Overhead and Uncertainty in Cost Estimates: A Guide to Their Review

John M. Stolz, P.E.
Jacobs Associates, San Francisco, CA, USA

Abstract: There are few industry guidelines that help owners better understand the cost estimates upon which project budgets are based. This paper begins by briefly amplifying the industry consensus that cost estimates for heavy civil and tunnel projects must be based on a "bottom-up" approach. The main focus is on explaining the categories of indirect costs typically used by contractors and their perhaps surprising contribution to overall cost. It then moves on to emphasize the need for an integrated project schedule that quantifies the duration over which these indirect costs are incurred. The paper concludes with a brief examination of and recommendation on the issue of estimating accuracy. These are some of the issues often overlooked when owners review a cost estimate.

INTRODUCTION

In the past few years, the tunnel industry has experienced an unprecedented surge in material and equipment price volatility, skilled labor shortages, and a shortage of bidders themselves. This confluence of volatility and shortages took the expected toll on owners' construction budgets with fewer project bids that were not only higher than the engineer's estimate, but also more dispersed—arguably, nobody could agree on what it cost to build tunnels!

The industry responded with calls for improving the quality of the cost estimating process, and for larger projects, integrating that process into a risk assessment program to help determine the amount of additional contingency that should be carried in the project budget without limiting owners' program budgets. The most comprehensive opus, *Recommended Contract Practices for Underground Construction,* published by SME in 2008, provides owners with valuable information that integrates the cost estimating process into a comprehensive suite of practices and disciplines that are the basis for crafting an effective contract.

In support of the industry's general recommendation for preparing "bottom-up" estimates, the following discussion provides information for owners to use in evaluating the categories of so-called indirect costs. These costs, while contributing a significant percentage of the total bottom-up estimated construction costs, are similarly organized on any large underground construction project.

INDIRECT COSTS

To review briefly, construction estimates consist of so-called direct costs, indirect costs, and profit. Direct costs are those costs that can be directly ascribed to the performance of a specific construction task—excavating a tunnel or shaft—and are grouped into direct cost items. Indirect costs, on the other hand, are costs expended in support of the construction project as a whole and are often referred to as "overhead" costs. As can be expected, sometimes the division between direct and indirect costs can get blurry, but indirect costs usually are not estimated until such time as a draft estimate is made of the direct costs, including a preliminary construction schedule. The following categories of indirect costs are typically always used when preparing a tunnel cost estimate.

Equipment Ownership

This indirect cost category captures the capital costs of providing the equipment needed to perform the work. In contrast, the equipments' operating and maintenance costs are carried with the direct costs. If the equipment is purchased or is part of the contractor's fleet, there is an associated acquisition cost based on either a purchase price or book value, some or all of which must be written off against the project. Rental equipment is usually a straight charge to the job. Then there are the applicable taxes, freight, and erection and dismantling costs in arriving at the cost charged to the project. Perhaps a piece of equipment needs some modification for use in the work. As can be expected, a detailed project schedule is needed to determine how many pieces of equipment are required—a piece of equipment probably would not be able to support two or more concurrent tasks, especially if they are some distance apart. Also, the total number

of operating hours for a particular piece of equipment must be known so that the appropriate write-off can be estimated based on how hard the equipment is used.

Some plant and equipment do not have operating costs, nor do they require maintenance in the sense that they consume fuel, oil, and grease. For tunnels, linear plant items (track, utility lines, ventilation fans and ducts, and so on) are examples of such plant and equipment. Nevertheless, they have an oftentimes significant capital cost and must be included in the equipment ownership item, as are other general plant items such as maintenance shop equipment and survey instruments.

Sometimes equipment ownership costs may be allocated to direct cost items in proportion to individual operating hours. This is especially true for heavy civil applications involving a significant amount of earth moving or concrete placement, such as for highway or dams. Contractors engaging in such work usually already have a fleet of equipment to perform this work. As such, the corporate equipment department usually charges the projects much like an equipment rental company. Tunnel projects, on the other hand, require a fleet of specialized equipment that usually cannot be used on a subsequent project without heavy overhaul or modification. Furthermore, a contractor's equipment department has no historical costs upon which to base an ownership rate. It is for this reason that equipment ownership for tunnel projects tends to be carried as an indirect cost.

General Mobilization and Demobilization

These two indirect cost items are always estimated and scheduled separately. For tunnel projects, these activities can be quite involved because a significant amount of plant and equipment is needed to support underground construction activities, including maintenance shops; warehouse areas; worker changing and shower facilities; fuel, oil, and grease areas; power drops, electrical substations, and power distribution systems; compressed air and distribution systems; and water supply and distribution systems. There could be a batch plant on site, room must be established for muck handling and loading for off-site disposal (and there may even be a muck processing facility such as a slurry separation plant), and the work area must be fenced. Often the contractor is required to provide a functionally complete project office for the owner in addition to one for the contractor's own use. Access roads may be blazed or temporary bridges built. Also, the contractor typically establishes the project erosion control facilities during general mobilization. These are all estimated as separate line items.

There may be cases where a particular item of work such as a drop shaft requires mobilization of certain equipment. In such cases, the mobilization and demobilization are usually priced in the direct cost items associated with that item of work, i.e., the drop shaft construction.

Equipment freight in and out and its erection and dismantling are usually carried in the equipment ownership item. However, their costs may be transferred to this item, especially when mobilization costs must be justified.

For general demobilization, punch list items are usually performed while select elements of the above plant and facilities are being dismantled and shipped off site.

These costs can be substantially higher than costs for building or industrial construction. Since many owners limit mobilization payments to some fraction of the contract and even meter payments based on some schedule of earned value for contract work, the cost estimate serves as a useful tool to help owners understand when it may be beneficial to make changes to the standard contract language.

General Plant Operation and Maintenance

This item identifies the cost for operating and maintaining the contractor's general plant, described in the General Mobilization and Demobilization items, and serves the project as a whole. This item could therefore include everything from providing drinking water supplies to monthly estimated power costs for facilities that have no operating costs, such as office trailers. Costs for office supplies and connectivity are also estimated here.

Costs are usually estimated by the month, starting after mobilization is complete and the contractor is ready to start contract work, and ending at the beginning of demobilization, when contract work is completed.

Weekend Maintenance
This captures the cost of manning pumps or performing other maintenance activities on weekends. Weekends are used for performing site safety inspections and performing noncritical but essential preventive maintenance or overhauls on equipment. For a tunnel boring machine (TBM) job, cutters might be changed on weekends, and the surveyors are almost always on site. Without weekends, this kind of nonproduction work would need to be scheduled during the week—invariably at the expense of performing production work. In addition, since tunnel work is usually performed on two long shifts or three regular shifts per day/five days per week, weekends are a valuable resource for another reason: they allow the contractor to accelerate its work if needed to mitigate the contractor's own delays since tunnel work does not lend itself well to accelerating the pace of work simply by adding crews or starting work in another area.

Clearly, estimating these costs requires knowing the number of project weekends. Since the level of weekend efforts will vary over the life of the project depending on what types of contract work is being performed, this information can only be reasonably estimated using a detailed project schedule.

Field Supervision
The cost of project field supervision—i.e., personnel above foreman classification—is summarized here. Various personnel are carried for the amount of time that their expertise is needed throughout the project, so their involvement is always estimated based on the project schedule. Some classifications, such as the project manager, project engineer, and business manager, are chargeable to the project from the date of award; other staff such as equipment superintendents, staff level engineers, and the purchasing agent start ramping up their involvement after the Notice To Proceed is given. Until the field offices are established, these personnel usually work from the corporate office or apartments near the site.

By the time general mobilization is complete, almost all field personnel are on site, including the safety manager and his/her on-site emergency medical technicians, the field and office engineers, the superintendents, QC manager, and clerical help. By the time tunnel excavation starts, the walkers and field engineers for each shift will be on site.

Field supervisory personnel may be salaried or hourly, exempt or nonexempt. They may be local hires, meaning they will be terminated after the project is completed, or they may be permanent employees relocated from the corporate office or another project. Regardless, each carries a separate set of benefits. Field supervision is therefore estimated by the month.

Overhead Maintenance and Service
This is a broad cost category that captures everything associated with the contractor's operation as a corporation. Typical corporate charges include those from the accounting, IT, HR, design, and corporate departments. Sometimes allowances are made for legal reviews and audits. These costs may be estimated monthly, but are usually applied as a percentage of expected contract billings since contractors usually absorb home office overhead costs for each construction project as a function of total yearly revenue from all construction projects undertaken.

Since the level of effort for some tasks varies from project to project, separate charges may be customary for assisting in the initial high volume of submittals, or for engaging the corporate design department in custom plant and equipment design.

To this, noncorporate project-specific requirements must be added for services such as maintaining project outreach, screening for drug tests, providing for the contractor's share of partnering and DRB expenses, and travel and inspection of off-site material and equipment fabrications by contractor and owner personnel. Site conditions may require engaging the services of a noise or blasting consultant. Usually the corporation will rent a number of apartments for key site personnel. Any costs for preconstruction surveys might be carried here. Any warranties required under the contract are usually priced in this item.

Collectively, these kinds of overhead and maintenance costs are usually estimated by the month over the life of the project.

Bond, Insurance, and Taxes
Conventions for what to include under this item vary from contractor to contractor. Some of these types of costs—most often employee general liability and workers' compensation insurances—are usually carried in the unit rates for labor resources, and therefore are spread throughout the direct costs since they are a function of the base plus vacation portion of the wage rate. Those costs that are calculated based on the contract value or some other basis are carried here, including:

- A bid bond, which is submitted with the bid as a guarantee that the bidder will undertake the terms of the contract. If the bidder is found nonresponsive, the bid bond assures the owner that it will receive the difference between the nonresponsive bid and the next lowest responsive bid.

- A performance bond, which assures that the owner receives payment for the cost to complete the project in the event of the contractor's default. The bond is usually written for the contract amount and replaces the bid bond on award of the contract.

- A payment bond, which assures that the contractor will pay subcontractors, laborers, and suppliers on the project. This protects owners against mechanics liens—or claims to title—on the project.

Insurance costs are more project specific. Certainly the item will include premiums for builder's risk (insurance against damage to the project while under construction), the usual contractor's automobile and equipment insurance, and perhaps an allowance for insurance deductibles that may be paid out during the course of a project. Other project-specific insurance may also be needed, such as railroad protective insurance.

Taxes include such items as state or local taxes, including property taxes and permit and license fees.

Financing Charges
This is the contractor's cost for complying with contract requirements for submitting a balanced bid. Since the contractor's cost in such matters is also a cost to the owner, these financing costs must be estimated, usually by generating a cash-flow curve for the project that takes into account the expected timing of contractor expenditures relative to the contract provisions that dictate when and how revenue is earned.

The financing cost is the sum total of the monthly interest expenses or revenues, calculated on the net difference between the revenue and expenditure cash streams for each month. When the net difference is negative—meaning the contractor is spending more than it earns for that month—the contractor must borrow funds at its borrowing rate. Conversely, when the net difference is positive, it can be invested at the investment rate.

The most significant contributors to financing charges that are within the control of the owner include mobilization payment caps or schedules that drag out the payments, the absence of a specialized equipment mobilization item, and timing of progress payments after an acceptable payment application has been made. However, owners should also review the specifications regarding retained earnings. Even though many states require owners to substitute securities in lieu of cash retention, there will still be a net (albeit smaller) cost since the rate for borrowing is almost always greater than the rate of return on investments.

Contractor Contingency
The amount of contingency that a contractor may carry for whatever risk elements it must bear responsibility for is quantified in this item. As an example of contractor contingency, many contracts require that a "normal" amount of inclement weather days based on a specified actuarial publication be built into the schedule. Since inclement weather day delays are usually considered excusable and noncompensable—meaning that the contractor can get a time extension but no reimbursement of monetary damage—bidders would be wise to examine the project schedule and have some way of determining the number of man-days for activities that experience normal inclement weather so that an estimate can be

made of their impacts—for example, in call-in pay. Similarly, when subcontractors quote prices for performing work, they may not be given details of the season in which they are working, so they may exclude inclement weather days from their quote unless otherwise directed. Again, a bidder may wish to know the value of subcontract work performed during a period when a potential inclement weather day might be encountered so that an assessment of the average daily standby cost to a subcontractor is known.

Contribution of Indirect Costs to the Bid Amount

When indirect costs are compiled as described above, they represent a sizable amount of the total bid—typically on the order of 70% of the direct costs when profit is included. This often surprises owners who may expect this ratio to be more like the language in the Changes Clause of their Standard Specifications; 15% or 20% for Overhead and Profit. However, neither the contractor nor the owner is "wrong," since the Changes Clause is intended to apply to the pricing of change orders that are relatively small compared to the total contract value.

PROJECT SCHEDULE

The foregoing discussion underscores the need for a comprehensive project schedule since so many indirect costs are time-dependent. The project schedule must also be cost-loaded, since not only does this assist in generating a cash flow schedule from which financing costs can be determined, but it also assists owners with their budgets in the timing and amounts of disbursements made via progress payments over the life of the contract.

BASE ESTIMATE UNCERTAINTY V. ACCURACY

The lead project estimator wields a large amount of influence over cost, and the project costs estimated are influenced largely by estimating experience and judgment. The spread in bids from responsible and responsive bidders on bid day is not only a result of market factor adjustments, it is also generated by the experience and judgment of the bidders as to the level of effort required and the production rates that can be achieved in performing the work. Many refer to this as estimating accuracy, with such accuracy increasing with project definition. However, it may be better to think of this as estimating *uncertainty,* since the term "accuracy" imparts a tendency to consider low accuracy estimates of inferior quality. This should be discouraged, because the accuracy *must always* be high—nothing should be left out except math errors, quotes should be firm and supportable, labor rates must be researched, and so forth. And yet, one can still be unsure of an accurate estimate, especially when project definition is low.

Note that this discussion is *not* about risk. The base estimate should not include risk, but only a best assessment of the cost and time required for construction of the project. Risk is more properly handled separately, since there are many more kinds of risk than construction or bid market risks.

The issue is really about *base uncertainty*: how much can things vary and still be considered reasonable? For example, an estimator may generate a cycle time analysis for tunnel excavation and support resulting in some production rate—say 40 feet per day. However, that production rate is founded on a number of conditions or parameters, such as TBM instantaneous penetration rates, that must necessarily contain some measure of uncertainty itself. When pressed to justify the 40 feet per day figure, an estimator is likely to concede that the production rate could just as easily be as high as, say, 45 feet per day (bump up the TBM instantaneous penetration rate 5% and cut the 30 minute segment build times by 5 minutes) or as low as 36 feet per day, just by varying some of the basic assumptions of the cycle time analysis by small amounts. And yet, such base uncertainties on individual direct costs can have a significant impact on total project estimated cost and duration. It would seem prudent to examine these kinds of base uncertainties for the major project cost elements to determine their overall impact to schedule and cost. This gives owners another tool to reduce subjectivity when establishing the overall project budget as a measure of confidence that the project cost will not be exceeded.

For things like labor rates, manning provisions and to a lesser extent crew sizes and subcontractor or vendor quotes are more certain because for labor rates, these are usually published. However, it should be

expected that vendors will tend to not give as much thought to providing competitive quotes for engineers' estimates as they do for those of bidding contractors who will then purchase their product.

On the other hand, construction productivity is usually the biggest uncertainty in an estimate. For underground construction where subsurface conditions can have a profound influence on means and methods, uncertainty should be expected, not only in production rates, but also in whether some work, like pre-excavation grouting, is needed or not.

In general, an uncertainty analysis should be made in these major categories. For tunnel construction, these categories include production rates for tunnel or shaft excavation and support, and tunnel or shaft final lining; separate variables affecting tunnel production that are occasioned by the uncertainty in groundwater control or ground improvement, interventions, and other more geotechnical-related unknowns; and other variables that represent a more pure cost, such as a range of the anticipated amount of muck that might be classified as hazardous and therefore cost more to handle and dispose.

SUMMARY

Having a thorough understanding of these three areas—indirect cost categories, project schedules, and estimating uncertainty—not only helps owners establish criteria for preparing cost estimates, but also guides them to the cost elements that may suggest when it is beneficial to make changes to the standard contract language. Understanding the categories of indirect costs helps owners better comprehend how contractors price their work for these costs and why these costs are so much higher than the standard allowances for overhead an markup in the Standard Specifications. It also explains why having a detailed project schedule is key because so many of these indirect costs are time dependent. Finally, understanding base uncertainty in an estimate gives owners a better idea about how confident they can be in the numbers when establishing a project budget. Supplied with these tools, owners can review a cost estimate with more confidence and greater effectiveness.