Management of Cost & Risk to meet Budget & Schedule

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1 Introduction

Even when a major infrastructure project is well planned and managed, project conditions change and problems can arise. Technical issues may be a common reason for change but, in a significant number of cases, political changes seem to have the most significant impact [1, 2]. These changes and impacts have resulted in significant and undesirable consequences which include cost and schedule over-runs, resource competition between projects, negative media attention and, consequently, public mistrust.

Thus we find that the public is skeptical of our ability, as a profession, to accurately develop initial budget estimates for the final costs of large, complex public projects. They are also skeptical of our ability to manage these projects to established budgets. Questions the public has asked include:

“Why do costs seem to always go up?”

“Why can’t the public be told exactly what a project will cost?” and,

“Why can’t projects be delivered at the cost you told us in the beginning?”

Our inability to answer these questions consistently and clearly is a consequence of many factors – including the large uncertainties associated with long project time-frames and, up to now, our inability to identify and correct inadequate estimating practices. Additionally, the effects of poor project management and poor communication with the public has further added to the problem – resulting in unfortunate results, including rejection of funding for proposed transportation projects.

Many government agencies have recognized this problem and in response are now requiring risk-based probabilistic cost and schedule estimating, as well as formal risk management plans [3, 4]. In many cases, the development of budget estimates and political or legislative action now requires enhanced cost-estimating including use of probabilistic, risk-based processes.

A variety of approaches using probabilistic, risk-based methods have been developed in an attempt to provide better cost and schedule estimates. Most of these methods incorporate one or more of the following changes from “traditional” estimating.

- Replace traditional contingency-based deterministic (single value) approaches with a risk-based analysis that presents estimates as ranges with probabilistic weighting;
- Consider the uncertainties that would potentially impact a project by an developing an explicit listing of risk factors (or risk events) that may be candidates for “risk management”;
• Recognize the importance of schedule uncertainty and cost uncertainty. This may be addressed using integrated cost and schedule models, or by equivalent methods.

The specifics of these various risk-based approaches vary widely in the level of detail and in the techniques used to gather data for input to the risk process. The authors, clients and colleagues [5, 6, 7, 8] believe that a flexible (depth and breadth of detail and degree of approximation), probabilistic, risk-based approach using an integrated cost and schedule model is the most appropriate way to quantify uncertainties for complex projects and to guide risk management in order to better define and control costs and schedules.

2 The CEVP® Process, History and Development

In January 2002, the Washington State Department of Transportation (WSDOT) Secretary was challenged by the State Legislature regarding the poor reliability of cost estimating and a history of increases to the cost estimate for a large highway project. WSDOT managers and key consultants were asked to develop a better cost estimation process. As part of defining “the problem”, a review of relevant data led to the following findings:

• There is a general failure to adequately recognize that an estimate of future cost or schedule involves substantial uncertainty (risk),
• Uncertainty must be included in cost estimating,
• Cost estimates must be validated by qualified professionals including experienced construction personnel who understand “real-world” bidding and construction,
• Large projects often experience large scope and schedule changes “creep” which affect the final out-turn cost. Provision for this must be made in the cost estimates and management must deal competently with managing potential changes,
• Inadequate communication with the public compounds the problem of poor estimating.

WSDOT decided to act on these findings by developing an improved cost estimating methodology that would incorporate a high level of cost validation with a comprehensive assessment of the risks that could impact a project, and an analysis approach that would quantify these risk impacts for risk management.

WSDOT’s strategy also included policy changes that would deal openly with the process of public infrastructure cost estimating so that the public would better understand, and would be better informed, as project managers and elected officials make critical project funding decisions. WSDOT decided to open the “black box” of estimating and present a candid assessment of the range of potential project costs, including acknowledgement of the uncertainty of eventual project scope, the inevitable consequence of cost escalation fluctuations, and other major risks. Key concepts that were identified as principles for the new approach included:

• Avoid single number estimates. Recognize that at any point in the development of a project, from initial conceptualization through the end of construction, an estimate will require selecting a representative value, considering many factors that are inherently variable,
• Use a collaborative and consistent assessment process that combines high levels of critical external peer review expertise, particularly in construction cost estimating in a competitive environment, with appropriate roles and responsibilities for the Project Team and the independent experts,
• Acknowledge that both cost uncertainty and schedule uncertainty are major contributors to problems with project estimating, and incorporate both in the evaluation methodology. WSDOT foresaw the clear advantage, in fact the necessity, to integrate the effects of cost and schedule uncertainty,
• Use a high level of rigor identifying and quantifying probabilities and consequences of risks,
• Be practical and use common sense notions of risk descriptions and quantification. The new WSDOT method was to be completely rigorous and treat uncertainty in ways that acknowledged correlation, independence and other probability principles. However, the sources of information and definition of uncertainty were likely to encompass a range which might extend from highly quantified issues to those where subjective opinion from the contributors was all that would be available. This range of uncertainty data needed to be captured objectively,
• Produce data that could be understood by the ultimate audience, the public.

The resulting “Cost Estimate Validation Process” or CEVP® [8] develops a probabilistic cost and schedule model to define the probable ranges of cost and schedule required to complete each project. There are three principal and integrated components to the CEVP® process: 1) Cost validation, 2) Risk Identification and 3) Modeling, as described following.

- In the beginning, there is a large potential range for “ultimate cost”
- The “ultimate cost” will depend on the outcome of many factors
- We can’t predict exactly - but we can develop probable ranges of cost which include all relevant risk and opportunity events we can identify

![Diagram showing probability and range of probable cost](image)

**Figure 1 – Future costs are a “range of probable cost”**

2.1 **Cost Validation**

The cost validation process includes a critical examination of the details of the cost estimate presented by the Project Team. These details include assumptions, unit rates, prices and quantities. The basis of each element is critically examined and either accepted or modified.

The scope of the project, as reflected in the cost estimate is examined and the estimate adjusted if significant changes are found. The completeness of the estimate is compared to the scope and any cost elements that may have been excluded or neglected are included and quantified.

The cost validation part of the process is led by a cost validation facilitator with extensive estimating and program delivery experience, supplemented by team members with both design and real-world construction experience. The use of personnel with experience in contractor's methods is necessary to bring that perspective into the cost review for a well-shaped determination of “base cost” - the cost without “contingency” - that is, the cost if “all goes as planned and assumed”.

The usual contingency that is included in each unit price and quantity – or which has been applied to the entire estimate – is identified and removed from the cost estimate to define the “base cost”. The uncertainties that are typically the basis for a “contingency” in an estimate will eventually be addressed (added) through the risk assessment and model development. The schedule for the project is reviewed; assumptions, constraints and logic are critically examined so that a “base schedule” can be defined.
During the discussions, and upon completion of the validation reviews, items of work that may have been missed, and the over- or under-estimated quantities and unit prices are identified and recorded. Estimates for missing items are developed and recommendations for adjustments are made. Finally, an agreed “base cost” is determined - this becomes the base to which the cost of potential risk and opportunity events are added by the cost/schedule uncertainty model.

2.2 Risk identification and quantification

In the CEVP® process, risk identification and quantification is led by an experienced risk elicitor/analyst who is familiar with uncertainty theory, de-biasing techniques and the structure of a subsequent cost and risk model. Other workshop participants include representatives from the project team who have familiarity with the plans, strategies, assumptions and constraints on the project, plus the Subject Matter Experts (SME’s) who bring an independent perspective on important areas of project uncertainty.

The risk and opportunity events that are the output of the risk workshop are defined and evaluated with respect the validated base cost and schedule. Other factors such as correlation or dependencies among events must be defined and accounted for. In addition, each risk or opportunity event must be allocated to the project activities that are affected by it or, if a given event affects multiple project activities, significant correlations among occurrences need to be addressed. Significant uncertainties and correlations among event impacts also need to be defined.

Risk elicitation in the workshop is an iterative process that combines subjective and objective information. Uncertainty characterizations and probabilities are defined simultaneously to provide reasonable, practical descriptions of uncertainty.

2.3 Modeling

The base cost and schedule, plus the quantified risk information, is analyzed with respect to a modeling framework that describes the planned project, its strategy and the schedule of activities required to deliver the final project. Several analytical methods have been used but most CEVP® analysis is done using simulation techniques [5, 6, 7, 8, 9, 10]. The output of analysis is in the form of a “range of probable cost and schedule” and other characteristics of the project of interest to management, such as cash-flow and risk ranking.

Following the successful development of CEVP® and its implementation on the “mega projects” in 2002, WSDOT applied the risk-based cost and schedule evaluation techniques broadly within the organization. The range of project sizes and types where CEVP® was used ranged widely from projects with budgets as low as $20 million or less up to the $multi-billion level mega projects. The detailed application of CEVP® over this range of projects has varied - in some cases with a number of simplifications and compromises made to the original principles of CEVP®. These simplifications were formally acknowledged and, in practice, different levels of risk-based analysis were given different names, such as Cost Risk Assessment (CRA).

The CEVP® approach has also been used to quantify uncertainty in programmatic measures such as program expenditure and cash flow and for programs consisting of a large number of individual projects, each of which have specific uncertainties but are often related to some degree. Specifics of the development of this approach have been reported [8, 11]. The approach has been used or adapted by numerous Agencies including the U.S. Federal Highway Administration and numerous State Departments of Transportation.
3 Improving the CEVP® Approach for Application to the Alaskan Way Viaduct Project

In early 2009, the Alaskan Way Viaduct Replacement Project (AWV), a multi-billion dollar highway program in Seattle, was Legislatively authorized by the State of Washington in cooperation with the City of Seattle and King County. An early management decision was to use CEVP® systematically in the evaluation of cost and schedule estimates and use of risk management. In this case, since there was a hard limit on available budget, WSDOT management and its advisors were clear in wanting to use a risk-based approach that was based on the highest level of principle and rigor - not a simplified approach that had been used in some cases previously. Over the past seven years, WSDOT has performed hundreds of CEVP® workshops, however, there were concerns that some parts of the process, over time, had been overly simplified. In particular, these concerns led to identification of the following six elements where an improvement was considered necessary:

1) Improve the accuracy and validation of the base cost and schedule estimates,
2) Involve a sufficient number of appropriately qualified independent Subject Matter Experts to support review of all key areas of the project to be constructed,
3) Conduct risk assessments and risk management workshops in a well managed and professional manner,
4) Do not bias the analysis and reporting of a cost and schedule assessment by introducing “constraining assumptions”. While acknowledging that the results of analysis using certain assumptions may be helpful when making comparative decisions, all reports for such a major project should include a “reference assessment” that is based on a complete description of all uncertainties to which the project is exposed, as may be possible with the data which is available,
5) It will frequently be advantageous to consider and report higher level risk factors that have not been included in the analysis, recognizing that such higher level risk factors may be outside the control of the project team,
6) Apply consistency and rigor when managing to budget by adjusting scope, methods, requirements and/or schedule as part of the CEVP® process.

A discussion of why these six topics were considered as priorities for improving the implementation of CEVP® and how these improvements were to be implemented is discussed in the following sections. The CEVP® process including the application of these principles was referred to as “CEVP+”.

4 Priorities for CEVP+

4.1 Improve the accuracy and validation of the base cost and schedule estimates

From the initial applications of CEVP® in 2002 it has been recognized that a high quality, comprehensive estimate of cost and schedule should be prepared as a starting point for defining the “base” cost and “base” schedule. Depending on the level of design, different levels of detail in the base estimates would be appropriate with general conceptual and parametric estimates being used in early stages of design and more specific line-item estimates being the standard as the design matured. Large percentages in “allowances” and other systematic adjustments were appropriate in early stages but should be minimized as final design progresses. Finally, as indicated by the “V” in CEVP®, the base estimates must be sufficiently validated.

In subsequent applications of the CEVP® process the principles of base preparation and validation were simplified and streamlined, especially when working with smaller and less complex projects. This simplification was justified by the smaller size of the projects and the lower level of project complexity. However, a much higher standard of base cost definition was required for the large, complex and high priority AWV project, particularly considering the constrained budget and tight schedule as required by the Governor and Legislature.
The improved CEVP+ process returned to basic principles with a focus on developing the most complete and accurate base cost possible through the following requirements:

- The base cost estimate must include a comprehensive basis of estimate document that includes a clear statement of the scope of work the estimator is addressing, calculations made, sources for all data, and assumption made,
- The base cost estimate must be consistent with the base schedule in terms of productivity assumptions and activity durations,
- Validation of base cost and schedule estimates should be done by a team of at least two independent experts who have sufficient time to examine the cost and schedule estimates in detail,
- The proposed cost and schedule estimates (including all supporting materials) should be provided to the validation team at least one week prior to the validation review or the use of these estimates in a workshop to define a base cost or schedule.

4.2 Involve a sufficient number of independent Subject Matter Experts for all key project areas

WSDOT has used Subject Matter Experts (SMEs) to assist in the CEVP® assessments since 2002. Many of these SMEs have come from outside organizations but the Agency has also been successful in using WSDOT staff that were not involved directly in a subject project and could be judged as “independent”. Because of budget constraints on smaller projects, the number of independent SME’s was sometimes limited to as few as two or three.

For the CEVP+ level of assessment used in the AWV Project, the need for independent SMEs with a high level of relevant experience dictated that almost all of these experts should be brought in from outside. WSDOT has limited experience with many of the key elements of the AWV project including tunnels, underground construction, design/build contracting and projects of the size and complexity of AWV. For the first two CEVP® assessments conducted in July and October 2009, 20 or more outside SMEs were engaged. These individuals were selected because of their specific high-level experience and expertise and their prior experience as consultants, public agency officials, constructors, and academics. In a few cases the SMEs came from WSDOT staff. For a few of the more salient subject areas, SMEs with overlapping expertise areas were brought in to help eliminate the possibility of subjectivity in the risk assessment process.

4.3 Conduct risk assessments and workshops in a well managed and professional manner

To assure that workshops and other data gathering sessions were conducted in an efficient and professional manner, the CEVP+ process used for the AWV Project adopted the highest standards and practices that had evolved and been used by WSDOT for risk assessments since 2002. Among the most important aspects of this process were:

- A risk elicitation professional should lead and control the process of information gathering. This responsibility acknowledges that the primary objective of a risk assessment or risk management process is to gather and balance information from two perspectives:
  1) the professionals on the project team who best understand the designs and estimates
  2) un-biased independent subject matter experts.
- Achieving this balance the responsibility of the experienced risk elicitors who have developed techniques for gathering and balancing information from such perspectives.
- The appropriate individuals to contribute ideas or opinions on a specific risk topic are those with specific expertise on this topic. In most cases the appropriate contributors should be therefore limited to the relevant design team members and the SMEs selected for their expertise and experience on this specific topic.
- The ideal size for risk elicitation workshops varies. It is often effective and most efficient to collect information by working with small groups of project team members together with
independent experts in a small workshop format. In other cases it may be most effective to
conduct individual or small group interviews.

- Large group meetings with design team members and independent experts representing a
  variety of issues may be appropriate for training or to start off a risk assessment workshop
  with a general project overview. However, this format is not appropriate for gathering
  specific information about the details of project uncertainties.

4.4 Do not bias the analysis and reporting of cost and schedule by introducing “constraining
assumptions”.

The integrity and accuracy of a cost and schedule estimate, or risk-based assessment, depends
on considering the full range of potential outcomes and uncertainties (risks). No element of the
risk assessment process is more important than recognition and acceptance of the fact that there
is always uncertainty in basic constraints such as scope, financing scenarios, schedule for
environmental processes or escalation rates. This principle has been recognized since the
beginning of CEVP® in 2002. However, in the application of CEVP® by WSDOT and other
agencies this principle is frequently compromised by applying constraining assumptions in the
interest of focusing attention on those design and construction risks which the project team can
best control, leaving the “higher-level” risks to management or political representatives. Often,
the “higher-level” risks have not been sufficiently evaluated.

The policy adopted in CEVP+ was to always conduct an “unconstrained analysis” as a reference
for the consideration of potential project outcomes. It may be appropriate, and valuable, to do
subsequent analysis that introduces one or more of the constraining assumptions. Such an
analysis may provide information that is very useful in comparisons among projects and other
considerations. However, the unbiased, “unconstrained analysis” is the most fundamental
assessment of the actual project outcome and should always be the primary statement of the
expected outcome, which may then be modified for the constraints that are to be applied.

When reasonable constraining assumptions about some elements of the project are used in
analysis, these should be reported in perspective. Following the reporting of the “unconstrained
analysis” it is appropriate to present:

1) clear and unambiguous communication about the assumptions that have been made for
   any “constrained analysis” and,
2) a quantitative evaluation of what the potential impact of these constraining assumptions
   may have on the final project outcome models.

4.5 It will frequently be advantageous to consider and report higher-level risk factors that have
not been included in the analysis

An analysis that is “unconstrained” from the perspective of the project team or other body
responsible for the project success is, nevertheless, subject to a set of uncertainties that may
impact project outcomes but which are beyond the knowledge and control of the project leaders.
Such factors as major change in the political environment and support for a project (election of a
different mayor or governor with a different vision of the project, for example) may be recognized
but are often inappropriate to try to incorporate in analysis.

Senior managers for the project team are usually aware of these higher level risks even if they
are not included in analysis. In the interest of providing the most complete reporting of potential
cost and schedule, it is recommended that higher level risk factors be identified and reported,
along with the clear statement that uncertainty about these high level risks are not incorporated in
the quantitative analysis.
5 Conclusions

The CEVP® process was initially developed as a tool for Agency managers to use in evaluating cost and schedule estimates for projects with a defined scope and delivery strategy. In application by WSDOT, however, the results of the CEVP® assessments soon became the basis for risk management and managing to fixed or highly constrained budgets. WSDOT had traditionally managed projects tightly and this practice was reinforced when, in 2003, the State Legislature passed regulations that required all projects to be delivered at or near a line-item budget set by the legislature.

The practice that evolved within WSDOT to meet these requirements was to use the results of a CEVP® analysis to 1) first identify the likelihood that a project would be delivered within budget and schedule and then, 2) if the project is projected to come in above budget, to cut scope or take other necessary actions using the CEVP® model to guide these changes. This approach has proved to be successful for WSDOT in managing most of its larger construction projects.

A similar approach is being used on the AWV project. There is a clearly defined limit to the cost for this project - set by the State Legislature considering funding from the City of Seattle and other Agencies. Successful design and construction of the project must fall within the budget limits that have been authorized. CEVP+ is being used to rigorously evaluate the probable range of cost for the project considering risk, to manage those risks defined by the CEVP® process and to adjust the scope to increase the likelihood that the final project will be delivered within the budget.

6 References