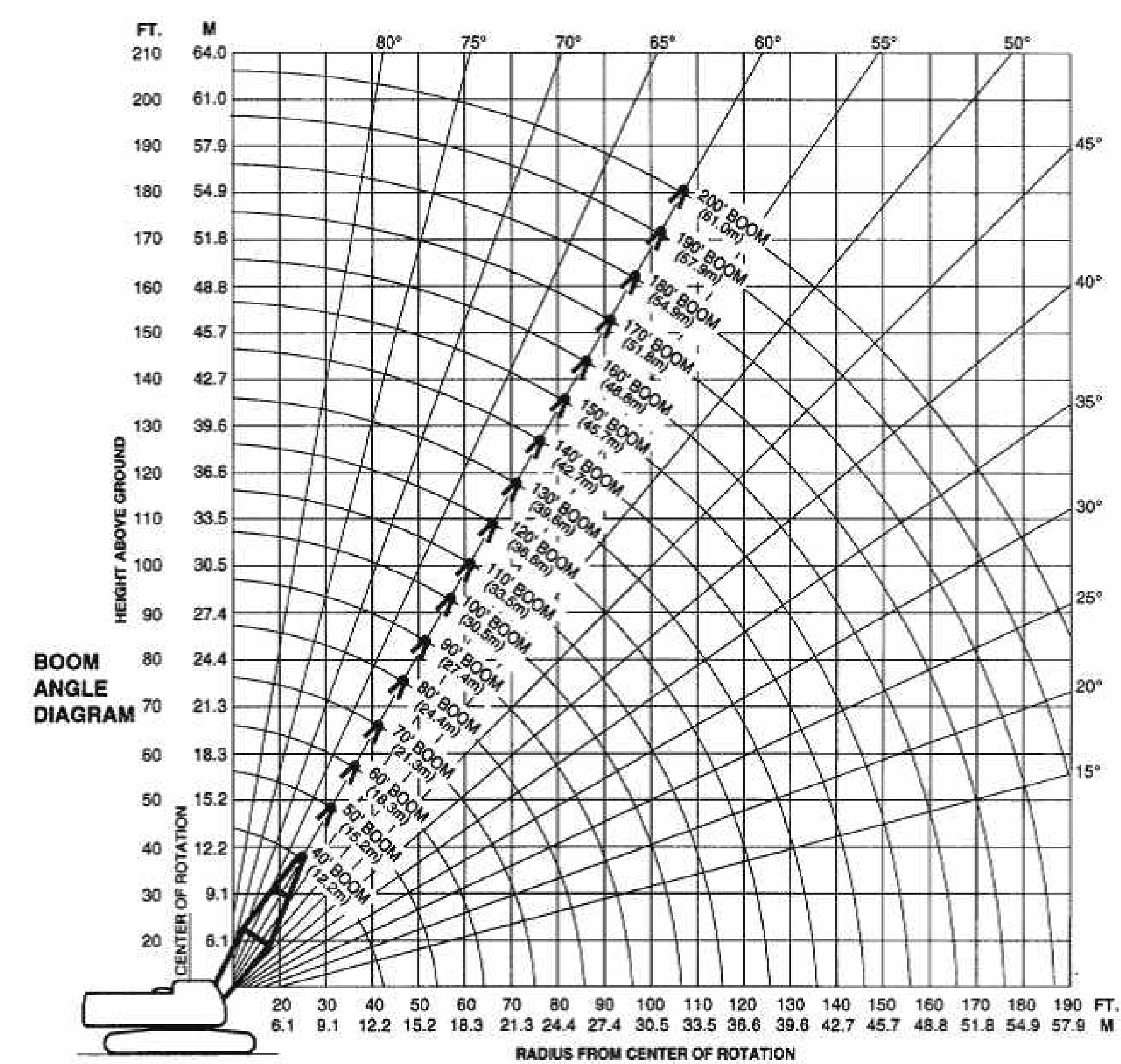


Figure 9-13. Boom angle diagram for Terex HC 80 Hydraulic Crawler Crane (illustration only; American HC specifications).

- **Step 4**: Determine the capacity.
  The capacity of the crane load is the lift capacity noted on the graph (step 1) minus the weight of the additional hoisting equipment required (steps 2 and 3):
  19,720 lbs – 1,350 lbs – 396 lbs = **17,974 lbs**

It is important to note that for this example the crane capacity was reduced almost 10% when considering the additional weight due to additional rigging and crane equipment. These items need to be accounted for when sizing a crane lift. Another interesting item to note is that, in the configuration described, the crane is able to lift approximately nine tons (18,000 lbs) of material. This is a significant difference from the 80-ton maximum capacity of the crane.

The graph and chart examples in figures 9-11 and 9-12 are for a simple crane setup. Cranes have many different configurations, and these configurations can complicate the charts and

Figure 9-14. Terex HC 80 Hydraulic Crane (left); 100-ton crane block (right) (American HC specifications).

Boom	Radius (Feet)	Boom Angle (Degrees)	Side Frames Extended (Pounds)	From Boom Pt. to Ground (Feet)
100' (30.5M)	21	80.4	80,910	104
	25	78.1	62,690	103
	30	75.2	48,580	102
	35	72.2	39,590	101
	40	69.1	33,190	99
	50	62.8	24,840	94
	60	56.1	19,720	88
	70	48.9	16,130	81
	80	40.7	13,540	71
	90	30.7	11,560	56
	100	16.0	10,010	33

Figure 9-15. Lift capacity chart for Terex HC 80 Hydraulic Crawler Crane (illustration only; American HC specifications).

graphs associated with a crane. For example, a jib may be added to the top of a boom on a crane, similar to the crane shown in figure 9-3. The addition of a jib will require additional tables for the length of the jib and the angle of the boom at certain jib lengths. A competent person skilled and experienced in crane sizing should be consulted for these complex crane configurations.

Crane Load Moment Indicators

Overloaded cranes may result in accidents, damage, and injuries. To reduce the likelihood of crane overload and potential accidents, some cranes are equipped with load moment indicators (LMIs), which are electronic systems that provide the crane operator with data such as the:

- Actual load
- Boom length
- Load radius
- Boom angle
- Rated load

This information may be used to provide information to the crane operator, which may allow the operator to check that the crane is within the desired operating conditions. This information may be tracked by a built-in control system that will restrict the crane movement if any of the parameters exceed the safe operating capacity of the crane. The load and load moment data are collected and displayed in real time.

Figure 9-16 shows a load cell that is attached to the crane. This load cell measures the actual total load that is on the crane. Sensors attached to the load cell measure the minute deformation of the load cell, which corresponds to the load. The actual load includes the weight of the load and the weight of the blocks, rigging, and wires, as well as any other potential loads, such as the wind load, which may vary significantly depending on the shape of the object being hoisted and the environmental conditions.

Figure 9-17 shows next-generation LMIs. This equipment, and other equipment with similar functions but different technologies, makes use of special sensors to provide the crane operator with information about the actual real-time working state as well as the correct working parameters specified by the equipment manufacturer.

The load is measured using a load cell, and the moment of force is then calculated based on this load as well as the boom length, load radius, and boom angle. The display in the cab

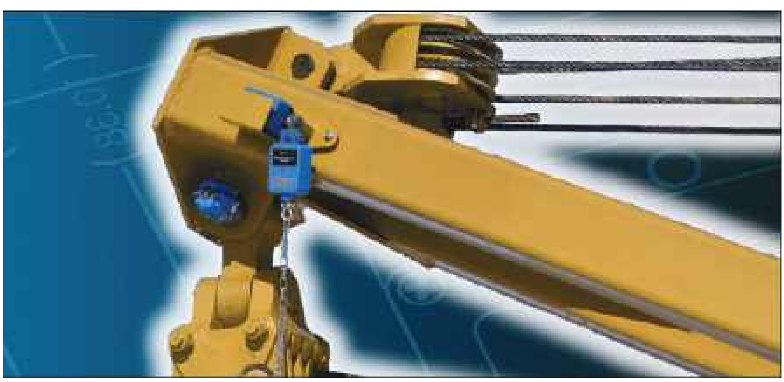


Figure 9-16. Load cell attached to crane provides real-time information regarding the load while it is being hoisted. Source: Cranesmart.

Figure 9-17. Hardware used to measure and display the real-time load moment on crane during operation. Source: Cranesmart.

then indicates the moment of force applied on the crane and the actual hoisting capacity (load rating) of the tower crane. If the load reaches a prescribed percentage of the crane rating (e.g., 75%) at a particular moment, it typically will provide a warning. If the load continues to get closer to the rated capacity, the LMI will automatically stop the lifting gear. LMIs require calibration, maintenance, and recertification. It is important to note that LMIs do not replace load charts. LMIs should not be used as the single source of information; they are an additional tool to provide more information to the operator.

Crane Advanced Technologies

In addition to sensing real-time loading and load moment, advanced technologies can be used to reduce the likelihood of collisions. Collision monitoring is most prevalent for tower cranes as the size of tower cranes may make it difficult for the operator to have good visibility. Moreover, many large construction sites may have multiple cranes with moving booms and varying loads throughout the day.

Figure 9-18. Tower cranes on a jobsite in China with collision monitoring.

Positioning the Crane on the Jobsite

In the construction industry, operations must be efficient in order to maximize profits. To maximize the efficiency of the construction operation, the preplanning team must consider the type of crane to use, the potential crane location, and the materials required to be moved. A review of the construction site layout is a good place to start to determine potential positions for the crane. A thorough understanding of the construction process will aid in identifying the specific areas where a crane is required. Quite often, the material not only needs to be hoisted to a construction location, but it also needs to be removed from trucks or retrieved from storage locations. A thorough understanding of the construction material flow on the jobsite is important to help determine the best location for the crane.

Once a general idea of where the crane needs to be located is determined, a more in-depth review of the site will help determine the type of crane, the various attachments that may be required, and the potential crane base support. When picking a location, focus on crane operations that move quickly. In terms of work cycle, the fastest to slowest operations are:

1. Hoisting
2. Swinging
3. Booming in and out
4. Traveling (pick and carry)

The most efficient operation of the crane is to hoist materials upward with very little movement from side to side. When the load is swung from side to side (slewing), the load may tend to swing like a pendulum, and the moving load may take longer to place. Using a crane with an extendable boom and moving the boom in and out can also cause a similar load motion and may destabilize the crane more easily than swinging the load in an arc. Picking a load and moving it with a crane (pick and carry) is a difficult operation and has to be well planned ahead of time. Cranes are very limited in the load that can be carried in this situation, and the process is very slow.

For simple crane operations, planning may be done easily using a paper copy of the construction site layout with possible crane locations penciled in. A compass can be used to determine the swing radius of the crane, which is helpful in terms of loads that must be moved as well as possible obstructions that may be dangerous. Once a radius is determined to move the load, the required height of the boom and the angle of the boom can be determined to assist in crane selection. Depending on the degree of risk presented by the lift and local regulations, the services of a professional engineer may be required.

More recently, crane locations can be simplified by using computer-generated drawing software. The crane can be located on a two-dimensional drawing as shown in figure 9-19. The plan view of the crane placement along with an elevation drawing provides detailed information on how the lift is to proceed. With the advent of three-dimensional drawings and building information modeling (BIM), animated three-dimensional movies can be developed to show the exact lift procedure and how the material will be placed (figure 9-20). These types of utilities are typically not necessary for common production lifts used throughout the work day, but they are useful for lifts that have challenges and are thus deemed a critical lift, as described in the following section.

Regardless of the method used to locate the crane, the location should be reviewed to ensure the crane can be operated per the crane setup requirements. Some important items to consider are:

- Space available to extend outriggers
- Space available for the rear counterweights to move (tail swing)
- Space available to set up the crane (long booms and jibs may require a large setup location)
- Adequate ground-bearing pressure to support crane
- Distance from steep drop-offs
- Locations where the crane weight may affect building foundation and basement structures

Crane Setup

Once the crane location has been determined, the crane will need to be set up. Depending on the crane selected and the type of lift, this can be a relatively quick process or it may take a significant amount of preparation, which may include engineering analysis. For many cranes, outriggers will be required in order to stabilize the crane. Many cranes have multiple outrigger settings and allow the outriggers to be partially extended, providing a great deal of flexibility in more confined spaces. However, it is important to note that the load capacity of the crane is reduced when the outriggers are not fully extended. The load charts will reflect the diminished load capacity.

Cranes also need to be leveled in order to perform safe operations. Manufacturers will specify the required level tolerance, which is often at most a 1% grade, approximately 0.58 degrees (ASCE, 2009). Manufacturers do not typically recommend that the outriggers be used to level the crane (opposing outriggers set to two different heights).

When setting up the crane, it is also important to have adequate ground support so the crane will not sink into the soil and tip. The measurement of the ability of the ground to support the crane is called ground bearing and is measured in pounds per square foot (psf). A geotechnical engineer or soils engineer can assist with the determination of the ground bearing for crane locations. When the soil is inadequate to support the load of the crane, pads and matting often are used to spread the load of the crane, which is often called cribbing. These supports can

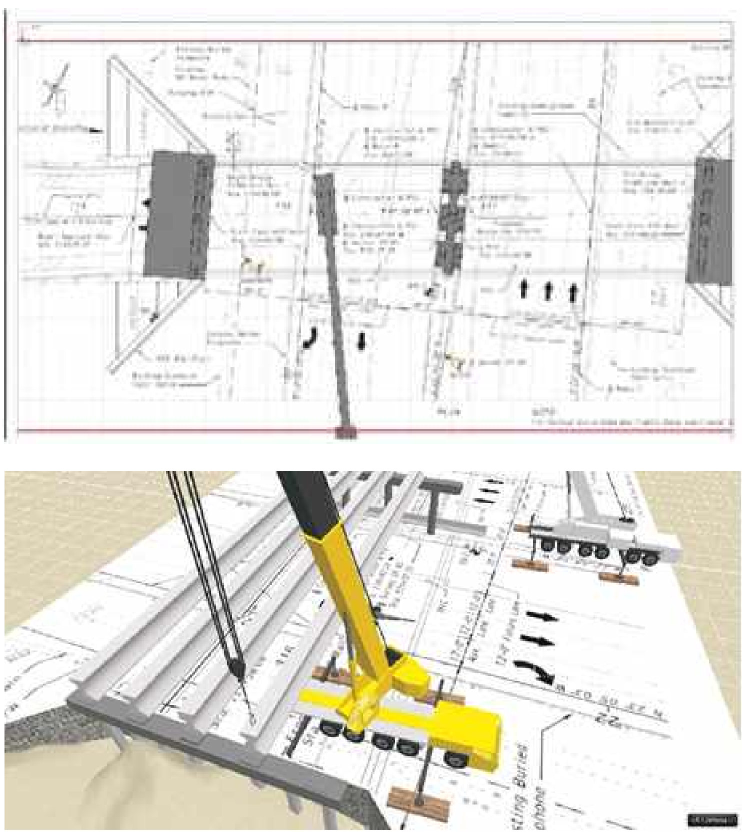


Figure 9-19. Positioning the crane: two-dimensional drawing with crane position. A three-dimensional representation of the crane location is shown below for clarity. Source: 3D Lift Plan.

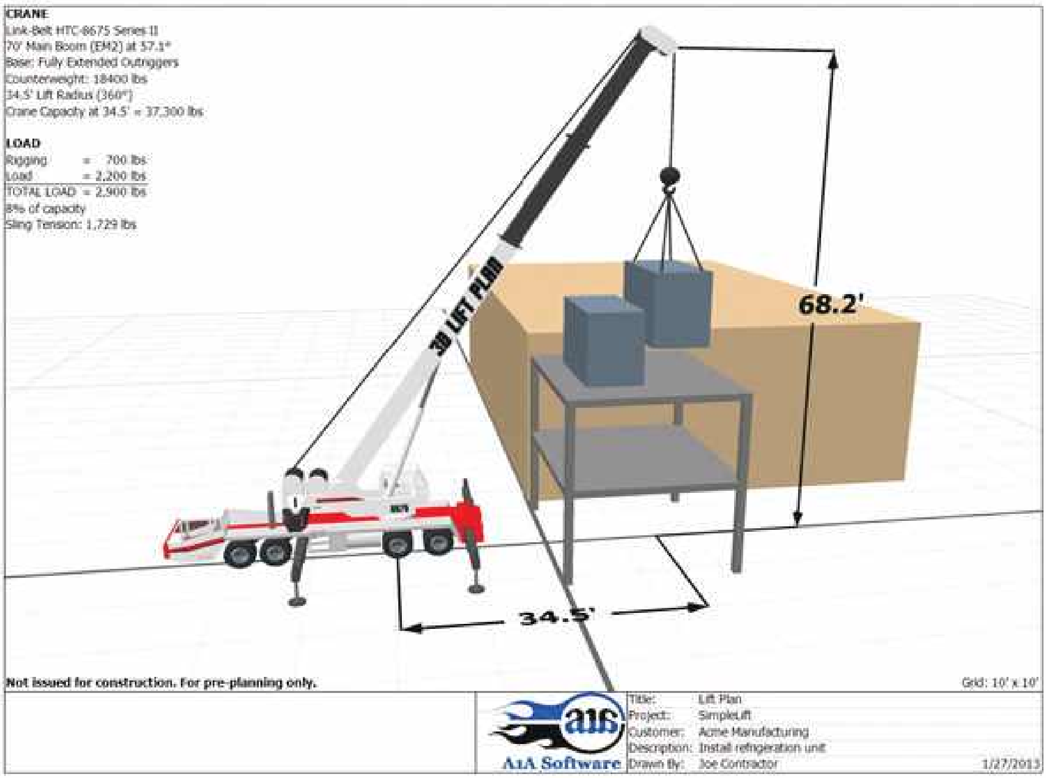


Figure 9-20. Positioning the crane: three-dimensional animation. Source: 3D Lift Plan.

range from lightweight plastic pads that can be easily moved (figure 9-21) to heavy timbers that support the entire crane. In some instances, a foundation-type structure may be required, which could include crushed rock, timbers, and steel plates, or, in rare cases for very large jobs, a concrete pad.

Figure 9-21. Crane supported with dense plastic pad. Source: http://www.outrigger pads.co.uk/specifications.htm.

Critical Lifts

All lifting operations with a crane need to be carefully planned with competent and experienced personnel. All the factors that affect a lift need to be understood in order to ensure a successful lift and provide a safe working environment for everyone on the construction site. Crane operations or situations that are especially difficult because of a challenging situation are deemed critical lifts. Some typical factors that will create a critical lift situation include:

- The load weight is close to the rated capacity of the crane (OSHA defines a critical lift as one that exceeds 75% of the rated capacity of the crane) (OSHA, 2002).
- The lift requires the use of more than one crane.
- The lift will traverse the load over an occupied structure or a public street.
- The material being lifted is of high value or is difficult to replace.
- The lift includes personnel being hoisted.
- The lift includes special hazards, such as in a chemical plant or nuclear power site.
- The lift is made out of view of the operator.
- The lift involves nonroutine equipment or rigging arrangements.
- The lift is near power lines.
- The lift is in high winds or other higher risk environmental conditions.
- The lift is determined by the operator to be potentially critical.

When conditions are appropriate, a critical lift plan should be developed. Items that should be included in a critical lift plan include (The Hartford, 2008):

- Description of the lift
- Crane position and configuration
- Lift height
- Load radius
- Boom length and angle
- Size and weight of the load
- Special load considerations (e.g., fragile equipment, includes people or hazardous cargo)
- Percent of crane's rated capacity
- Personnel involved
- Rigging plan
- Communication method
- Ground conditions
- Environmental conditions
- Inspection procedures

An example of a critical lift form is included in figure 9-22.

CRANE CRITICAL LIFT PLAN

THE HARTFORD

General Information:

Scheduled Lift Date:	Scheduled Lift Time:
Jobsite:	
Specific Lift Location:	
Lift Height:	
Description of Lift:	

Personnel:

Crane Operator:	Qualifications:
Lift Supervisor:	Qualifications:
Rigger:	Qualifications:
Hoisted Personnel (if applicable):	

Lift Criteria:

- ☐ Lifting greater than 75% of the rated capacity
- ☐ Lift involving more than one crane
- ☐ Lift over occupied structures or in tight quarters
- ☐ Blind lift (out of the view of the operator)
- ☐ Lift near power lines
- ☐ Hoisting personnel
- ☐ Lift involving non-routine rigging techniques
- ☐ Lift where the center of gravity may change
- ☐ Lifting high value, hazardous or explosive loads
- ☐ Lifting of submerged loads
- ☐ Other (describe): ______________________________

Crane:

Manufacturer:		Model:	
Mobile Crane Capacity (lbs):	Over Rear:	Over Front:	Over Side:
Route of Crane Travel:			
Tower Crane Capacity (lbs):		Maximum Radius (ft):	
Boom Length:		Jib Length:	
Load Block	# of Sheaves:	Size:	Weight:
Secondary Block	# of Sheaves:	Size:	Weight:
Hoist Rope Diameter:			
Maximum Rated Capacity for Lift Radius and Boom Angle (lbs):			
Maximum Crane Load for Lift Radius and Boom Angle (lbs):			
Lift Rated Capacity (%):			

Load:

Load Weight (lbs):	Source of Load Weight:
Load Weight Confirmation:	
Total Rigging Weight (blocks, lifting beam, slings, shackles, rope, etc.) (lbs):	
NOTE: Attach a diagram of the intended path of the load.	

Rigging:

Sling(s):	Number:	Diameter:
	Length:	Capacity (lbs):
Shackle(s):	Number:	Size:
	Type:	Capacity (lbs):
NOTE: Attach a rigging plan or diagram that identifies intended lift points, sling angles, and sling connections		

Site Conditions:

Ground Conditions:	
Outrigger Position:	Mat Size (under outrigger floats):
Degree of Level (°):	Level Confirmation:
Maximum Allowable Wind Speed in MPH (per crane manufacturer):	

Crane:

Manufacturer:		Model:	
Mobile Crane Capacity (lbs):	Over Rear:	Over Front:	Over Side:
Route of Crane Travel:			
Tower Crane Capacity (lbs):		Maximum Radius (ft):	
Boom Length:		Jib Length:	
Load Block	# of Sheaves:	Size:	Weight:
Secondary Block	# of Sheaves:	Size:	Weight:
Hoist Rope Diameter:			
Maximum Rated Capacity for Lift Radius and Boom Angle (lbs):			
Maximum Crane Load for Lift Radius and Boom Angle (lbs):			
Lift Rated Capacity (%):			

Load:

Load Weight (lbs):	Source of Load Weight:
Load Weight Confirmation:	
Total Rigging Weight (blocks, lifting beam, slings, shackles, rope, etc.) (lbs):	
NOTE: Attach a diagram of the intended path of the load.	

Rigging:

Sling(s):	Number:	Diameter:
	Length:	Capacity (lbs):
Shackle(s):	Number:	Size:
	Type:	Capacity (lbs):
NOTE: Attach a rigging plan or diagram that identifies intended lift points, sling angles, and sling connections		

Site Conditions:

Ground Conditions:	
Outrigger Position:	Mat Size (under outrigger floats):
Degree of Level (°):	Level Confirmation:
Maximum Allowable Wind Speed in MPH (per crane manufacturer):	

Primary Method of Communication Used:		
Pre-Lift Meeting	Date:	Time:
	Personnel:	

Inspections:

Crane:	Daily Inspection Date:	Competent Person:
	Annual Inspection Date:	Competent Person:
Rigging:	Date:	Competent Person:
Personnel Platforms:	Date:	Competent Person:

Approvals:

Project Manager/Engineer:	Date:
Supervisor	Date:
Crane Operator:	Date:

Completion/Cancellation:

Completion:	Date:	Time:
Comments:		
Cancellation:	Date:	Time
Reason for Cancellation:		
Comments:		

Crane Critical Lift Plan Checklist

Figure 9-22. Crane Critical Lift Plan from the Hartford Insurance Group.

CONCLUSION

The use of a crane on a construction site is often necessary and can increase construction efficiency. However, cranes that are not set up and operated correctly can have dangerous consequences. OSHA estimates that each year there will be over 80 fatalities (ASCE/OSHA) due to crane operations in the United States. Accidents such as a crane tipping over, a load striking an individual, or a crane coming into contact with a live electrical line occur far too often. It is important to choose the correct equipment for the job, ensure a safe setup, and operate the crane in accordance with the manufacturer's specifications.

MULTIMEDIA FEATURES

OSHA video for superintendents on cranes: http://content.asce.org/files/other/cranesafety_hb.asx

Tower Crane Extension: http://www.youtube.com/watch?v=vx5Qt7_ECEE&feature=em-share_video_user

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