

# Estimando proyectos grandes y complejos

## Estimating large complex projects

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### Resumen

Gestionar proyectos de construcción de grandes capitales requiere de la coordinación de una multitud de recursos humanos, organizacionales, técnicos y naturales. Frecuentemente, las complejidades del diseño y construcción de esos grandes proyectos son tapadas por sus desafíos económicos, políticos y sociales. Las ramificaciones y efectos que resultan de las diferencias entre la estimación de costo inicial, el costo de la propuesta adjudicada y el costo final del proyecto son significativas. Hay numerosos factores que inciden en el costo final del proyecto entre su inicio y finalización. La duración es generalmente de varios años y puede incluso superar la década para aquellos especialmente complejos y desafiantes. En ese período de tiempo, cambios en los alcances del proyecto cambian frecuentemente. El tópico del presente artículo es mostrar estrategias para apoyar la estimación realista de costos. A través de investigación bibliográfica y entrevistas con agencias de transporte de EE.UU. y otros países, los autores desarrollaron y presentan una base de datos con los factores clave que producen problemas en la estimación de costos.

**Palabras Clave:** Incremento en costos, estimación, gestión de estimación, estimación de procesos, costo de proyectos, alcance de proyectos

### Abstract

Managing large capital construction projects requires the coordination of a multitude of human, organizational, technical, and natural resources. Quite often, the engineering and construction complexities of such projects are overshadowed by economic, societal, and political challenges. The ramifications and effects, which result from differences between early project cost estimates and the bid price or the final project cost, are significant. Over the time span between the initiation of a project and the completion of construction many factors influence a project's final costs. This time span is normally several years in duration but for highly complex and technologically challenging projects, project duration can easily exceed a decade. Over that period, changes to the project scope often occur. The subject here is a presentation of strategies that support realistic cost estimating. Through literature review and interviews with transportation agencies in the U.S. and internationally the authors developed a database of the factors that are the root causes of cost estimation problems.

**Keywords:** Cost escalation, estimating, estimate management, estimating processes, project cost, project scope

## 1. Introducción

Project cost escalation is a major problem for government agencies. Over the time span between the initiation of a project and the completion of construction many factors influence a project's final costs. Over that period, substantial project scope changes often occur. During the early stages of a project many factors that influence project costs are not known, these could be such things as insufficient knowledge regarding the exact project location, environmental mitigation requirements, or work-hour restrictions. There are also other process type factors that often drive project cost estimate increases.

These factors can include, for example, unforeseen engineering complexities and constructability issues, changes in economic and market conditions, changes in regulatory requirements, local governmental and stakeholder pressures, and a transformation of community expectations. Some researchers have stated that there are systemic problems in agency estimating processes, even to the point that purposeful underestimation of projects is common to gain project funding (Flyvbjerg et al., 2002). The impact of all of these issues is compounded if there is a lack of human resources with appropriate training in

cost estimation or an institutional lack of cost estimation management processes. The factors cited in previous research make it clear that there are distinct challenges related to cost estimation management and development of early project estimates. These challenges are:

- Difficulty in evaluating the quality and completeness of early project cost estimates;
- Difficulty in describing scope solutions for all issues early in project development;
- Difficulty in identifying major areas of variability and uncertainty in project scope and costs;
- Difficulty in tracking the cost impact of design changes that occurs between major cost estimates.

Many of governmental agencies are seeking to strengthen the economies of their countries by executing some very challenging projects. As examples, Peru has recently signed contracts for a 700 kilometer \$613 million Trans-Oceanic and Panama is developing a master plan for constructing 3<sup>rd</sup> Lane Locks. This research and the objective of the paper is not to suggest wholesale changes to estimating processes, but rather provides a clear and concise collection of strategies that will result in improved cost estimate management.

## 2. State of practice

Over 100 documents have been reviewed and summarized in preparing this paper. The documents consist of journal articles (63%), reports (12%), conference proceedings (12%), and other documents (presentations, summaries). The literature was analyzed with attention to cost estimating procedures and cost estimation management. The data collected from all of these sources permitted the identification of the root causes behind cost escalation and lack of project estimate consistency and accuracy. Specific estimating practices and cost management approaches were identified that led to the cataloging of estimating strategies.

## 3. Cost escalation factors

Construction projects have a long history of underestimation Federal-Aid (2003), (Flyvbjerg et al., 2002). The factors that lead to the underestimation of

projects have been identified through a large number of studies and research projects. The factors driving underestimation of project costs can be divided by project development phases: planning, and execution. As defined here planning involves all project development phases prior to bidding including long-range planning, programming, advanced planning/preliminary design, and final design. Execution entails contract bidding, award, project construction, and closeout.

The factors that affect the estimate in each development phase are by nature internal and external. Factors that attribute to underestimation and that are controllable by the agency are internal, while factors existing outside the direct control of the agency are classified as external. This arrangement of factors is shown in Table 1. The Table has been constructed to provide an over arching summary of the factors that have been identified from many sources and a better understanding of how project estimates are effected. It is important to note that most of the factors point to “forces” that impact project scope and timing.

## 4. Planning-internal

While numerous internal factors can lead to underestimation of project costs at the planning stages seven primary internal factors have been well documented: bias, delivery/procurement approach, project schedule changes, engineering and construction complexities, scope changes, poor estimating, and inconsistent application of contingencies. Each of these factors separately or in combination with others can cause significant project costs increases.

Bias is the demonstrated systematic tendency to be overly optimistic about key project parameters. It is often viewed as the purposeful underestimation of project costs in order to insure a project remains in the construction program. This underestimation of costs can arise from the estimators' identification with the agency's goals for maintaining a construction program Akinci and Flscher (1998), Condon and Harman (2004), Hufschmidt and Gerin (1970), Pickrell (1992).

Delivery/Procurement Approach effects the division of risk between the agency and the constructors, and when risk is shifted to a party who is unable to control a specific risk, project cost will likely increase. The decision regarding

which project delivery approach, design-bid-build, design-build, or build-operate-transfer, and procurement methodology, low bid, best value, or qualifications based selection effects the transfer of project risks [Harbuck (2004), New Jersey (1999), Parsons (2002)].

Project Schedule Changes, particularly extensions, caused by budget constraints or design challenges can cause unanticipated increases in inflation cost even when the rate of inflation has been accurately predicted. It is best to think in terms of the time value of money and recognize that there are two components to the issue: 1) the inflation rate and 2) the timing of the expenditures [Board (2003), Booz·Allen (1995), Callahan (1998), Touran and Bolster (1994)].

Engineering and Construction Complexities caused by the project's location or purpose can make early design work very challenging and lead to internal coordination errors between project components. If these issues are not addressed cost increases are likely to occur (Board (2003), Booz·Allen (1995), Callahan (1998), Touran and Bolster (1994), Federal-Aid (2003)].

Scope Changes, which should be controllable by the agency, can lead to underestimation of project costs. Such changes may include modifications in project construction limits, modification of the design, or correction of key project item dimensions Chang (2002), (Semple et al., 1994).

Poor Estimating (errors and omissions) can also lead to project cost underestimation. Estimate documentation must be in a form that can be understood, checked, verified, and corrected. The foundation of a good estimate is the formats, procedures, and processes used to arrive at the cost (Arditi et al., 1985), Carr (1989), Harbuck (2004), (Merrow et al., 1981), Merrow (1988).

Inconsistent Application of Contingencies causes confusion as to exactly what is included in the line items of an estimate and what is covered by contingency amounts. Contingency funds are typically meant to cover a variety of possible events and problems that are not specifically identified or to account for a lack of project definition during the preparation of early planning estimates Noor and Tichacek (2004), Ripley (2004), Association (1997).

Table 1. Underestimation factors

	Planning	Execution
Internal	<ul style="list-style-type: none"> <li>• Bias</li> <li>• Delivery/Procurement Approach</li> <li>• Project Schedule Changes</li> <li>• Engineering and Construction Complexities</li> <li>• Scope Changes</li> <li>• Poor Estimating (errors and omissions)</li> <li>• Inconsistent Application of Contingencies</li> </ul>	<ul style="list-style-type: none"> <li>• Inconsistent application of Contingencies</li> <li>• Faulty Execution</li> <li>• Ambiguous Contract Provisions</li> <li>• Contract Document Conflicts</li> </ul>
External	<ul style="list-style-type: none"> <li>• Local Government Concerns and Requirements</li> <li>• Time Value of Money</li> <li>• Scope Creep</li> <li>• Market Conditions</li> </ul>	<ul style="list-style-type: none"> <li>• Local Government Concerns and Requirements</li> <li>• Unforeseen Events</li> <li>• Unforeseen Conditions</li> <li>• Market Conditions</li> </ul>

## 5. Planning-external

External factors that can lead to underestimation of project costs include local government concerns and requirements, rate of inflation, and market conditions. Again it is recognized that each of these factors can act separately or in combination with others to cause significant project costs increases.

Local Government Concerns and Requirements typically include mitigation of project effects and negotiated scope changes or additions. Actions by the agency are often required to alleviate perceived negative impacts of construction on the local societal environment as well as on the natural environment. The required accommodation is often unknown during the early stages of project development Board (2003), Daniels 1998, Mackie and Preston (1998), Schroeder (2000).

Time Value of Money is a key factor in the underestimation of costs for many projects. The time value of money can adversely affect projects when 1) project estimates are not communicated in year-of-construction costs, 2) the project completion is delayed and therefore the cost is subject to inflation over a longer duration than anticipated and/or 3) the rate of inflation is greater than anticipated in the estimate Akinci (1998), (Arditi et al., 1985), Board (2003), Booz-Allen (1995), Merrow (1988).

Scope Creep is similar to changes in scope; however, these changes are usually the accumulation of minor scope changes. Projects seem to often grow naturally as the project progresses from inception through development to construction Board (2003), Harbuck (2004), Mackie and Preston (1998).

Market Conditions or changes in the macro economic environment can affect the costs of a project, particularly large projects. Typically, the risks associated with large projects are much greater, both for the agency and contractor, and that affects project costs. Inaccurate assessment of the market conditions can lead to incorrect project cost estimating Summary of Independent Review (2002).

## 6. Execution-internal

Cost growth occurring during the construction of a project cannot be ignored and must be planned for

when estimating a project. Internal factors that lead to the underestimation of project costs during the execution of a project stem from poor project management and design documents.

Inconsistent Application of Contingency can be both an internal factor contributing to underestimation during the planning stage and a contributor to cost overruns during the execution of the project Noor and Tichacek (2004), Ripley (2004).

Faulty Execution by the agency in managing a project can lead to project cost overruns. This factor can include the inability of the agency representatives to make timely decisions or actions, or provide information relative to the project, and failure to appreciate construction difficulties cause by coordination of connecting work or work responsibilities Board (2003), Chang (2002).

Ambiguous Contract Provisions dilute responsibility and cause misunderstanding between the agency and project constructors. The core assumptions underlying an estimate are confused by ambiguous contract provisions Chang (2002), Harbuck (2004), Mackie (1998), Measuring (1998).

Contract Document Conflicts lead to errors and confusion while bidding and later during project execution they cause change orders and rework Harbuck (2004), Mackie (1998), Measuring (1998).

## 7. Execution-external

External factors that lead to the underestimation of project costs during the execution of a project stem from those items that are primarily out of the control of the agencies.

Local Government Concerns and Requirements can affect the project costs during the execution phase. Similar to the effects during the planning phase, mitigation actions imposed by the local government, or environmental groups during the construction of a project can extend the project duration affecting inflation allowances or add direct cost. Summary of Independent Review (2002), Woodrow (2002).

Unforeseen Events are unanticipated and typically not

controllable by the agency, occurrences such as floods, hurricanes, or other weather related incidents. Events controlled by third parties that are also unforeseen include terrorism, labor strikes, and changes in financial markets. These actions can have devastating consequences to project costs Akinici (1998), Chang (2002).

Unforeseen Conditions are notorious for causing cost overruns. Unknown soil conditions or contaminated soils can affect construction processes. Utilities are often present that were not described on the drawings. There are a multitude of problems that are simply unknown during the planning stage and which can increase project cost (Semple et al., 1994), Transportation (1999).

Market Conditions affect the project costs during the execution phase similar to the effects during the planning phase. Changing market conditions during the construction of a project that reduces the number of bidders, affects the labor force, and other related elements can disrupt the project schedule and budget Board (2003), Chang (2002), Mackie (1998), Summary of Independent Review (2002).

## 8. Estimating strategies

Project estimates are made at various times during project development. An estimating strategy must correspond with the information available at the time the estimate is developed. Thus, certain types of estimating practices are used during the different project development phases. Cost engineering research has proven that the ability to influence and manage cost is greatest at the earliest stages in project development.

The statement has been made in many forums that "initial cost estimates are not reliable", Transportation (1997). With increased size, complexity, and the introduction of new technology comes exponentially larger risk, Warrack (1993). This is a lesson that many agencies and their estimators have not fully learned. To produce accurate cost/schedule estimates agencies must develop strategies that address all of the major factors influencing project cost. Based on the identified problems it is recommended that agencies adhere to the following estimating strategies.

## 9. Management strategy

Cost Containment Procedures – Develop a protocol for actions when costs are exceeded at milestones. These actions should include a justification for changes and approval of a revised budget if costs cannot be contained.

Approval Authority – Develop policies on required approvals for changes in scope, schedule, and cost as they occur throughout the project development process.

## 10. Scope/schedule strategy

Scope Uncertainty – Develop a mechanism that clearly describes what is included in the project scope and schedule and what is not included, especially in relation to estimated project costs.

Scope Change Form – Develop a procedure that encourages the project team to document scope changes and scope creep such that their impact on cost and schedule can be evaluated and tracked.

## 11. Risk strategy

Probabilistic Estimates – Consider the use of probabilistic estimates. Probabilistic estimates of cost or schedule can be performed using readily available software tools. These tools support additional analysis of the output variances and sensitivities to input factors.

Contingency – Contingency is often the most visible quantification of the project risk. It should directly reflect the status of the project scope definition and design completion. Simply using a typical contingency value (e.g., 10%) should be avoided when more information is known about the project. The major factors contributing to the project contingency should be included in a description of the contingency.

Contingent actions – Once specific risks have been identified and their potential impacts quantified, strategies, and tactics for dealing with these risks should be developed and prepared for possible implementation. One of the most important aspects of risk management is the

development of potential contingent actions to mitigate or provide optimal paths to overcome identified risks.

## 12. Delivery and procurement method strategy

Alternative Procurement Methods – Consider alternatives to traditional low-bid procurement when value for money can be justified. For example, best-value procurement techniques have been successfully applied for highway and other public sector construction to attain more qualified contractors, more innovative solutions, and shorter construction times.

Packaging of Contracts – Develop appropriately sized projects for the available market. Understanding the impact of market competition is essential for developing an accurate estimate.

## 13. Document quality strategy

Internal Reviews – Develop document review processes that can be matched to project complexity and which provide a thorough assessment of the completeness and accuracy of the work by individuals who are not directly responsible for the project (independent check and review). Internal document reviews should:

- Determine the practicality of the design concept;
- Determine the constructability of the design; and
- Verify that the data provided by others has been properly used and is still appropriate.

External Reviews – First-of-a-kind and technically-complex projects require a document review process that utilizes the most experienced professionals for the particular type of work envisioned. Expert teams composed of external professionals should be formed to assess document quality.

## 14. Estimate quality strategy

Creation of Project Baseline – Create a project baseline

of approved scope and resulting cost, then track all changes in project scope, schedule, and cost throughout project design. This allows for the tracking of project changes and a valid comparison for which the current project can be compared.

External Estimate Reviews – Establishment of an estimate review process, using external expert teams will aid in achieving estimate quality. The sharing of lessons learned should be encouraged particularly for first-of-a-kind projects involving technical complexity or unknowns.

## 15. External issue strategy

Approval Authority – Development of approval authority protocol as discussed in the Scope/Schedule Strategy will assist in dealing with external issues.

## 16. Integrity strategy

Estimate Reviews – Use estimate reviews as discussed in the Estimate Quality Strategy to provide objective opinions on project cost.

Public Disclosure – Develop consistent public disclosure processes that communicate project costs and associated uncertainty consistent with the level of engineering/design completion.

The use of these strategies will enhance the quality of agency estimates of project cost and scope.

## 17. Conclusion

The cost escalation factors that lead to project cost growth have been documented through a large number of studies and matched to changes in cost estimates. Each factor presents a challenge to any agency seeking to produce accurate project cost estimates. These factors can be mitigated through strategies that focus on controlling the possible effects of these factors. The eight global strategies presented here are aligned with the factors that cause project cost escalation on projects. The

fundamental focus of achieving accurate cost estimates should be to use –Strategies– that address the causes of estimating problems.

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