CHAPTER

11

Lean construction techniques

Introduction

Lean construction techniques are a collection of processes intended to eliminate construction waste and still meet or exceed the project owner's expectations. The application of lean principles results in better utilization of resources, especially labor and materials. The strategy for lean supply is to provide materials when needed to reduce variation, eliminate waste, improve workflow, and increase coordination among construction trades. The jobsite project team's responsibility is to create a realistic construction flow that reflects the general contractor's (GC's) and the subcontractors' dependency on material suppliers. Material deliveries are then scheduled so that the materials arrive on site just as they are needed for installation on the project. While lean construction does not replace a construction project's detailed contract schedule, it utilizes short interval planning and control that improves the timely completion of construction tasks. Another aspect of lean construction is the expanded use of off-site construction or prefabrication of building components. Reduced fabrication on the project site enables workers to concentrate on installation of material fabrications rather than creation of construction components, which ultimately saves time, reduces material waste, enhances on-site safety, and improves quality of installation. Acceptance and incorporation of lean for a company or project requires top-down support from the ownership of the project owner, GC, and architect teams, all the way through design engineers and jobsite construction management, to subcontractors and foremen.

Implementation of lean construction is the next logical step from activity-based costing (ABC) and other cost control methods such as work packages and earned value discussed in previous chapters. Similar to ABC, there have been many academic articles and research by Ballard, Howell, Kim, and others on lean construction. In addition to lean techniques, this chapter includes other advanced cost saving and cost reduction methods. This includes target value design, just-in-time (JIT) planning, last planner, pull planning, value engineering (VE), subcontractor and supplier

impacts, supply chain material management, and jobsite laydown and material handling. Many of these – such as JIT, last planner, and pull planning – are direct subsets of lean, but this chapter has combined all these advanced cost control topics into one discussion.

Lean construction

There is not one exact definition of lean construction, but rather a body of research leading to a philosophy of planning and implementation of advanced cost control methods. A lot of lean topics are intermixed. Contractors do not need to adopt them all in order to accept a lean philosophy; in fact, some argue that a few of these concepts don't apply strictly to lean. But if 'eliminate waste' is the ultimate goal, and loosely defined, then these all fit under the lean umbrella plus additional advanced cost control concepts; essentially there is no limit. The Lean Construction Institute's website defines lean as "enhances value on projects and uncovers wasted resources such as time, movement, and human potential" (www.leanconstruction.org).

Like activity-based costing and other cost control topics, lean has been adapted to construction from production industries such as the automobile industry, specifically from Toyota. Minimizing waste is not just for construction materials but eliminating any inefficiency such as a surplus of inventory, improving labor productivity, and creating a satisfied client are all premises behind lean. Anything that doesn't add value must be eliminated; lean creates value. Lean is influenced by total quality management where the lack of quality in any facet of design or construction results in rework which disrupts the flow of work. Increasing speed of design or construction in an effort to save money can actually cause waste and increase defects and therefore costs more money. The adage that 'time is money' does not always hold true. Since construction starts with design, the root of many lean savings ideas stems from improving design operations. Although the term *lean construction* is widely understood, it could be expanded to include *lean design* or even *lean built environment.*

Lean topics such as pull planning or just-in-time are not tools, but processes. Lean maximizes value by minimizing waste. Lean is not happenchance; rather it needs a formal process and adoption by all the team members for it to be a success. Acceptance of lean processes also requires a top-down commitment from design and construction company owners as well as project owners or clients. Repeat design- and construction- and project owner-teams are a benefit to the lean process. If they have worked together they know what to expect from one another. Lean is also best suited for complicated projects and ones that use an integrated project delivery (IPD), where all three parties share in the same risks and sign the same contract as shown in Figure 11.1. IPD

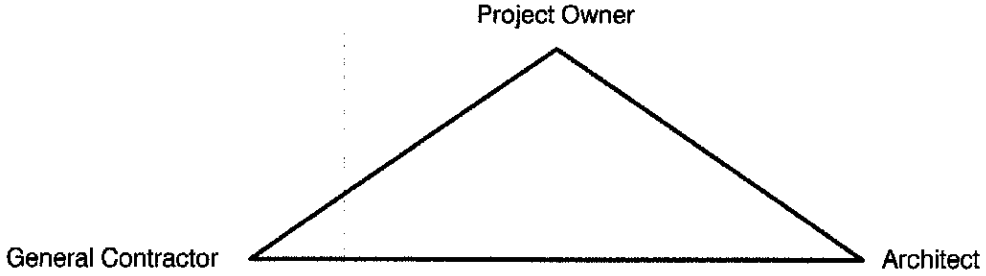

Figure 11.1 IPD organization chart

improves lean success and lean improves IPD success. If IPD is not the project owner's chosen delivery method, then design-build or construction manager-at-risk, also CM/GC, delivery methods would best implement the cost savings topics discussed in this chapter. Lean is also better suited for negotiated projects than bid projects.

The construction industry tends to resist new concepts such as activity-based costing and lean, labeling them production oriented. Construction contractors, and their proven means and methods, are also slow to change as shown in the next example. It is common to hear out on the jobsite that "if it isn't broke, don't fix it." The construction industry is different than other industries as discussed in previous chapters. Some identify that the problem with contractors is their detailed focus on independent activities, estimates, and schedules. It is better to focus on bigger picture goals and interaction of activities. Subcontractors also cause fragmentation in cost analysis and therefore make it more difficult for contractors to adopt lean. Though many construction leaders do have an open mind to improving their processes and have adopted many of the techniques discussed here.

Example One: This large international design-build construction company went through a major transformation during the mid-1980s when it laid-off over half of its engineering work force and replaced very experienced licensed nuclear engineers with younger engineers at a much lower salary. They also increased their hiring of internationally educated engineers, paying them less than the U.S. engineers under the premise that their international degrees were not as acceptable, even though these engineers could operate a calculator and design pipe and wire and concrete just as good as their U.S. counterparts. This new work force struggled with incorporating new energy codes and building codes, especially after the Three Mile Island nuclear incident. Eventually the contractor hired many of the laid-off experienced engineers back, but this time as consultants at twice the wage they had been receiving as full-time employees. Simply reducing or eliminating costs is not always a cost savings move.

The following sections introduce target value design, just-in-time deliveries, last planner, pull planning, and supply chain material management. These concepts and processes are all subsets of lean construction. The term 'lean accounting' is synonymous with lean construction and is the process to document actual cost results from implementing lean construction improvements.

Target value design

Target value design (TVD) is a subset of lean construction. TVD has also been referred to as target value costing and originated in manufacturing industries – again, from the automobile industry. Similar to lean, TVD works well with negotiated and design-build projects. The project owner sets the budget and the design team is tasked to design to that budget. The budget is divided up amongst the different design disciplines like pieces of a pie. Each design package must financially fit within their piece of the pie, so the entire project meets the owner's budget; they design to the target cost. This process either assumes the designers have estimating capabilities in-house or an outside estimating consultant is engaged, or a construction manager is contracted early. Some

critical subcontractors may need to be brought on to the team early during design development such as mechanical, electrical, and plumbing (MEP), precast concrete, curtain wall, landscape, elevator, and others. This process then makes it difficult to obtain competitive bid pricing which therefore makes TVD sometimes unfeasible especially on public works bid projects.

The owner's satisfaction is the number one priority for the design and construction team, especially if the owner's focus is on cost. The design team must anticipate cost when making design decisions rather than wait until bids are received. If the budget is exceeded the project must be redesigned, often with input from value engineering. The design must be targeted to 'final' cost as a design parameter, which is often different than bid or contracted cost. The target value design process includes active management of owner contingency logs and value-added logs, which are similar to a subcontract buyout log or VE log.

A target value design project often starts with a workshop where all of the team members buy into the concept. A considerable amount of collaboration is needed between all of the parties, not only the project owner, architect, and general contractor, but also the design engineers and major subcontractors. The estimate is established from the top down, which in construction is the opposite way most estimators work, generally beginning with a more detailed focus, such as quantity take-offs and pricing recaps, and summarizing as they work towards the final price as shown previously in Figure 4.1. In this regard, TVD is similar to pull planning which will be discussed later where the end is determined and the plan is developed in reverse. If one element of the project is over budget, such as structural steel, money must be moved from another system to compensate, such as electrical. Like many lean concepts, TVD connects well with building information modeling. Fourth and fifth dimension modeling can help with early contractor-generated estimates.

Target value design has some pitfalls though. Each of the budget pieces of the pie might initially fit together, but when contractor bids are solicited there is no guarantee that prices will correspond. Project owners often request detailed schedules of values from contractors with their bids and proposals. But contractors have been known to weigh one portion of the estimate heavier than another due to potential change order opportunities or front-loading strategies of early pay request line items. TVD also does not consider changes of economy, such as the price of copper pipe and wire escalation, or supplier and contractor backlog changes which can impact pricing. Change orders also occur on most construction projects and the owner's budget needs to anticipate these. Design-build and CM/GC project deliveries are both understood to have fewer change orders than traditional lump sum bid projects and therefore fit the TVD model better. A satisfied owner is looking for the design to match final cost, not just budget or even bid cost. If the project utilizes a cost-plus pricing method with no guarantee of total price, this places the owner at risk. Although the initial project budget and bid might have fit the target, the final price might not.

Just-in-time deliveries

Just-in-time deliveries of construction materials have been adapted from JIT manufacturing. The goal is that materials which will be needed within 36 hours of installation are on site, but not too early or too late. The contractors perform a balancing act with having just enough material but not too much. Remote projects such as the Olympic Hotel case study will not lend themselves as

well to JIT as would a downtown metropolitan skyscraper. Construction sites which are too large may not be managed lean as materials may be spread too far from their place of installation. Too much material on site for too long also exposes it to weather damage and potential theft. Doubling handling material is one of the most significant causes of labor inefficiency as will be discussed later in this chapter. But a problem with holding suppliers off from delivering too soon assumes that the fabricator has room in their storage yard (therefore not lean) and can be stored out of the weather and secured. Other problems can occur when the fabricator sells your project's materials to another general contractor who needs it quicker or is willing to pay a premium and the supplier grabs whichever material is easiest to move or sell.

Last planner

Planning is hard work; it is look-ahead scheduling. The individual or group of individuals responsible for accomplishing the work is labeled 'the last planner.' This includes carpenter and electrician foremen on the construction side, and the structural and electrical engineers on the designers' side. The principle architect is not the last planner. Most architectural firms employ project managers (PMs) just as general contractors, project owners, and subcontractors do. The last planner concept should extend down through the organization chart to the project engineers (PEs), cost engineer, and jobsite cost accountant if possible.

Many general contractors develop top-down schedules and dictate to subcontractors when their work is to be performed. A collaborative schedule created with subcontractor input, not the marketing salesforce but foremen and superintendents, is a much more feasible schedule. The same benefit can be had when a GC's proposed project superintendent assists with developing the estimate. Follows are examples of superintendents which did not utilize the last planner lean construction process.

Example Two: This superintendent was very experienced in concrete tilt-up buildings. He had spent the last ten years working in one office building complex, building one concrete tilt-up shell after another. He did not include his foreman in any planning issues. The foreman did not meet with the architect or owner or even the GC's own project manager. The superintendent would give the foreman hand-drafted sketches he had personally crafted from the drawings, one footing or column at a time, not allowing the foreman to have a set of drawings. Unfortunately, the superintendent suffered a heart attack and could not return to work. The contractor's executives felt that since the foreman had worked for the same superintendent for ten years that he must be ready to step in and run the work. Unfortunately, he failed and was eventually dismissed. If the foreman had been included as the last planner he might have been ready for the increased responsibility.

Example Three: Another general superintendent was building a high-technology facility out of state. He had two trailers, one for him and the GC's management team including a meeting room for the project owner, and another trailer for three assistant superintendents and foremen. These assistants were focused on the carpentry, concrete, and structural steel work. The general superintendent never introduced his assistants to the design or owner teams. He asked that the project manager and project engineer not visit the foremen's trailer as they would disrupt his crew. The general's superintendent pushed the direct work portion of the project, but the project owner's focus was on the MEP subcontractor scopes. Because the PM and PE did not communicate directly with the foremen and assistant superintendents, this portion of the work was not well coordinated and resulted in rework and change orders. Although the concrete was finished under budget, the project owner chose another GC for his next negotiated project. The project owner, GC, and assistant superintendents and foremen could all have benefited from the last planner process.

Pull planning

Pull planning or pull techniques are also adopted for lean construction from manufacturing industries. The people who are the pullers are the ones who use the output and would be considered the 'last planners' as discussed earlier. The process may also begin with a workshop and facilitator. Each stakeholder should be represented, including subcontractors. Just as target value design starts with the total budget and works backwards, pull planning starts with work which needs to be in place in three to four weeks and plans backwards to accomplish that goal. Each contractor and designer is given a set of colored sticky notes and posts their delivery dates and commitments and what needs to happen to accomplish those dates. This would be comparable to each subcontractor developing a three-week look-ahead schedule, which is often done for the weekly foremen's meeting, and then those schedules would be shared with the other companies. But in this case, all of the companies collaboratively develop one schedule together. A photograph of the pull planning schedule from the Olympic Hotel and Resort project is included as Figure 11.2.

Lean construction enthusiasts feel that contractors should not overcommit or overload their schedule. A little under-loading is acceptable as that allows for adjustments during the process if necessary. Conversely many contractors would argue that crews need to be given just slightly more than what they can accomplish in a week, not less. Some contractors feel that employing a superintendent or foreman who is slightly underqualified to perform his or her duties, but is ambitious and wants to work hard and learn, is a better fit than an overqualified individual. This philosophy would support a slight overload of work versus an underload.

The goal of pull planning is not only to achieve collaborative buy-in from all parties, but to work together to remove all constraints from accomplishing the work, so that the only thing left for the last planners is to get the job done. Some of the categories of potential restraints which should be considered include:

- Project owner has funded the project;
- Design is done and has been quality checked and change orders will be limited;
- Permits are in hand and inspectors are scheduled;

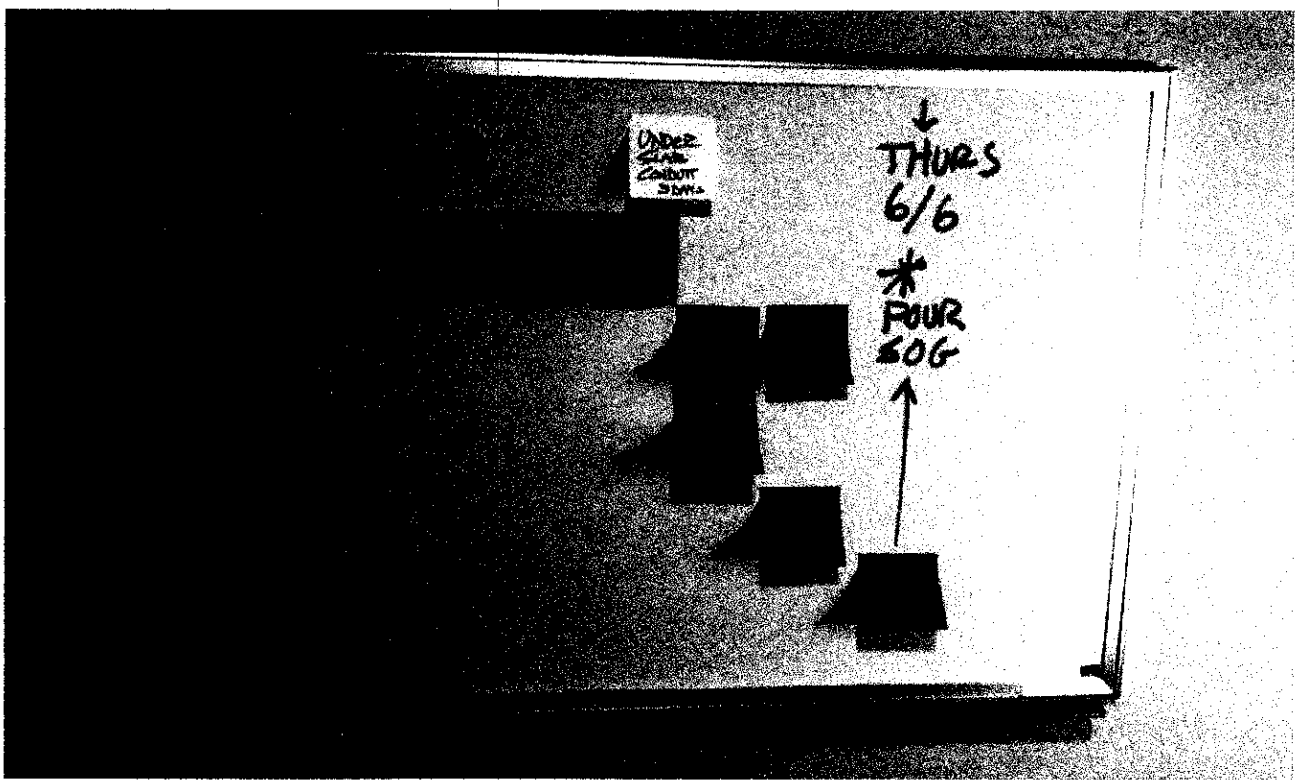

Figure 11.2 Pull planning schedule

- Requests for information and submittals have been processed and answered;
- Material is on site, or will be on site;
- Qualified and sufficient labor is on hand;
- Predecessor activities have all been identified and will be accomplished;
- The jobsite is clean and safe;
- Sufficient time and cost estimates have been allowed for; and
- No rework and no waste are the ultimate goals.

Value engineering

Value engineering to some members of the built environment, especially some designers, implies cheapening of the project's design, but that is not true VE. VE includes analyzing selected building components to seek creative ways of performing the same function as the original components at a lower life-cycle cost without sacrificing reliability, performance, or maintainability. VE studies may be performed by consultants during design development, as a contractor-performed preconstruction service, or by the contractor during construction. The most effective time to conduct such studies is during design development. Target value design, as just discussed, needs to happen before design to be efficient; VE is the opposite and often happens either during the deign process or after design. The traditional lump sum delivery method of design–estimate–VE–redesign results in wasted time and additional design fees and therefore is not considered a lean construction topic by some.

Value engineering studies are typically performed during the preconstruction planning phase. The intent of the process is to select the highest value design components or systems. The essential functions of each component or system are studied to estimate the potential for value improvement. The VE study team needs to understand the rationale used by the designer in developing the design and the assumptions made in establishing design criteria and selecting materials and equipment. The intent of VE is to develop a list of alternative materials or components that might be used. Preliminary cost data is generated, and functional comparisons are made between the alternatives and the design components being studied. The intent is to determine which alternatives will meet the owner's requirements and provide additional value to the completed project. Often life-cycle cost data is analyzed for each VE alternative before presentation to the project owner.

Preparation of value engineering proposals includes analysis of advantages and disadvantages of each alternative and the ones representing the best value are then selected for presentation to the designer and the owner. The VE proposal looks very similar to a post-contract change order proposal, including all detailed costs and markups and substantiation. All cost data prepared by the VE team should be included with the proposal, similar to a change order proposal. Each VE proposal is tracked in a log, similar to other cost control or equipment tracking logs managed by the construction team. The proposals are submitted to the designer and the owner for approval. If approved, VE proposals should be incorporated into the contract documents. VE proposals approved after the construction contract is awarded must be incorporated into the contract by change order. A sample VE log from the Olympic Hotel and Resort case study project is included here as Table 11.1.

Table 11.1 Value engineering log

Evergreen Construction Company
Olympic Hotel and Resort
Updated: 2/20/2020

Item	*Description*	*Date Proposed*	*Value Proposed*	*Value Accepted*	*Value Rejected*	*Date Resolved*	*Comments*
14	Replace janitor's closet VCT with sheet vinyl	1/15/2020	$3,500	$3,500		1/16/2020	Better maintenance
15	Move window blinds into owner's scope	1/22/2020	–$15,550				Still open, tax considerations
16	Add one more year to landscape warranty	1/22/2020	$5,750		$5,750	1/31/2020	Owner will contract separately
17	Open paint spec to three suppliers	1/31/2020		–$12,322		2/10/2020	

continued...

Subcontractors and suppliers

A typical commercial general contractor today subcontracts 80% to 90% of the construction project. Subcontractors, also referred to as specialty contractors, therefore, are important members of the GC's project delivery team and have a significant impact on the GC's success or failure. Since subcontractors have such a great impact on the overall quality, cost, schedule, and safety success for a project, they must be selected carefully and managed efficiently. There must be mutual trust and respect between the GC and the subcontractors, because each can achieve success only by working cooperatively with the other. Consequently, project managers and superintendents find it advantageous to develop and nurture positive, enduring relationships with reliable subcontractors. PMs and superintendents need to treat subcontractors fairly to ensure they remain financially solvent not only to finish this project but to be available to provide competitive bids on future projects.

The use of subcontractors by the general contractor is a risk management process. Subcontractors provide the GC with access to specialized skilled craftsmen and equipment that they may not have in-house. One of the major risks in contracting is accurately forecasting the amount and cost of labor required to build a project. By subcontracting significant segments of work, the GC can transfer much of that cost risk to subcontractors. When the project manager asks a subcontractor for a price to perform that scope of work, the subcontractor bears the risk of properly estimating the labor, material, and equipment costs. Craftspeople experienced in the many specialized trades required for major construction projects are expensive to hire and generally used on a project site only for limited periods of time. It would be cost-prohibitive for a GC to employ all types of skilled trades as a part of their own full-time work force.

Subcontracting is a risk-reduction process, but it does not eliminate all risk. The project manager and superintendent give up some control when working with subcontractors. The scope and terms of the subcontract define the responsibilities of each subcontractor. If some aspect of the work is inadvertently omitted, the general contractor is still responsible for ensuring that contract requirements are achieved. Specialty contractors are required to perform only those tasks that are specifically stated in their subcontract agreements. Consistent quality control may be more difficult with subcontractors as shown in a few of the examples discussed throughout this book. Project owners expect to receive a quality project and hold the GC's superintendent and PM accountable for the quality of all work whether performed by the GC's direct crews or by subcontractors. Subcontractor bankruptcy is another risky aspect of subcontracting, which can be minimized by good prequalification procedures and timely payment for subcontract work. Scheduling subcontractor work often is more difficult than scheduling the GC's crews, because the subcontractor's craftsmen may be pulled off the GC's project and moved to other projects. Many GC superintendents feel safety procedures and practices of subcontractors are not as effective as those used by the GC's own work force. All of these financial and control aspects are even more crucial when subcontractors also subcontract portions of their work to third-tier subcontractors and suppliers as shown in Figure 11.3.

It is imperative that the general contractor selects quality 'best-value' subcontractors if the project manager and superintendent are to produce a quality project, on time, safely, and within budget. PMs must remember that poor subcontractor performance will reflect negatively on their professional reputations and their ability to secure future projects. Once the subcontractors have been selected, contract documents are executed documenting the scopes of work and the terms and conditions of the agreement. Each subcontract and supplier purchase order will receive a unique

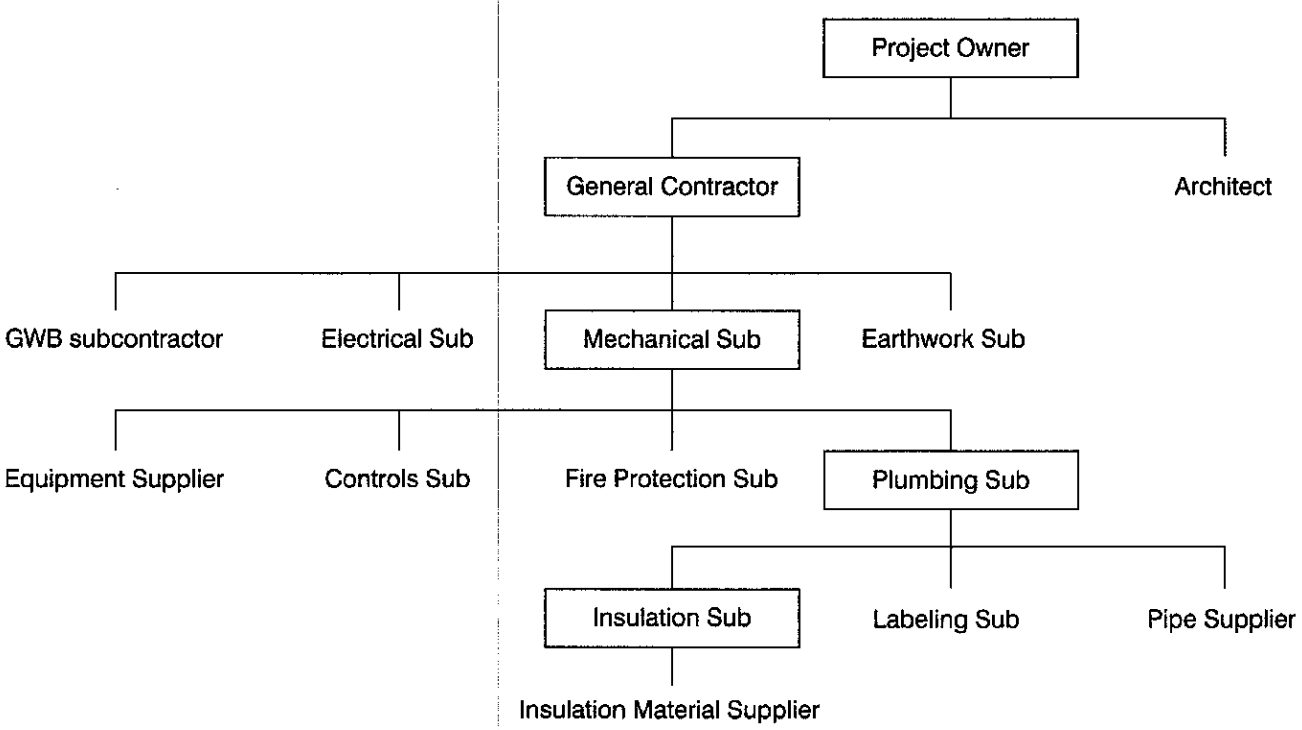

Figure 11.3 Organization chart

cost code and buyout contract values will be input into the cost control system. Subcontractor management is an integral part of project management. While the project superintendent manages the field performance of the subcontractors, the PM and cost engineer manage all subcontract documentation and financial affairs and are responsible for ensuring that subcontractors are treated fairly and paid timely.

This short introduction on procurement and subcontracting has not necessarily been a 'lean' cost control topic. But as introduced in Chapter 10, 'Activity-based costing,' subcontracting has an impact on the general contractor's ability to implement ABC and lean processes. As mentioned, the GC has passed financial risk to its subcontractors, especially if they are contracted lump sum. In one sense using the marketplace to buy out subcontractors and suppliers at the lowest competitive price is a cost reduction tool and is therefore lean but only if additional best-value attributes are considered beyond cost such as quality, schedule, and safety performance. Ignoring the role of subcontractors in any discussion of cost control is omitting 80–90% of the scope of the construction project. This brief discussion of subcontractors and suppliers naturally leads into material management covered in the next two sections.

Supply chain material management

Many lean construction research case studies assume the general contractor is also the material supplier, which is not customary. GCs rely heavily on support from subcontractors and suppliers to successfully build a project as discussed earlier. All construction materials are provided through suppliers. Cost control responsibility within the fabrication facility belongs to the supplier. Good supply chain material management by the GC relies on shifting as much on-site

material fabrication and assembly to suppliers, especially local suppliers. Supply chain material management shifts the cost control focus as close to the beginning of a construction project as possible, to design and material fabrication, and not solely on the traditional cost control focus of a contractor's direct jobsite field labor.

Off-site prefabrication

Removing or minimizing construction waste is a fundamental plank of lean construction and is accomplished through prefabrication of construction materials. Off-site prefabrication of materials improves *quality control*, as the materials are built and stored out of the weather, facilitates in-process inspections, improves *safety* in a controlled environment, reduces *cost* as it changes fabrication of many construction materials from project-based to product-based, and improves *schedule* adherence as many activities can be performed in parallel rather than in series. Materials may be specified by the design team as 'purchased' products, rather than field-assembled, but oftentimes a general contractor can weigh the advantages of shop fabricated versus field assembly as part of their means and methods preconstruction planning. There are many prefabrication shops and assembly yards which specialize in assembly and sale of construction materials. In addition to construction of single-family prefabrication homes, commercial construction examples of off-site material prefabrication include:

- Standard examples: Cabinets, structural steel, mechanical duct, concrete rebar, wood trusses, precast concrete beams and concrete planks;
- Occasional examples: Structural insulated panels, apartment wall and floor wood-framed panels, brick panels, bathroom plumbing carriages;
- Potential examples: Whole apartments or hotel units, concrete columns, concrete floors, concrete walls, and others.

Applications of off-site prefabrication extends into activity-based costing, just-in-time planning, building information modeling, and other cutting-edge cost saving construction processes. The following are great examples of efficient use of supply chain material management and off-site prefabrication.

Example Four: The State of Alaska has very cold winters and the typical building season is limited to four, or at the most six, months a year. One general contractor in Juneau, Alaska invested in a large heated warehouse. He fabricates many building components local, in a secure, well equipped, and environmentally controlled facility. This allows him to win many more projects than his competitors as he can limit the amount of time his crew is working in the cold weather. He fabricates almost complete buildings including floor and wall and roof elements and puts them on a barge and ships them out to remote islands for quick cost-efficient assembly. He also attracts the best labor in the area as his crew is offered year-long employment.

Example Five: Timber frame construction is an old system with a new life. It is very similar to post and beam construction. This Pacific Northwest specialty contractor chooses only the best trees and fabricates every beam and column and rafter for pre-assembly in its yard. It pre-drills for oak peg connections and ships the materials ready for assembly to the remote San Juan Islands. The construction system is not the least expensive, but it is local and efficient with excellent quality and has life-cycle benefits.

Example Six: General contractors may purchase door frames from one supplier, door leafs from another supplier, door glass from a third, and door hardware from a fourth. If the door frames and door leafs are a combination of wood and hollow metal, there may be at least two more suppliers. If all of these materials are shipped 'loose' and uncoordinated, there will be substantial assembly labor expended in the field by the GC's carpenters. Many contractors will package all of these elements into one supplier, but that is not always cost efficient. Another method is to have the materials shipped from one vendor to another, including the painter, such that when the doors, frames, and hardware arrive on site they have been 'machined' and are ready for installation without rework, which is a goal of lean.

Local material purchases

It is not only lean to purchase construction materials locally, it is also sustainable and a good means of quality and schedule control. A general contractor which chooses suppliers that fabricate materials locally can easily physically visit the warehouse or yard and witness progress. Third-party inspectors may also visit the shop and inspect and test as is the case with structural steel fabrication. Materials that are purchased and/or fabricated locally, say within 100 miles of the project site, will utilize less fuel in transportation. Purchasing locally results in additional Leadership in Energy and Environmental Design (LEED) points or credits being awarded, if the project owner is pursuing a sustainable certificate or plaque as shown in Figure 11.4. There is also a non-measurable, maybe moral, reason a contractor should do business with as many of its local neighbors as reflected in the next example.

Figure 11.4 LEED plaque

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Example Seven: This small general contractor built quality custom and speculative homes in his rural county. He had a great reputation and never had to compete for work. Even though he was a residential GC, he was union and only employed union carpenters and laborers and cement finishers and subcontractors. He believed strongly in 'trading local' which to him meant you bought your clothes from the only clothing store in town and didn't travel to the 'big city.' The people he traded with would in turn employ him to build their homes and commercial building projects. He purchased his gas for his personal cars and business equipment from the local gas station, even though it was a little more expensive than another station 15 miles away; he had built the business owner's home as well. The gas station owner later hired a contractor from out of town to build an investment apartment project. Consequently, the local residential GC did not purchase any gas from this station again.

Jobsite laydown and material handling

It is imperative that the jobsite be organized efficiently in order for the construction project to be successful. The jobsite layout affects the cost of material handling, labor, and the use of major equipment by the general contractor and the subcontractors. A well-organized and clean site has a positive effect on the productivity of the entire project work force and their safety. The jobsite layout plan should identify locations for temporary facilities, material movement, material storage, and material handling equipment. Ignoring this may have an adverse effect on productivity, safety, and cleanup as reflected in the next example. The proper choice of tower crane types and locations is essential for a productive plan, especially on downtown hi-rise projects. The Olympic Hotel and Resort project fortunately had ten acres of site with plenty of laydown area and access for mobile cranes. The site layout plan should be developed by the GC's superintendent and it should consider not only the needs of the GC's direct work, but also the requirements of all of the subcontractors working on site. The site plan should indicate:

- Existing site conditions, such as streets, adjacent buildings, and overhead and underground utilities;
- Planned locations for all temporary facilities such as fences and gates, trailers, temporary utilities, sanitary facilities, erosion control, and drainage; and
- Material handling and storage areas, equipment storage and access, craftsmen and visitor parking, and hoisting methods such as a tower crane.

Example Eight: Every construction site element needs to be considered when developing the site logistics plan. Every construction project is visited by a vendor truck, also known as a food truck or taco truck and some other fun nicknames. Some jobsites have multiple trucks showing up before work, again at the 10:00 am coffee break, and at noon for lunch. The vendor trucks need to have the superintendent's approval with respect to location and timing and cleanup. This GC superintendent did not approve of vendor trucks; he felt they resulted

in wasted time for his craftsmen and generated garbage. His crew and all of the subcontractors would break for coffee and lunch and walk two blocks to a corner convenience store. This distance extended their breaks away from work. On the way back to the site occasionally some garbage would end up on the ground and the superintendent would send a laborer out for four hours a week at the end of shift on Friday to clean up. Keeping the truck off the site to save labor actually cost more labor.

The superintendent should consider all site constraints, equipment constraints, jobsite productivity, material handling, and safety issues when preparing the jobsite layout plan. Some additional factors that should be considered in developing the jobsite plan include traffic flow on and off the site and location of site offices convenient for visitor control. Some of the goals of the site logistics plan are to: eliminate double handling of material which is a lean productivity factor, protect materials from weather and theft, and keep materials close to work but not too close such that the craftsmen are stumbling over them. These are all just-in-time lean considerations as discussed earlier. In addition to a productivity tool, the jobsite layout plan is a great proposal, interview, and marketing tool. It shows the project owner that the contractor has thought through the project – a personal touch. It may make a difference on a close award decision with a negotiated project. The jobsite layout plan for the Olympic Hotel and Resort is shown on the eResource.

Summary

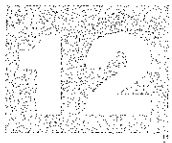
Lean construction loosely defined includes designing, fabricating, and constructing projects as cost effectively as possible, eliminating waste, all the while maintaining the same if not improved levels of quality, schedule, and safety control. Lean construction has several sub-categories including target value design, just-in-time material deliveries, last planner participation, and pull planning scheduling processes.

Target value design starts with the project owner setting a strict budget that both the design team and the construction team must adhere to. Construction projects, such as skyscrapers, have been practicing just-in-time material deliveries before JIT was included as a study of lean construction. Efficient JIT management requires delivery of materials when needed, not too early so that double handling is minimized and not too late such that it affects the schedule of installation.

Ultimately the people involved in designing and installing materials, the last planners, should be the ones involved in estimating, scheduling, and cost control. Essentially this is the structural engineer who sizes the spot footing and the carpenter foreman responsible for excavation, forming, and placing the footing concrete. Pull planning is a collaborative scheduling approach which includes those last planners preparing short interval schedules by scheduling backwards, often with multi-colored sticky-notes.

Value engineering seeks the same goal as target value design but happens generally after some design has been completed. Contractors prepare cost-saving or life-cycle-saving proposals for project owners and designers to consider and accept, which then require re-design and incorporation into the general contractor's contract and various subcontract agreements. Subcontractors

CHAPTER



Equipment use and depreciation

Introduction

When choosing topics to be covered in this book we talked with contractors and accounting firms and researched other construction accounting books. One topic that is very important to the concept of cost accounting has always been depreciation. Depreciation is defined as the *wear and tear on fixed assets* such as real estate, construction equipment, and office furniture. Depreciation is an important means of reducing taxes for investors and corporations, which is especially true for construction companies which own equipment. But the process of accounting for depreciation is not necessarily a project manager's responsibility; tracking and allocating depreciation is more a chief financial officer (CFO) and home office accounting function. Similar to other markups on the bottom of the estimate summary such as fees and insurance and labor burden, accounting for depreciation on the equipment ledger has usually been accomplished by the home office accounting department, not the jobsite project management team. This is often done internally through use of accounting journal entries. If construction companies, not equipment companies, own their own equipment, the accounting department may create an invoice and send out to the jobsite to have the project manager (PM) cost code and approve the rental costs. Depreciation reflects negatively on the financial statements as an expense, but is a paper expense only, not a reduction in cost.

All along, the approach to this book has been to connect home office accounting with other financial responsibilities of the jobsite team including the project manager and the jobsite cost accountant. This chapter therefore expands on the discussion of construction equipment depreciation to include additional related jobsite project management concepts, as well as defining types of construction equipment and their ownership structures; internal or external. If the equipment is owned outside, the project management team will need to arrange and manage equipment purchase order contracts with equipment companies to secure rental. If owned internally, ideally all construction equipment will be job costed and not sitting in the contractor's storage yard. Equipment requiring maintenance needs to quickly be repaired to support jobsite productivity

and the cost of those repairs needs to be accounted for in the proper location. Estimating and cost coding of construction equipment rental and repairs was introduced in previous chapters.

The rules for accounting of depreciation are determined by the Internal Revenue Service (IRS) as it relates to corporate income taxes and more specifically allowance for tax deductions. Taxes and depreciation are complicated topics and ones that the contractor will rely on expert accounting help for, possibly with the services of an outside certified public accountant (CPA).

Equipment types

How many different types of construction equipment are there? There is likely close to an infinite list of different types of equipment and it would be difficult to cover each one. Tools are differentiated from equipment for this example as tools would be purchased for a project and are expendable, but equipment might be rented and depreciated and should last longer than for just one project. There are several good construction equipment textbooks available, such as J. Schaufelberger's *Construction Equipment Management* (1999) which describes equipment operation. Following are just a few basic lists of equipment which the construction team might encounter:

Heavy-civil contractors:

- Graders,
- Dozers or bulldozers,
- Dump trucks,
- Track hoes or excavators,
- Compactors,
- Scrapers, and others.

Marine contractors:

- Barges and Tug boats,
- Marine cranes,
- Pile drivers,
- Under-water equipment, including welders, and others.

Cranes:

- Tower cranes:
  - Horizontal jib tower crane, also known as 'hammer-head crane,'
  - Luffing tower crane,
  - Mobile tower crane, also known as self-erecting or 'fast cranes';

- Mobile cranes, including trawler or crawler cranes;
- Light cranes, including truck cranes also known as 'cherry-pickers' or boom trucks;
- Miscellaneous cranes not typically used for construction:
  - Gantry cranes,
  - Ship yard cranes,
  - Bridge cranes;
- Personnel and material hoists and temporary elevators are not cranes per se, but their estimating and operation considerations have many similarities to tower cranes.

Commercial and residential construction equipment:

- Forklifts,
- Pickup trucks,
- Flatbed trucks,
- Backhoes,
- Scissor lifts,
- Scaffolding is not necessarily considered equipment but the accounting for rental and erection and maintenance is similar to other methods of equipment.

Light equipment:

- Surveying equipment, including total-stations and lasers,
- Compressors,
- Welding machines,
- Construction electrical generators,
- Concrete vibrators and troweling machines and screeds, and others.

Office furniture and equipment:

- Computers and printers and scanners and plotters,
- Copy machines,
- Desks and chairs and file cabinets,
- Construction office trailers and tool vans and dry shacks are not necessarily considered equipment but are handled similar to many of these other items with respect to accounting.

Equipment ownership

All of these types of equipment may be owned by the construction company and most discussions on construction equipment accounting and depreciation are focused on internally owned equipment. But actually, very few construction companies own any equipment. The exception might be large heavy-civil contractors and marine contractors. They rely on a much larger percentage of specialized self-operated equipment for their construction operations than do commercial and residential contractors which rely on direct labor and the use of subcontractors. Commercial and residential construction is 80% or more subcontract costs whereas civil and marine work is 50% or greater equipment costs. Most commercial and residential contractors will either set up separate equipment companies or will rent from outside sources. Equipment may also be provided and operated by subcontractors as part of their scope and obligations. There are advantages and disadvantages of all of these arrangements.

Internally owned

Contractors that own and operate their own construction equipment endeavor to keep that equipment busy on jobsites whenever possible. Upon purchase, a piece of equipment will simultaneously show up as an asset on the contractor's balance sheet in the amount of its book value, and as a liability in the amount of the loan balance owed to the bank. As the loan is gradually paid off, the liability will be reduced and the amount it has been depreciated will correspondingly reduce its value on the asset side of the balance sheet. These types of contractors are heavily leveraged and purchase equipment through the use of long-term loans which require significant monthly payments. Construction company loans will be discussed as a subsection of the last chapter of this book. If the equipment is not in use and in the contractor's storage yard, loan payments must still be made to the bank. The equipment will continue to age and depreciate and corresponding deductions in value will be made to the corporate balance sheet. When an internally owned piece of equipment is sold, it will also have an effect on the contractor's balance sheet and income statement.

Maintenance and repair costs for internally owned equipment will be charged to jobs if the equipment is in use or charged to home office overhead if the equipment is idle. The accounting for this type of equipment is often performed by the corporate CFO through the use of internal journal entries. Contractors which own equipment must keep it busy or bear significant financial risk. Conversely contractors may choose to own equipment if their equipment requirements are unique and they do not want to be subject to availability and rental charges from outside third-party supply firms. Contractors which own equipment have the flexibility to adjust their own internal rental charges which may allow them to be the low bidder on projects which are heavily equipment dependent, such as civil and marine work.

Contractor equipment companies

To clients and even many on the contractor's team, internally owned versus separate contractor equipment companies may look identical, but they are actually significantly different with respect

to accounting and risk management. Many construction companies choose not to own their own equipment but rather set up separate equipment companies or separate divisions, which own the equipment. These separate companies are formed as limited liability corporations (LLCs) and will have a different name from the construction company. The equity ownership of these companies is usually a select group of individuals within the construction company, often the corporate officers. For example, Evergreen Construction Company (ECC) has five executive officers which comprise their board of directors (BOD). Those five officers include the chief executive and operational officers (CEO and COO), CFO, Vice President of Marketing, and Human Resources Officer. These five individuals establish a separate LLC which will own and rent equipment to their own construction company, ECC. They named their equipment company Main Street Equipment, LLC. They are therefore renting equipment to themselves. They charge rental to the construction company very similar to rental charges from an outside equipment company. If there is ever a problem, such as a market downturn or a safety accident which can be attributed to a piece of equipment or operation, then the construction company is financially protected as they had rented the equipment from Main Street. The corporate officers are also personally protected as they formed a separate LLC. The LLC can report a loss on their income statement or declare bankruptcy and shield the equity owners personally, and also the construction company, from a lawsuit or economic harm.

Experienced project owners which utilize open-book contracts, such as the AIA A102, do not see the financial separation between the construction company and the construction company's equipment division that the contractors will represent. They often regard all equipment supplied by the contractor as internally owned and strive to protect themselves from excessive equipment rental charges or maintenance costs. The best method for them to do this is to contractually modify or insert language into the A102 contract Articles 7.5.2 and 8.1 such as:

- Contractor's monthly, weekly, or daily rental rates will not be in excess of the average rates charged by the three largest local equipment suppliers;
- Contractor's cumulative rental on any owned piece of equipment will not exceed 85% of the purchase price (book value would be better but that would be difficult for the client to determine);
- Equipment repairs and maintenance of contractor-owned equipment will not be job-costed.

Outside ownership

The easiest method to manage equipment rental from a project manager's perspective is from outside third-party suppliers which own and rent construction equipment as a main source of business. This equipment is expected to be delivered to the jobsite in perfect condition and is expected to remain that way during the course of construction. Equipment breakdowns have a significant effect on jobsite labor productivity. Contractors can obtain bids from outside sources and negotiate rental rates and conditions. Conversely, the PM cannot really negotiate with his or her own construction company BOD on the rental of one of their own forklifts. The contractor will enter into a purchase order agreement for the rental or lease of equipment which is not furnished with an operator. An example rental purchase order for a forklift is included here as Figure 12.1. If equipment is rented with an operator, a subcontract agreement should be developed by the jobsite team rather than a purchase order. Any company that provides labor on the jobsite must also provide general liability insurance and the subcontract agreement allows for this.

Evergreen Construction Company
1449 Columbia Avenue
Seattle, WA 98202
206.557.4222

Purchase Order

Vender:	*Cedar Rentals*	PO No.:	*2209*
	992 Eastlake Ave.	Date:	*03/01/2019*
	Seattle, WA 98101	Job Name:	*Olympic Hotel*
Attention:	*Janet Jones*	Job Address:	*Rt. 4, Box 787*
Phone No.:	*206.233.9922*		*Rainforest, WA 98101*

Item	Quantity	Units	Description	Unit Price	Amount
1	*1*	*EA*	*50' Extended reach forklift rental*	*$3950/mo*	*$3950/mo*
2			*Minimum 6 month rental period*		
3			*Supplier services once per month*		
4			*Supplier responsible for maintenance*		
				Total:	***$3950/mo***

Delivery:	*1 week*
Shipment:	*Your Truck*

Terms and Conditions:

1 Supplier accepts PO issued only by ECC authorized personnel
2 Supplier shall invoice each item separately each month on the 20th of the month
3 Invoices received without PO attached will not be processed

Requested by:	Approved by:	Purchased by:
Randy Smith	*Chris Andersen*	*Jennifer Thompson*
Superintendent	*Project Manager*	*Cost Engineer*

Figure 12.1 Purchase order

A very important aspect to equipment rental is the management of economical rental durations. This again is easier to control with outside rental companies than with internally owned equipment. Equipment rental often is accompanied by mobilization or delivery charges and demobilization or pickup charges. These charges can be substantial and repeated rotation of the same piece of equipment on and off the jobsite can add up. The jobsite accountant or cost engineer should work closely with the superintendent to ensure efficient equipment use. There are also more economical durations to rent equipment, for example it is more economical and potentially less expensive to rent a welding machine for:

- One whole day rather than six hours,
- For one whole week rather than four days,
- For one whole month rather than three weeks, and
- For one whole year rather than ten months.

Table 12.1 Rental equipment rates

Cedar Rentals
992 Eastlake Ave.
Seattle, WA 98101

Rental Equipment Rates

Description	*Daily ($)*	*Weekly ($)*	*Monthly ($)*
Air Compressor, 185CFM DSL	118	450	1,075
Crane, Truck Mounted, 14-16T	495	1,750	5,150
Vibration Plate, Medium	70	280	650
Dump Truck, 5YD	325	1,300	3,250
Water Truck, 2,500 Gal	325	1,300	3,900
Forklift, 40'–42', 6,000#, 4WD	285	1,090	2,600
Forklift, 50', 8,000#, 4WD	350	1,300	3,950
Forklift, 55', 10,000#, 4WD	425	1,615	4,620
Generator, 45KVA (32KW)	175	600	1,800
Loader, Skid, Medium	185	705	1,750
Excavator, Mini, 7,500#	235	905	2,580
Backhoe, 4WD, Extendahoe	265	1,010	2,900
Boomlift, 40'–42', ST 4WD	350	965	2,300
Boomlift, 60', ST 4WD	425	1,215	3,465
Boomlift, 80' w/5' Jib, 4×4	865	3,295	7,850
Scissor Lift, 19' Vertical	105	300	760
Scissor Lift, 26' Vertical	110	420	1,000
Scissor Lift, 32' Narrow	140	525	1,250
Trash Pump, 3"	65	190	545
Shopvac, Wet/Dry	33	90	230
Welder, 225Amp, Gas	50	150	465

A very good local Pacific Northwest equipment supplier's partial rental rate sheet is included here as Table 12.1. We appreciate their contributions to this body of work. It is easy to see the economics of managing rental periods from this table as discussed earlier.

Subcontractor ownership

The most cost-effective way for a general contractor (GC) to have equipment on the project is not to rent it at all, either internally or externally, and require all of its subcontractors to provide their own equipment. If a GC operates more as a construction manager (CM) and provides little

to no direct labor, he or she may also be able to avoid providing any equipment, or at least minimal equipment. The CM will still provide a trailer for the on-site staff, a pickup truck for their superintendent, office furniture and office equipment, potentially a tower crane and personnel and material hoist, and likely a forklift. But the more equipment is provided by subcontractors, the less the GC or CM needs to worry about idle time, maintenance and repairs, or mobilization costs for equipment.

Equipment operation

Although robots have garnered an increased role in construction today, they are not yet operating heavy construction equipment. How the equipment is operated, by whom, and how it is contracted are important aspects of construction cost accounting and risk management. There are a variety of methods for how operation of equipment is handled. This section briefly introduces self-operation, subcontractor-operated, and supplier provided, subcontractor-operated and provided, and owner-operator equipment options.

Self-operated

If contractors own their equipment, either as part of the construction company or through a separate but internally owned equipment company, they will likely operate the equipment with their own forces. This provides the contractor with the comfort that they know the equipment operator and his or her capabilities and that those individuals are loyal to the construction company. The contractor will pay the operator as they would any other construction craft employee. A time sheet will be filled out by the foreman and then cost-coded to either the equipment code they are operating or the work they are performing as discussed in the 'Equipment allocation to job cost' section later. Labor burden will also be figured for the employee and charged to the job.

Equipment operation is performed by operating engineers (OEs), which are an organized craft and labor union. It is an interesting side note that surveyors are also members of the OE's union. Merit shop, or open shop contractors do not need to employ OEs and may choose to operate equipment with general laborers or construction foremen. Regardless, in most cases, equipment operators must be certified or licensed to operate the equipment they are using. Everyone may be able to drive the jobsite pickup truck, but not everyone may operate the forklift or the tower crane. This author's son is an assistant commercial construction superintendent who is a certified forklift operator and helps with this on occasion, and also spends a couple of hours each day in his pickup truck tracking down materials.

Rented and subcontractor-operated

If equipment is rented from an outside supplier, the contractor may operate it with their own operating engineer as discussed earlier, or they may employ a separate contractor to operate the equipment. This may be the case with large equipment such as a tower crane, where the contractor does not have an experienced or available OE in house, nor wants to take the chance on employing

an operator off the street. There are equipment companies which will rent equipment to general contractors with operators (then requiring a subcontract agreement), or rent the equipment bare without an operator (then requiring a purchase order), or furnish the operator only (also requiring a subcontract agreement). If the GC subcontracts out operation-only of equipment, they will pay a loaded wage rate which will include the OE's direct wages, labor burden, and profit and overhead and other markups. The subcontracting firm providing the OE will take care of distribution of wages and contributions to labor taxes such as social security. Some equipment may also require two operators, such as a large crawler crane. One of the operators is in the cab of the crane and the other is attending to maintenance. This second OE, nicknamed the 'oiler,' may also drive the crane when relocating from jobsite to jobsite. Tower cranes will require a separate 'rigger' who may be employed on a subcontract basis as well or employed internally. The rigger is often a member of the ironworkers' union as they are customarily well-versed in crane operation and hoisting and associated safety issues.

Subcontractor provided

The general contractor will not need to concern itself with choice of equipment operators when subcontractors provide their own equipment. An example of this is an earthwork subcontractor that owns and operates a variety of construction equipment as noted earlier with heavy-civil such as excavators and dozers. It is the subcontractor's responsibility to choose qualified employees and handle their wage compensation and labor burden contributions. The subcontractor is also responsible for all equipment licensing and maintenance expenses. The GC will still make sure that the subcontractor is utilizing only qualified equipment operators. Copies of operator licenses and certifications will be made available to the GC either as part of the subcontractor's project-specific safety plan or as a separate submittal.

Owner-operators

Many single pieces of equipment are owned and operated by one individual. This is very common with many forms of earthwork equipment including backhoes, track hoes, and dump trucks. Many long-haul semi-trucks are driven by owner-operators. The general contractor will then pay the equipment owner an hourly (or weekly or monthly) rate which combines the rental of the equipment along with the wages of the owner, his or her necessary labor burden, and markups such as insurance and fee and overhead and licenses. This loaded rental rate will also include costs for necessary maintenance and repairs. For the GC who employs an owner-operator it is similar to one-stop-shopping.

Equipment allocation to job cost

Previous general conditions chapters reinforced a subset of the revenue equation where fee equals overhead and profit. Jobsite overhead is part of job cost. The overhead included with fee is home office overhead (HOOH). Assuming fee is fixed, any reduction in HOOH will improve profits

and any increase in HOOH reduces profit. Construction corporate executives will reinforce to the project teams their need to produce an acceptable fee, if not improve upon it. The allocation of equipment costs, including rental and operation and maintenance, plays a very important role in managing HOOH and improving profits. Essentially the construction company wants all equipment to be job-costed and not sitting idle in the storage yard or under repair while away from a construction project. Some of the *strategies* or methods to keep equipment costs from eroding profits are described in the following. Many of these are applications of activity-based costing as discussed prior.

- Move equipment rental from the HOOH to project overhead.
- Move equipment rental from jobsite overhead to job cost; this is moving it from an indirect expense to a direct expense. An example incudes a welding machine and mobile crane which should be charged to structural steel erection.
- Require subcontractors to provide their own equipment, such as forklifts for material unloading and cranes for hoisting to the roof.
- Subcontract more work and self-perform less work, thereby decreasing the need for rented and operated equipment.
- Charge all owned-equipment maintenance to the job and not the home office, especially on negotiated projects where equipment maintenance may be a job cost.
- Include maintenance responsibility clauses in all rented equipment purchase orders or subcontract agreements.

The jobsite accountant or cost engineer and superintendent will need to work together closely to track equipment which is on the project. There are several project management tools they will utilize to accomplish this. Equipment internally owned by the construction company will be tracked on its *equipment ledger* by the CFO, which includes allocations of rent and maintenance and depreciation. The equipment ledger was introduced in Chapter 7 with other financial statements. On the jobsite the construction team will utilize a simple Excel spreadsheet as an *equipment log* which lists each piece of equipment, its source, cost code, arrival date, departure date, and potentially any comments associated with operation and maintenance.

Another paper tool used by all general contractors, and most subcontractors, is the *superintendent's diary*. This is also known as a daily report or log or journal and should be authored by the project superintendent. It records a variety of contemporaneous information about the happenings of the project for each day worked. The diary is filled out by the superintendent at the end of each work day. Some of the items it includes are:

- Weather,
- Work accomplished and other work that was hindered and why,
- Material and equipment deliveries and equipment pickups,
- Visitors and inspections,
- Subcontractors working that day, manpower on site, hours worked, and a variety of other important project management reporting issues.

The diary plays an important role in tracking rental equipment as well. The cost engineer records on the equipment log what equipment is on site and what it is working on, but because

of the authenticity of the superintendent's diary it is also reviewed when there is a dispute with a supplier or subcontractor regarding manpower, equipment deliveries, equipment problems, and equipment demobilization.

Equipment rented externally is accounted for very similar to construction materials. Monthly invoices are received and cost-coded by the jobsite accountant and turned in to the main office for payment. Internally owned equipment may be completely accounted for by the main office through the use of journal entries, or equipment time sheets are sent to the jobsite for cost coding by the project financial team. Equipment rental, similar to construction material, is not subjected to retention by the general contractor of the supplier.

Maintenance expense allocations

The fact is construction equipment requires ongoing and routine maintenance and on occasion, breaks down. These costs can be very substantial and are not typically anticipated or allowed for in a contractor's estimate. Looking at the detailed general conditions estimate for the hotel case study project on the eResource, there was a line item for equipment maintenance but only a minor cost allowance had been included. Even more expensive than maintenance are the cost ramifications to construction productivity when the equipment is shut down. Imagine working on a 40-story skyscraper and the tower crane or the material and personnel hoist are shut down for a week! The best method a contractor can use to manage these costs is to only rent equipment which is in very good condition, require the provider to perform routine maintenance and pay for all repair costs, and include a clause in the purchase order requiring the supplier to have a backup machine ready in case there is a complete breakdown and replacement is necessary.

Equipment which is owned by the contractor, whether internally or through a separate but internally owned equipment company, will endeavor to have its maintenance costs paid for at the jobsite and not cost-coded to the home office. The best method to accomplish this is to repair the equipment while it is still on the jobsite. While under repair, the jobsite team may continue to pay rent for its own company's equipment, even though it is not in use, again to keep costs off of the home office books. Even when the equipment has served its use on the project, it may stay on the jobsite equipment log for an extra week and routine maintenance is performed before it is shipped to a new project or the company's storage yard. Savvy open-book clients may not allow contractors to job-cost equipment maintenance, which increases the contractor's risk of self-owned equipment. An additional risk of self-owned equipment is ongoing safety code or regulation changes dictated by the State which require contractors to upgrade or modify their equipment. If the equipment is externally rented these risks are then all the supplier's responsibility.

Depreciation

Depreciation reflects the wear and tear or normal aging that fixed assets such as buildings and construction equipment realize. Assets lose value immediately after purchase; they all have a useful or productive life and don't last forever. Although the exact duration of the useful life of any asset is variable, the IRS has established a limit of depreciable years for each type of asset which is discussed later. The pickup truck the superintendent drives is not worth the same in the second

year of operation as when he or she first drove it off the lot; it has 'depreciated' in value. If only rent is received on assets, and depreciation is ignored, at the end of the useful life of the equipment there would not have been a fund readied to purchase its replacement. One purpose of depreciation is to create a reserve fund for equipment replacement.

Only fixed assets can be depreciated. This includes buildings, construction equipment, furniture, and office equipment. Bare land and people cannot be depreciated. Most construction companies are not in the business of buying and improving or building and operating buildings. This is the purpose of real estate developers as will be discussed later in this book. Real estate is a very risky business and if the construction company does own buildings, they will likely organize separate LLCs for each piece of property, similar to equipment companies. This discussion will focus primarily on depreciation related to contractor-owned construction equipment. When equipment is purchased it represents an asset on the balance sheet as well as a liability either in increased owner's equity or a long-term bank loan. The asset and liability balance out.

Most of this discussion on depreciation is focused on company-owned equipment and buildings. If contractors rent equipment from outside sources, or if subcontractors provide equipment, then they will resolve their depreciation issues similar to maintenance and licenses discussed earlier. The management of company-owned equipment depreciation processes are CFO related and not typically jobsite accounting related. Although companies which own a lot of equipment will attempt to have at least their depreciation and loan payments covered by jobsite rent or revenue, so it is worthwhile for the project manager and jobsite cost accountant to understand some of the basics behind these processes. There are three primary reasons to track or account for depreciation:

- Equipment revenue and cost and depreciation affects financial statements;
- Equipment costs are allocated to project costs in lieu of home office overhead; and
- Tax reporting and payments.

The total and monthly portion of the original purchase value that the contractor plans to depreciate is determined by subtracting the expected salvage value from the purchase value and spreading over its useful life, as is reflected by the following equations:

Purchase value – Expected salvage value = Total depreciation available
Total depreciation / Useful life = Depreciation per year

Depreciation for tax purposes

Depreciation represents one of the largest tax deductions available not only to construction contractors which own buildings and equipment, but to any corporation or investor. Depreciation represents a loss in asset value and therefore a loss in income, on paper, which is used to offset other financial gains. Depreciation is a paper loss of the asset, there is not an actual outflow of cash such as is the case with wages paid to construction craftsmen or the purchase of concrete. Corporate accountants and CFOs who prepare taxes, or their outside CPAs who prepare taxes

Table 12.2 Depreciation recovery periods

Asset Example	*Useful Life (years)*
Office computers and copy machines	5
Most construction equipment, including forklifts and pickup trucks	5
Other office equipment and furniture	7
Barges and Tug boats used in marine construction	10
Qualified leasehold improvements	15
Farm buildings	20
Water treatment plants	25
Residential real estate	27.5
Non-residential real estate	39
Railroads and tunnels	50

on behalf of contractors, will follow strict depreciation guidelines set out by the IRS. The IRS does not make tax laws, Congress creates the laws. The IRS manages the tax collection process passed by Congress on behalf of the U.S. Government. Two IRS publications related to construction asset depreciation include Form 4562, and its instructions, and Publication 946 (www.irs.gov). The useful lives for assets as determined by the IRS are included with these instructions. Table 12.2 includes IRS-determined useful lives for some of those items which are most common for construction companies.

The IRS recognizes three systems available to contractors to depreciate their equipment for tax purposes. The three methods for tax depreciation include straight line and two methods allowed by law under the modified accelerated cost recovery system (MACRS). These two are based on the concept that an asset loses more of its value during the early years of its life and less towards the end. These two include the 200% double declining balance approach for those assets with a useful life of five years or less and the 150% declining balance approach for equipment with a useful life of greater than five years.

The formulas and variables utilized for depreciation are briefly introduced here and discussed again later. The depreciation rate (R) and depreciation value (D) formulas here reflect the straight-line depreciation method, where equal amounts are deducted each year over the use life of the asset:

- P: Initial purchase price of an asset
- S: The expected future salvage value
- N: The number of years allowed for recovery as previously listed in Table 12.2
- R: The depreciation rate per year in percentage; $R = 1/N$
- D: The depreciation value for a given year (n); $Dn = (P–S)/N$
- B: Book value which is the current value of an asset calculated by subtracting cumulative depreciation from original purchase price; $B = P–\sum D$

The depreciation amounts for each year for a piece of equipment with a useful life of five years under the *straight-line depreciation method* would be accounted for as follows:

Year one: 20%; Year two: 20%; Year three: 20%; Year four: 20%; and Year five 20%

The *double declining balance (200%)* and the *150% declining balance methods* allow for accelerated depreciation in an asset's early years. Most construction companies utilize the 200% method for maximum early-year tax deductions. The straight-line depreciation rate equation of R = 1/N is replaced with R = 2.0/N and R = 1.5/N respectively. These two accelerated methods also replace (P–S) in the straight-line depreciation value equation with the previous year's book value, such that Dn = (Bn–1) x R. Five years of depreciation for a typical piece of construction equipment would therefore be subject to the following depreciation rates utilizing either the double declining balance or 150% methods:

200%: Year one: 40%; Year two: 24%; Year three: 14.4%; Year four: 8.6%; and Year five: 5.2%*
150%: Year one: 30%, Year two: 21%, Year three: 14.7%, Year four: 10.3%, and Year 5: 7.2%*

Note (*): Each of these methods allows for more depreciation than allowed if an adjustment is not made during the last year. The total which can be depreciated cannot exceed the book value (B), which is the original purchase price (P) less the expected salvage value (S). Therefore in the above declining balance example equations, the calculated depreciable amount reflects 5.2% and 7.2% of the book value, but the actual tax deduction will likely be less and a manual calculation will be necessary. Assets with depreciable useful lives other than five years will have different depreciation rate percentages.

Two additional depreciation methods, known as Section 170 Deduction and Bonus Depreciation, allow for even greater early year tax deductions than the double declining balance and 150% methods, but we will leave that discussion to the CPA and CFO board rooms for the present.

All three of the depreciation examples assume a purchase date of January 1, which is unlikely. Very few assets will be purchased on January 1 of a given year. Full-year depreciation for the first and subsequently the last year of the equipment's life is therefore less than the middle years. The IRS also allows for half-year, mid-quarter, and mid-month depreciation conventions. If a piece of equipment with a five-year life was purchased on January 1, and it utilized the straight-line approach, it would have five equal portions of depreciation. If it were purchased on July 1, it would receive 50% of a full year's depreciation in the first year, equal full-year portions in years two through five, and a second 50% deduction in the sixth year; this being the mid-year approach to depreciation. A mid-quarter purchase divides the calendar into eighths and allows for a 1/8th portion in the first year for the quarter it was purchased, assuming it was purchased in February, 25% equal portions in the remaining first year quarters (totaling 7/8 for the first year), full year proportions for years two through five, and in the sixth year the final 1/8th deduction. Numerous other combinations are available for purchase during other months and quarters. A similar, more-complicated approach is available if a contractor chooses the mid-month convention where the year is divided into 24 segments. Table 12.3 reflects straight-line depreciation examples of each

Table 12.3 Straight-line depreciation options

Forklift Example, Five-Year Useful Life Purchase Value – Resale Value = Depreciable Value $125,000 – $25,000 = $100,000 = $20,000 per year									
Date	*Depreciation*	*First Year*							
Purchased	*Method*	*Portion*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*Total*
1/1/2019	Full Year	100%	$20,000	$20,000	$20,000	$20,000	$20,000		$100,000
7/1/2019	Half Year	50%	$10,000	$20,000	$20,000	$20,000	$20,000	$10,000	$100,000
2/15/2019	Mid Quarter	7/8	$17,500	$20,000	$20,000	$20,000	$20,000	$2,500	$100,000
4/15/2019	Mid Month	17/24	$14,167	$20,000	$20,000	$20,000	$20,000	$5,833	$100,000

of these methods for the purchase of a $125,000 forklift with a useful life of five years and an expected resale value of $25,000.

The sale of company-owned equipment also affects the balance sheet and the income statement. The book value of the equipment is theoretically what it is worth at any point in time. The book value stems from the original purchase value less accumulated depreciation and is reflected in the equation following. The book value is therefore the expected salvage value at a given point of time. If the equipment sells for more than the current book value, the company realizes a profit and must pay income tax on the sale. That profit will be taxed as a long-term capital gain and will be subject to a flat 15% or 20% tax (depending on the individual or firm's marginal tax bracket, see Chapter 18) which is usually less than what the company pays on construction profits. If the equipment is sold for less than the book value, the company realizes a loss and can either use that loss on their current income taxes to offset other gains or roll the loss forward to a year when there are other gains available to offset.

Purchase value – Accumulated depreciation = Book value
Sale value – Book value = Profit or Loss

Depreciation for internal accounting purposes

For equipment which is owned by a contractor and fully job-costed, it is not a negative cash flow draw. But equipment which is stored and not in use does reflect negatively on the contractor's income statement. Internally owned equipment is also not a source of profit for the contractor, as the amount of rent paid by the job, likely from a journal-entry transaction, is approximately equal to the amount the equipment has depreciated or lost value and loan coverage. Internally owned and job-costed equipment is subject to the following financial statement actions:

- Balance sheet: The book value of the asset is reduced each month by the amount it is depreciated. The loan on the asset, which is a long-term liability, is correspondingly reduced and funded by the rent received.

- Income statement: Equipment rent and maintenance expenditures are paid as job-cost and should equal invoices charged to and revenue received from the client. Company-owned equipment records depreciation as an expense on the income statement.
- Equipment ledger: Value is decreased or depreciated, and a reserve fund is increased.
- Job cost history report: An ongoing and complete to-date history of rent paid by the job and maintenance costs if applicable.

If equipment is idle and not job-costed there is a totally different set of financial statement results, including a loss in potential revenue for the company. The goal of company-owned equipment is to be 100% job-costed. The accounting for equipment is different for commercial contractors than for heavy-civil contractors which tend to employ fewer subcontractors and own and operate more of their own equipment. If equipment is not company-owned, then expenses are noted on the income statement and handling of invoices is similar to material purchases and reflected on the job cost history report and the accounts payable report.

There are three methods available to contractors to internally account for depreciation including straight-line and two accelerated approaches, the sum-of-years or digits, and the declining balance approach. The straight-line and declining balance approaches are similar to those utilized for tax purposes. The *sum-of-years depreciation method* recognizes accelerated depreciation in the early years of an asset. The straight-line depreciation formula is revised for this method as Dn = (P–S) x fraction. The fraction varies each year depending on the length of the useful life of the asset and the amount of years remaining to be depreciated. The fraction, shown as a percentage here, corresponds approximately to the following rates for a typical piece of construction equipment with a useful life of five years:

Year one: 33.3%; Year two: 26.7%; Year three: 20%;
Year four: 13.3%; and Year five: 6.7%

Summary

There are many elements of construction equipment which warrant careful consideration by the contractor's ownership and the project management team, including the jobsite cost accountant. There are a variety of different types of equipment and assets which must be managed and accounted for, including depreciation for financial planning and tax purposes. Contractors can own equipment, they can set up separate equipment companies as LLCs, or they can rent equipment from outside sources. Contractors do not want construction equipment sitting idle in the company's storage yard; they endeavor to have all equipment active on construction jobsites. One way to manage costs and shift risks is to require subcontractors to provide their own equipment. All construction equipment must be operated by individuals who are trained and certified. Maintenance and repair of equipment can have substantial cost ramifications as well as jobsite productivity impacts. The project manager must look to his or her contract with the client to establish requirements and allowances for equipment rental and repairs, especially with respect to contractor-owned equipment.