# The Development of a New Cost-Risk Estimating Process for Transportation Infrastructure Projects

***The Washington State Department of Transportation has worked to build public confidence and improve project management by using a new method to validate and communicate the probable cost and schedule of its projects.***

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Federal, state and regional engineers — as well as contractors and owners — are aware of the growing public concern and skepticism about the ability to estimate and manage the costs of large public projects. To the public, the story is sour for those projects where, in its eyes, costs "just seem to grow and grow." The public frequently brings up the following questions:

- Why do costs seem to always go up?
- Why can't the public be told exactly what a project will cost?
- Why can't projects be delivered at the cost stated in the beginning?

The inability to answer these questions consistently is a consequence of many structural factors including poor cost estimating practices, poor project management and poor communication within the design and construction community and with the various public bodies. But more fundamental issues underlie this problem, which has led to a significant erosion of public confidence in infrastructure agencies. The ultimate consequence of this perceived failure results in problems such as the rejection of necessary project funding and support, which has been demonstrated, for example, by the negative vote for the Los Angeles Metro program and, more recently, by the rejection of several tax increase proposals for highway projects, including Referendum 51 in Washington State and the Transportation Ballot Measure in Virginia, both in 2002.[1] In March 2002, the Washington State Legislature passed a $7.7 billion package, including a 9 cent gasoline tax, for transportation improvements across the state over a ten-year period, to be approved by voters through Referendum 51. Referendum 51 was rejected by 62 percent of the voters, one of whom stated that the "costs are too high and projects are never done on time or on budget." On November 5, 2002, in northern Virginia, 55 percent of the voters rejected a proposal to increase the sales and use tax by 0.5 cents for regional transportation projects.

The number of high-visibility projects where it appears (to the public) that costs are "out of control" seems to be increasing. The cost increases involved can be staggering. Several examples of projects with cost problems demonstrate the extent and seriousness of the problem. These projects include:

- The Jubilee Line Transit Project in London — two years late and £1.4 billion (67 percent) over budget;
- The Channel Tunnel — £3.7 billion (80 percent) over budget;
- Denmark's Great Belt Link — 54 percent over budget;
- The Woodrow Wilson Bridge bid — 72 percent over estimate.

The over/under budget numbers, or percentages, reported are based on the cost initially published for the project or that reported at time of decision to proceed, which is consistent with Flyvbjerg's definition.[2]

In addition, except for the Woodrow Wilson project (which is just beginning construction), all these projects were put in service long after the initially planned completion date. The most recent "poster child" example is Boston's Central Artery, which is billions over its initial budget (with the final number yet to be determined) and years late. Unfortunately, throughout history there have been many examples of cost and schedule problems including, quite possibly and probably, the building of the pyramids.

## A Critical Examination of the Problem — International

Inventorying 1,400 projects worldwide, a study found that specific, relevant cost management information was very difficult to obtain due to the fact that reliable records for completed projects were usually absent from the public record.[3] Little objective history could be found, including findings that would support recommendations for improvement. Because of the difficulty in obtaining "hard data," firm conclusions could not be reliably drawn from this study, but the following relevant findings were obtained, as reported by owners and researchers:[3]

- There are significant cost and schedule overruns suggestive of poor management in at least 30 percent, and possibly more than 50 percent, of the projects.
- It appears that the factors that most directly influence success or failure are the expertise and policies of the owners, and local procurement procedures.
- The professional teams engaged in projects were judged to be competent by the owners, leading to the consideration that problems in poorly performing projects may lie primarily with the ability of the owner to lead and/or manage the project process.
- Risk mitigation is not well understood or applied, even in elemental ways. This area was considered to be promising for development, in particular since it related to cost overruns and unforeseen events.
- Cost performance data — especially for good results — should be treated very cautiously. Consistent, complete and relevant data are very hard to get and almost impossible to validate after completion.
- Conclusions based on reported cost data, unless the conclusions are grossly evident (meta-findings), should also be treated with caution.

Other studies evaluating how costs have been estimated for 258 projects spanning seventy years have recently been published.[2,4] The problem of accurate cost forecasts is chronic and has been so for over seventy years. Moreover, as an industry, infrastructure planning, design and construction professionals, along with owners, have not corrected the chronic underestimation of the real cost of infrastructure projects. If they had done so, there would have been a uniform number of results over budget as under budget. The problem is not only an inability to estimate accurately, but also a bias to estimate on the optimistic side.

The studies also demonstrate that there is a dearth of consistent and reliable records. Therefore, specific conclusions, while in general reasonable and expected, may be flawed or limited. Two current research efforts in the United States are trying to address this absence of consistent data: a Federal Transit Administration (FTA) review of transit projects and a Federal Highway Administration (FHWA) review of selected highway projects. Initial results should be available later in 2004 or early 2005.

## A Critical Examination of the Problem — U.S./Boston

Several recent projects from the Boston area illustrate another aspect of the issue. They also show that not all projects get into trouble regarding cost. From the public's point of view, the Central Artery/Tunnel (CA/T) Project and the Boston Harbor Cleanup Project (BHP) were at the extremes of project performance.

The CA/T Project was initially presented in 1986 with a cost under $3 billion, a number that followed FHWA cost guidelines. However, this number did not have a solid relationship to the actual project as constructed, with respect to scope, complexity and time. In 1990, as construction was about to begin, the estimate was $6 billion.[5] The project will ultimately be delivered at more than $15 billion in current (2005) dollars.[6] This latter study on the cost growth of the CA/T Project stated that the low original estimate developed in 1982 was presented in the 1985 Environmental Impact Statement (EIS) before detailed technical studies were undertaken. (Of course, an initial low estimate is not a direct cause of cost growth.) Other major cost increases were associated with scope additions as well as environmental and other mitigation changes before and during construction, and major delays.

The 1987 Facilities Plan for the BHP presented a range of costs from $4 to $4.9 billion. The media drew from early BHP planning another number, $6.1 billion, that included additional project elements and a very generous inflation factor that created its own set of public credibility issues that, in large part, drove the cost refinements made in 1992. In that year, in the very early stages of construction, a thorough review of the project cost was performed and the estimate was fine-tuned to $3.65 billion. When the project was completed a decade later, the final cost was $3.8 billion.

Among the many differences in these two projects was the way that the original estimates were prepared and presented, which dramatically affected the initial cost estimate "number" that the public remembers. The CA/T Project costs were the estimated costs of the project in 1986 dollars with no escalation or contingency built into the number, which was consistent with FHWA requirements at the time. The BHP estimate, to which the project was managed and that was used for public reporting and in disclosure to potential bond investors, was built from the estimated costs for the total final program and included contingencies and escalation to the projected midpoint of construction. It also included the costs of planning, design, construction management and any soft costs that could possibly be required for delivering the program.

Each project cost estimate was different — in scope, context and timeframe — and was being used, and understood, differently for each project's owner. However, the public and the media never understood these major differences. The majority of the "public" had, and still has, in the case of the CA/T Project, no knowledge that the numbers represented two completely different scopes, contexts and timeframes. For the CA/T Project, the media has continued to use the 1986 number as the basis of comparison in every discussion of cost on that program over the years. Therefore, public opinion has been shaped by these (poorly understood) numbers.

## Improving Cost Validation

A third example from Boston illustrates how procedures can be changed to improve the standard of cost estimating practice. When the Massachusetts Water Resources Authority (MWRA) became concerned that the early estimated project cost numbers for another project, the MetroWest Water Supply Tunnel program, were significantly underestimated, it critically reviewed its cost estimating procedures. This review was conducted despite the fact that conceptual stage planning estimate numbers were being used by mid-level project managers in the permitting and public processes that were required to gain final project approval and, therefore, were already available to the public (if not widely appreciated).

The MWRA's concern, based on the contemporaneous and contrasting experiences of the BHP and the CA/T Project, was that if these numbers became the public reference point for the project, false expectations would be created that would haunt the entire project delivery program. The MWRA stopped dissemination of the initial project estimates and conducted a detailed review, which found that the estimates by the design team might not include the full scope of the project or other factors. For example, there was no escalation included and the costs for design, construction management and other "soft costs" were not included. The initial estimate numbers did not represent the total cost to deliver the program; they included only the anticipated construction costs in present-day dollars with no contingency.

To determine the probable cost at completion of the MetroWest Tunnel Project, the MWRA embarked on a comprehensive review of the project costs as they were being presented to either validate them as presented or to determine necessary changes. A complete review of the design team's estimate was done by a group of independent professionals with management, design and construction experience. The group included a person with specialized experience in estimating and constructing this type of project from a contractor's perspective.

The result of this review was a revised cost estimate that included *all* costs, including planning, design, construction (escalated to anticipated project mid-point), construction management, contingency and all soft costs (such as permitting, compliance, land costs and mitigation costs).

The new cost estimate was used in all subsequent public discussions of the cost of delivering the program and was the cost that was taken to the MWRA's board of directors for approval. With good management, and good fortune, the MWRA and its designers and contractors delivered the MetroWest Tunnel Project on schedule and under the projected program estimate. In this process, the MWRA has:

- Demonstrated that its cost-validation process was reasonable and corrected an early, inadequate initial cost estimate.
- Determined a reasonable (i.e., correct) cost estimate that allowed the MWRA to manage within budget and schedule, and to deliver the project that it had committed to the public.
- Avoided media and public criticism of "continually escalating program costs."

This experience in cost review, cost philosophy and cost estimating approach became one of the critical foundations for the subsequent Washington State Department of Transportation's (WSDOT) Cost Estimate Validation Process (CEVP).

## Core Issues Regarding Cost Estimating for Complex Projects

Recent attention to cost and schedule estimating practices, and their historical limitations, have led to a better understanding of some core issues that have been part of the problem. Key among these practices are:

- The failure to adequately recognize, for complex infrastructure projects, that any estimate of cost or schedule involves uncertainty, or risk, and that this uncer-

tainty should be incorporated in an estimate.
- The need for the validation of estimates from the external perspective of qualified reviewers, specifically including experienced construction personnel who understand how the project will be both bid and constructed.
- The bias that occurs when estimating policies and procedures affect a cost estimate (as demonstrated by Flyvbjerg).[2] Therefore, it is necessary to use methods and policies that mitigate any special interests the estimator may have to obtain a long-range, comprehensive and accurate estimate.

Cost estimating is a complex but inexact science. However, most current budgeting policy and procedures require that "precise cost numbers" be made available early in the planning process, usually prior to the start of detailed design work. The seeming (but false) precision of these cost numbers is a perilous trap. Unfortunately, large projects can, and do, experience large scope and schedule "changes" that affect the final cost. Usually, these changes increase the cost. The following key points illustrate concerns regarding the contemporary estimating process, and show some of its contradictions:

- "The number" representing an estimate often hits the streets before any reasonable "engineer's estimate" is complete.
- The uncertainty inherent in any estimate may not be fully acknowledged, at least explicitly, in most estimating methods. (It is not possible to completely know the ultimate cost of a project until all construction on the project is complete and the last bill is paid.)
- Different types of estimates are used at different times. Initial estimates are typically done "top-down" and are developed with reference to a comparable project or activity. Their accuracy depends on how close the new project is to the reference project. In contrast, later, more detailed "aggregate component estimates" are constructed "bottom-up" by considering the pieces of an estimate — for example, by using detailed quantities and unit prices. Either approach to estimating can be used at various stages of a project from concept and planning, through the various phases of engineering design to construction. Differences in understanding and presenting the appropriate precision of such estimates can easily lead to confusion, skepticism and loss of trust with the public and media.
- All estimates contain substantial uncertainty. The notion of "contingency," while a valuable approach to addressing uncertainty in traditional estimating, has its limitations. When undertaking new types of projects, the meaning of contingency may be misunderstood by the public and it may be unrealistic given the size and complexity of the project.
- Among the policies and procedures that are widely suspected to be contributors to the current estimating problem are financing procedures that build in incentives for low estimates and use current dollar estimates that ignore the impact of major risk events (political changes, for example), and the time cost of money (escalation).
- The way in which many estimates are communicated matches poorly with the public's intuitive understanding of "what engineers can tell us." Also, the typical evolution or "development" of an estimate is poorly understood. Changes in estimates are often seen by the public as illustrating either doubtful engineering competence or, worse, untrustworthy dissembling.

These were the types of issues that WSDOT wanted to address as it sought an improved approach to scrutinize and communicate project schedules and estimates. Essential elements of the process were to include external review by independent, knowledgeable management, design and construction professionals as well as incorporating a "validation" of base cost and schedule estimates and assumptions. Also important was to find a way to replace any dependence on methods using "contingencies" and to treat estimate and schedule uncertainty explicitly. The objective was to move away from single-value estimates toward estimates with quantified uncertainty, expressed as a range of costs with corresponding probabilities.

## WSDOT's Perspective

WSDOT leadership recognized that these concepts would represent a significant change in the normal transportation estimating process. To be successful, there would have to be fundamental cultural changes within the agency. The response of the public, press and governance bodies was uncertain.

WSDOT was looking at a set of large, high-visibility, long-delayed highway projects in Washington State and, in particular, the Seattle area. The total cost of these projects, as envisioned, was in the vicinity of $20 to $35 billion. WSDOT knew that without public confidence, several of these large, urgently needed projects would not receive funding required to move forward. More specifically, they knew the entire state's transportation issues would not be addressed without good public trust.

*Traditional Approaches.* Traditional approaches usually present "best case" estimates. Doing so is a trap because everything is not going to go well or as predicted, which is the basis of "normal" cost estimates. In general, WSDOT (a well-regarded state transportation department staffed with competent and experienced project planners and design engineers) had a good record concerning the development of planning and engineer's estimates when compared to bid and final construction cost. However, the proposed expansion of State Route 167 south of Seattle became an exception to that record when its "estimated cost" in presentations to legislators rose from $150 million in the planning/scoping phase to $972 million at preliminary design. This, plus other well publicized U.S. infrastructure project cost problems, such as the CA/T and Seattle Sound Transit projects, confirmed WSDOT's concern that meeting the "public confidence challenge" would not be easy.

Project delivery planning and cost estimating in transportation normally involves four distinct phases: planning, scoping, early design and late design. In the planning phase, overall needs and problems are addressed, and a general route (i.e., point "a" to point "b") is identified. During scoping, general scenarios are identified that would meet the need or problem identified in the planning phase, and conceptual estimates are developed from past projects and engineering best judgment. However, no two projects are the same. During early design, as design details become clearer, more certainty comes into the estimate. The different scenarios identified during the scoping stage are now being further developed in a detailed design effort, while being examined and screened through a critical and extensive environmental permitting review process. During late design, an engineer's level estimate can be developed. By this time, the different scenarios have been whittled down to a selected option and detailed engineering design and estimating work is underway.

*The Public Perception Problem.* A critical problem identified in Washington State was that, while an engineering level estimate has a strong performance record (construction is generally completed within the engineer's pre-bid estimate plus or minus 10 percent, and cost of changes during construction are limited to around 6 to 7 percent of the bid price), the public and press rarely compare the ultimate project against the engineer's estimate. Rather, they compare the cost of a completed project against an estimate (which is often inadequate) that was developed during the scoping stage, primarily for use in evaluating and comparing alternatives, and where little detail is known about the future project.

Why is this done? Because the political process currently relies on scoping level estimates to make funding commitments. Those funding commitments, based on the scoping level estimates, become the baseline public cost estimate for a given project. There are, at least, three possible ways to help correct the problem:

- Change the political process. (This is very unlikely and would occur very slowly.)
- Develop a method to provide better estimates of the range of project costs based

on current assumptions. (This is a distinct possibility.)
- Learn to manage the projects (including scope growth) to deliver the promised project within the estimated cost range. (This is a necessary requirement.)

The second point contains the most promise. WSDOT knew that it could not rely simply on a track record of sound engineering estimates to generate public confidence in the future for the larger, more complex projects. It therefore identified objectives that could help them better develop, present and manage their estimates. These objectives included:

- Scrutinize scope assumptions, project estimates and schedules;
- Review project risks early and manage those risks;
- Communicate the range of potential project costs carefully; and,
- Develop early strategies to manage the risks and meet project goals and objectives.

WSDOT wanted the public and decision makers to have the best possible information about the probable cost ranges of major transportation projects. The word *range* is important and fundamental to CEVP. The future cannot be completely and accurately predicted, but using recognized risk and uncertainty techniques, the range of costs and time a project will require can be better forecasted. Only then can the best, and the worst, possibilities be planned for and managed.

## The Process

In January 2002, the Washington State Secretary of Transportation, Douglas MacDonald, goaded by questions from State Senator Daniel McDonald (no relation), asked a small group of consultants and WSDOT managers and engineers to develop a response to the problem of providing more accurate and useful planning stage estimates for such projects. Secretary MacDonald had been Executive Director at the MWRA for most of the construction period of the BHP and also for the planning, project commencement and most of the construction period for the MetroWest Tunnel Project and other elements of the MWRA's water supply improvement program. As such, he understood well the need for the accurate cost estimates that were necessary to competently manage these projects.

WSDOT's strategy and its undertaking, to the public and elected officials, was to deal openly with the process of public infrastructure estimating so that the public would better understand and be better informed as they, and elected officials, make critical project funding decisions. The challenge was to develop a valid procedure to do this. WSDOT decided to open the "black box" of estimating and present a candid assessment of the range of potential project costs, including acknowledgment of the uncertainty of eventual project scope, the inevitable consequence of cost escalation due to inflation and other major risks.

Therefore, with the approval of Secretary MacDonald, a core team at WSDOT developed a specific management-cost-risk assessment tool that was called the Cost Estimate Validation Process (CEVP).[7] The new procedure included:

- The cost validation process from the MetroWest Water Supply Tunnel Project; and,
- The impacts of risk and opportunity events derived from procedures previously developed for infrastructure tunnel projects.[8-10]

After guidelines were developed by the core team, plans were made for a test application of the process to WSDOT's I-405 highway project.

However, before the test was completed, the department decided to apply the new concept to a set of ten major highway projects, so that more realistic cost numbers (ranges) could be communicated to the public, political decision makers and media in time for the up-coming funding vote. The more realistic cost estimates (ranges) were an essential component of WSDOT's management accountability and its project delivery commitment to the public.

Therefore, in February 2002, WSDOT launched the CEVP program with a major commitment of its personnel, including functional and project staff, staff from project partners, members of the consultant teams already working on some of the larger projects and the core CEVP development team. To this were added external specialized consultants, including a group of very senior engineering, construction and cost estimating specialists drawn from around the country.

As the CEVP methodology emerged, several key approaches were identified that integrated management strategies with process requirements. Among these approaches were:

- *Avoiding 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 to characterize many factors that are inherently variable. These variable factors will include issues that have been identified and quantified (the known/knowns), have been identified but not yet quantified (the known/unknowns) or may not yet have been identified (the unknown/unknowns). Some factors will be controllable by design or by the owner, some will not. But all of these contributing factors are fundamentally uncertain and need to be treated as such.
- *Using a collaborative assessment environment* that combines high levels of critical external peer review expertise, particularly in construction and estimating construction in a bidding environment, with appropriate roles and responsibilities for the project team. Project teams and owners are (and should be expected to be) biased. They are generally too optimistic about the project and want to see it advanced, funded and built. This bias must be balanced with independent subject matter experts, peers and others with valued experience that is based on experiences separate from the specific project.
- *Acknowledging that both cost uncertainty and schedule uncertainty are major contributors* to problems with project estimating, and both should be incorporated in the evaluation methodology. WSDOT foresaw the clear advantage — in fact, the necessity — to integrate the effects of cost and schedule uncertainty. CEVP was developed to incorporate quantified uncertainty for both risk and opportunity factors, and to identify these factors using an aggregated-component approach that separated components whose cost and/or duration could be considered separately, and to integrate cost and schedule using schedule-based analytical methods.
- *Being practical and using common-sense notions of risk descriptions and quantification.* The CEVP 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 from highly quantifiable 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. First-order/second-moment (FOSM) methods were concluded to be sufficient.
- *Producing project output that could be understood by the ultimate audience — the public.* This emphasis led, ultimately, to a bold approach that used the concepts of cost estimate range, acknowledged uncertainty and used probabilistic estimate descriptions in a successful media/public engagement.

*Implementing the New CEVP Cost Estimating Tool.* With the above approaches established, WSDOT assembled the team to implement CEVP. The team consisted of a core group of well-qualified WSDOT staff and outside subject matter experts (SMEs). This team brought together local, national and international expertise in the areas of risk assessment, cost estimation, design, construction, project management, risk management and other specialty areas.

Selecting the makeup of the team to evaluate a specific project was done carefully and deliberately. For each project, the team was fine-tuned to match the specific technical

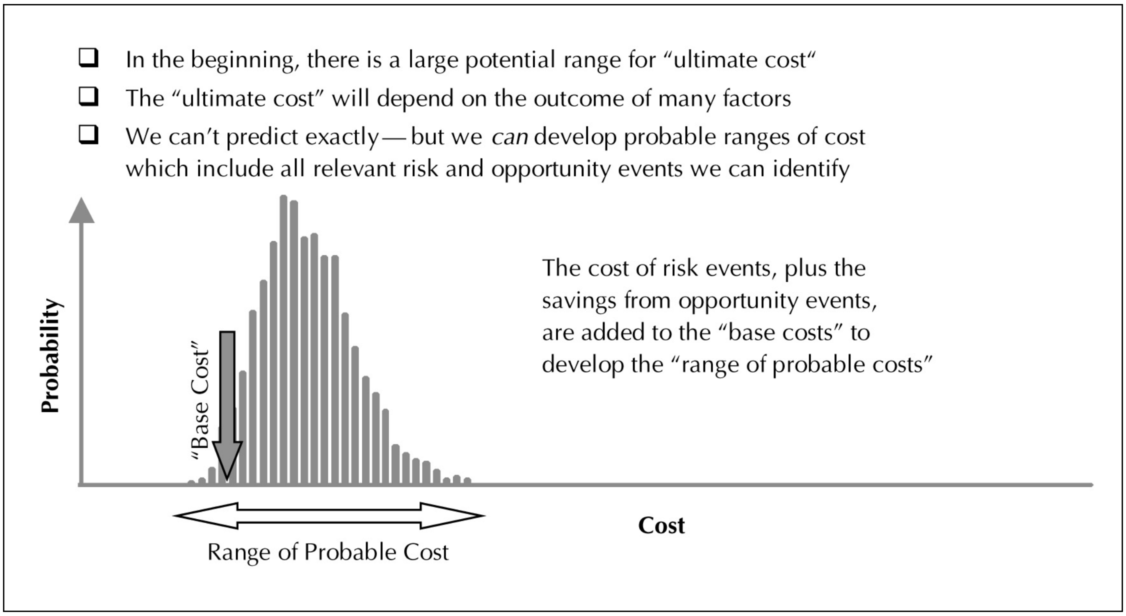



**FIGURE 1. A future cost estimate is not a number, but rather a "range of probable costs."**

needs of the project being reviewed with the skills of the CEVP team members.

*Description of CEVP.* The process provides a probabilistic-based evaluation of a cost and schedule estimate. The principal target outcome is to comprehensively and consistently define the potential cost and schedule required to complete the project. The basic approach requires performing a peer-level review or "due diligence" analysis of the scope, schedule and cost estimate for a project and then to frame this analysis to incorporate uncertainty (including "risk" and "opportunity"). Specific objectives of the method are to evaluate the quality and completeness, including risk uncertainty, of the estimated cost and schedule. The results of an assessment are expressed as a distribution of values for the project (see Figures 1 and 2) related to project objectives (such as cost, schedule to completion, probability of meeting a certain milestone, etc.), along with appropriate characteristic values and attributes of that objective.

The process is usually conducted in a format that includes a workshop where the input from project team participants and independent SMEs is obtained. The process focuses on the project team for both input of primary information and also the eventual responsibility to apply workshop results to the improvement of the project. WSDOT has consistently demonstrated that the involvement of the project team (i.e., its ownership of the process) achieves these two fundamental benefits.

The starting point for the CEVP risk workshop is the project team estimate that has been reviewed and evaluated by the cost team. This initial estimate typically provides a "point estimate" for project cost and schedule, usually including allowances and/or contingencies, but without specific identification of significant uncertainties or risk and opportunity events. The objective of CEVP is to validate individual cost and schedule components, and replace contingency and other approximating components with individually identified and quantified significant uncertainties (including risks and opportunities).

*CEVP Considers Two Fundamental Components — Base Cost & Uncertainty.* The WSDOT approach is based on a definition and analysis of two fundamental components of any project performance objective (such as total cost): the base component and the uncertainty (risk and opportunity) component. This approach can be applied to cost, schedule, safety or other project performance measures. For estimates of cost, the following definitions

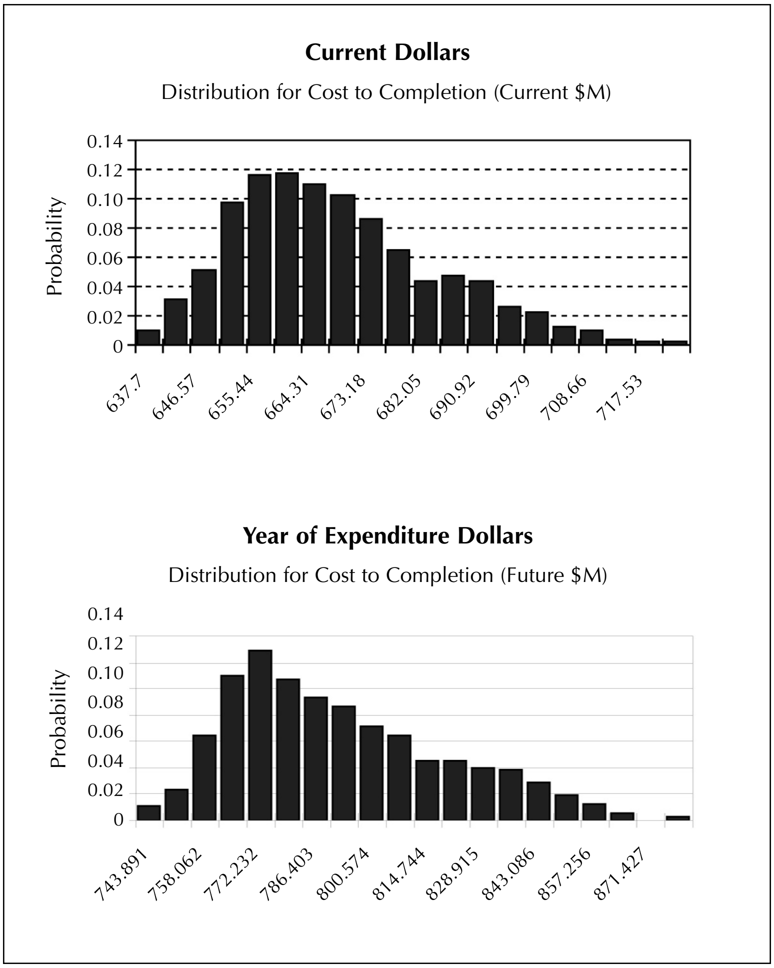



**FIGURE 2. Distributions of current and future costs for a typical WSDOT project (I-90 Snoqualmie Project).**

illustrate the differences between these two fundamental parts:

- *Base cost* is the most probable cost for a unit or element of the planned project that can be expected if the project goes as planned. The base cost typically will include small uncertainty or variance. However, when significant uncertainties exist in the base cost and schedule, uncertainty in, and correlation among, these components may be included. The base cost is usually not a lower bound or minimum cost estimate because some risk elements or opportunities are typically included as part of the strategy for the planned project.
- *Uncertainty* is expressed in the potential adverse (risk) or beneficial (opportunity) events that affect the project and that result in impacts to cost, schedule, safety, performance or other characteristics, but do not include the uncertainties inherent in the base. Correlation among risk events and their consequences can also be included.

Although the process can address any of the project performance measures, the principal WSDOT applications have been focused on cost and schedule.

## CEVP Methodology

The CEVP methodology is organized into the following key steps:

*1.* Assemble relevant project data, involve the project team.
*2.* Define the project flow chart.
*3.* Critically evaluate the project cost estimate to determine the base cost.
*4.* Define and assess (quantify) uncertainty events (including risk and opportunity).
*5.* Integrate base (cost) and uncertainty (costs) in a probabilistic model.
6. Analyze results and write CEVP report.

*Assemble Relevant Project Data, Involve the Project Team.* The process requires that the project team prepare plans, exhibits and project documents to describe the scope, character and timeframe of the project. The conventional cost estimates will include the base project costs plus allowances and contingencies. The

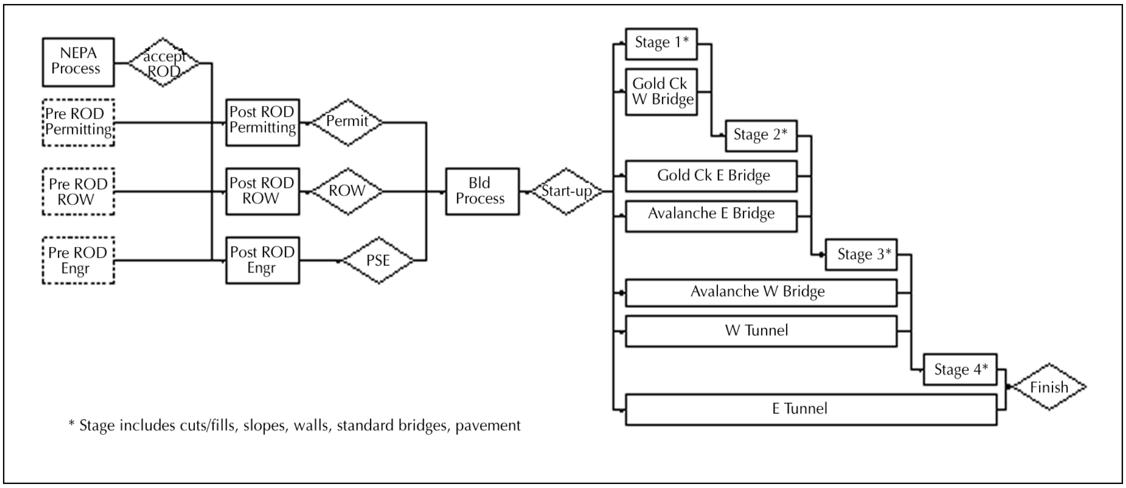



**FIGURE 3. An example of a project flow chart (for the I-90 Snoqualmie Project).**

integrated team of project and CEVP members (hereafter called the CEVP team) then critically reviews the project team's estimate with the following primary objectives:

- To establish the project scope, character and major strategy assumptions for the CEVP evaluation.
- To clearly define the scope, estimates, schedules and assumptions for each scenario if multiple project scenarios or alternatives are to be evaluated.

*Define the Project Flow Chart.* The project team provides a detailed description of the expected project plan, with the major activities and their schedule. From this information, the team develops a project flow chart (see Figure 3) that represents the sequence of major activities to be performed in the project. Major decision points (for example, funding decisions) and project milestones, as described by the project team, are explicitly represented in the flow chart. The base costs and durations, as well as any related major uncertainties or correlations for each activity are entered on the flow chart using values as confirmed or defined by the base cost review team.

*Critically Evaluate the Project Cost Estimate to Determine the Base Cost.* CEVP requires separating the project team's cost estimate into a base cost and other costs that effectively represent the risk and opportunity uncertainties. The base cost estimate is then subject to evaluation by SMEs to determine the quality of the project team's cost estimate. The level of detail applied to this validation (the "V" in CEVP) can range from a comprehensive audit of the cost estimate, through a "validation" of the results based on selected sampling and verification of cost line items, to a "reasonableness" assessment of the base cost component. The level of detail used in the cost evaluation will influence the ultimate outcome of a specific CEVP assessment. However, different levels of cost estimate "quality" can be addressed by appropriately quantifying levels of uncertainty and bias later in the process (either risk or opportunity).

The CEVP cost validation workshop is led by a project manager with program delivery experience, who is supplemented by a CEVP team member with both design and real-world construction experience. The use of a team member who has an independent contractor's background is necessary to bring that perspective into the cost review and determination of reasonable base costs.

The project team first briefs the CEVP team on the detailed scope of the project and identifies any cost and schedule risks that they feel may not be adequately represented in the project estimate.

The CEVP team then obtains, and discusses with the project team, the estimate that has been prepared for the project, reviewing what the estimate represents and what basis was used in its development and discussing what metric, if any, has been used to calibrate the estimate and what contingencies have been included in the estimate.

A review of the scope of the project is completed with the project team on an element-by-element basis to ensure that all elements/phases of the project have been accounted for in the estimate.

The project team's estimate is reviewed to ensure that items (such as right of way, mobilization, permitting, mitigation, temporary facilities and utilities, construction phasing requirements, seasonal constraints, cuts/fills, hazardous material issues, archaeological issues, storage and disposal of material, haul distances, compaction and testing, protection of work, testing of mechanical and electrical systems, occupancy permits, de-mobilization, etc.) have been recognized and addressed from a cost standpoint.

The schedule for the project is also reviewed. Is it realistic? Does it consider adequate time for mobilization and the set-up of temporary facilities and utilities? Does it consider construction permitting and construction phasing? Does it deal with differing site conditions, traffic or operational issues, seasonal constraints or site access limitations? Does it require the testing of piping or electrical and signals?

Unit prices and production rates that have been assumed for the major items of work are reviewed and evaluated on whether the production numbers (that the unit costs are based on) are reasonable and if there are any risks that those unit prices may not take into account (such as high groundwater or the presence of organic material, etc.).

The amount of contingency that is included in each unit price or on the entire estimate is identified and stripped out of the project estimate. This procedure is done in order to develop a "base cost" of the project (the contingency is subsequently replaced by the probable cost of risk and opportunity events).

During the discussions and upon completion of this review, items of work that may be missing and/or over- or underestimated are identified and recorded. Estimates for missing items are developed and recommendations for adjustments are made. Finally, an agreed "base cost" is determined, which becomes the base for the addition of the cost of potential risk (and opportunity) events in the subsequent cost and schedule uncertainty model.

When the base schedule and base cost have been defined, these values are distributed among the project activities as described in the project flow chart. It should be noted that a critical, independent evaluation (validation if possible) of the project team's cost estimate, including a critical assessment of assumptions, is in itself very valuable — as was the case for the validation of the MetroWest Water Supply Tunnel's estimate by the MWRA.

*Define & Assess (Quantify) Uncertainty Events (Including Risk & Opportunity).* A major part of CEVP is to specifically and explicitly address uncertainty, including uncertainty in the base cost and schedule as well as risk and opportunity events. Risk is captured by identifying and characterizing a group of significant risk and opportunity events. A risk event is a possible problem (described in terms of its likelihood of occurrence and potential consequences if it does occur) that, if it occurs, will cause significant impacts to cost, schedule or project performance. Examples of risk events include the potential for additional requirements to meet environmental regulations, the consequences of a natural disaster, adverse geotechnical conditions in constructing high retaining walls or the discovery of unexpected utilities. Whereas risk events reflect potential adverse impacts, opportunity events reflect potential beneficial impacts.

Experts from the project team and other independent experts, who have a valuable perspective on the risk/opportunity issues, develop the list of risks (the risk register) in a workshop setting, or review and supplement a list that has been developed in advance. Uncertainty in the base costs and durations can also be assessed when they are significant, and these are defined consistently with the risk and opportunity events. Relationships among events can also be addressed through correlation, if appropriate.

The CEVP risk workshops are led by an experienced risk elicitator (a risk 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 SMEs who bring an independent perspective on important areas of project uncertainty. The identification and quantification of uncertainties requires a balance of project knowledge, risk analysis expertise, cost estimating expertise and objectivity. Project knowledge and the independent expertise of SMEs are essential to identify the uncertainties. Risk analysis expertise is required to capture balanced information on risk and model uncertainties.

The risk workshop first follows certain preparatory activities, including:

- Appropriate training of participants in the principles and procedures of uncertainty assessment methods;
- Preliminary work with the project team to capture the plan and strategy of the project in a draft flow chart;
- A preliminary list of risks; and,
- Identification and validation of the base costs (the cost validation workshop).

The goal of the risk workshop is to identify and model the uncertainty in project cost and schedule. The objectives and principal activities of this process are:

- To identify potential risks and opportunities by engaging in an open brainstorming process that typically begins with a prior list of potential uncertainties from the project team, lists from similar projects and other sources. In the workshop, it is necessary to provide a critical environment that allows for this initial information to be combined with other suggested risks. As a practical matter, the team should identify screening criteria to help focus on identifying a prioritized list of the significant cost and duration risks.
- To characterize risks and opportunities. This process combines subjective and objective information to identify the consequences to the project if each of the risks were to materialize. Typically there are varying opinions on the range of consequences, such as increased cost or delay, and the risk elicitator is responsible for leading the group to an appropriate consensus to define the consequences of the risks. Independence and correlation among risks is defined.
- To define the likelihood or probability of the risk (and its consequences) occurring.
- To analyze risk information and base costs using a simulation process.

When possible, the risk and opportunity events that the workshop defines should be independent events. When doing so is not possible, the dependencies among events must be defined. In addition, each risk or opportunity event must be identified with the project activities that are affected 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. This information is also incorporated in the cost and schedule uncertainty model and will be reflected in the simulation analysis results.

Risk elicitation within CEVP, and in the risk workshop, is an iterative process that must be able to combine subjective and objective information. Uncertainty characterizations and likelihoods are defined together to provide reasonable and practical descriptions of uncertainty. First-order descriptions and models are sufficiently accurate for most projects.

*Integrate Base (Cost) & Uncertainty (Costs) in a Probabilistic Model.* The next step is to develop and implement a probabilistic model for quantifying the uncertainty in project performance with respect to the stated measures (for example, uncertainty in project cost and schedule to completion). Both escalated and non-escalated (current dollar) costs are provided as outcome by entering a rate of inflation (or different rates for different components, if required) in the model. The analysis is typically done using Monte Carlo simulation techniques. Typically between 1,000 and

**TABLE 1.**
**Ranked Listing of the Cost Risks for a WSDOT Project (SR 520)**

| Rank | Contribution to Risk Cost (%) | Risk Event |
|---|---|---|
| 1 | 26 | T12 — Possible changes to seismic design criteria |
| 2 | 21 | T2 — Sound transit rail N link alignment |
| 3 | 13 | T30 — Project delivery method |
| 4 | 10 | T31 — Other (low risk) items |
| 5 | 10 | T22 — Right of way |
| 6 | 7 | T3 — Market conditions (high bids) |
| 7 | 3 | T14 — Constructability of I-405 I/C |
| 8 | 2 | T26 — Local access improvements |
| 9 | 2 | T28 — TDM |
| 10 | 1 | T16 — Construction staging areas |

10,000 equally likely project realizations (or outcomes) are adequate for the purpose, depending on the desired performance measure (for example, mean value versus probability of meeting a milestone). These realizations are a sample set from the true population of project outcomes. This sample set is used to develop distributions, ranges and statistics for the stated project performance measures. (Cost is referenced here, but other quantities such as schedule can be, and are, quantified.)

*Analyze Results, Write CEVP Report.* Results of the model analysis are presented as cost and schedule probability distributions, usually presented in a graphical form (see Figure 2 on page 62) with supporting tabulations of characteristic statistics. These distributions can describe a variety of situations of interest including:

- Current dollar (time of assessment) versus time of expenditure ($YOE) cost;
- Fully funded or partially funded scenarios;
- Comparative design options;
- Expected date of completion for the project; and,
- Expected schedule to meet project milestones.

Interpreting, documenting and reporting the results conclude CEVP. The specific form of the reported results can vary depending on need, and the results from an evaluation can be used for a number of applications, including:

- Project assessment and management;
- Risk management and value engineering;
- Integrated management of projects and programs;
- Design/build and other construction applications;
- Communications; and,
- Financial management.

CEVP is iterative in nature. For many project applications, it is appropriate to conduct a reassessment of the project from time to time to update project changes, cost and schedule estimates.

## Risk Rankings

Another key output from a CEVP assessment is the ranked listing of those risk and opportunity factors contributing to the uncertainty in a particular estimate such as those illustrated in Table 1. The ranked risk table presents the most important risk issues, along with a measure of their contribution to the total uncertainty in the estimate. The variety of risks — including technical risks, policy risks, environmental risks, construction risks, etc. — can be treated in a consistent way using these data.

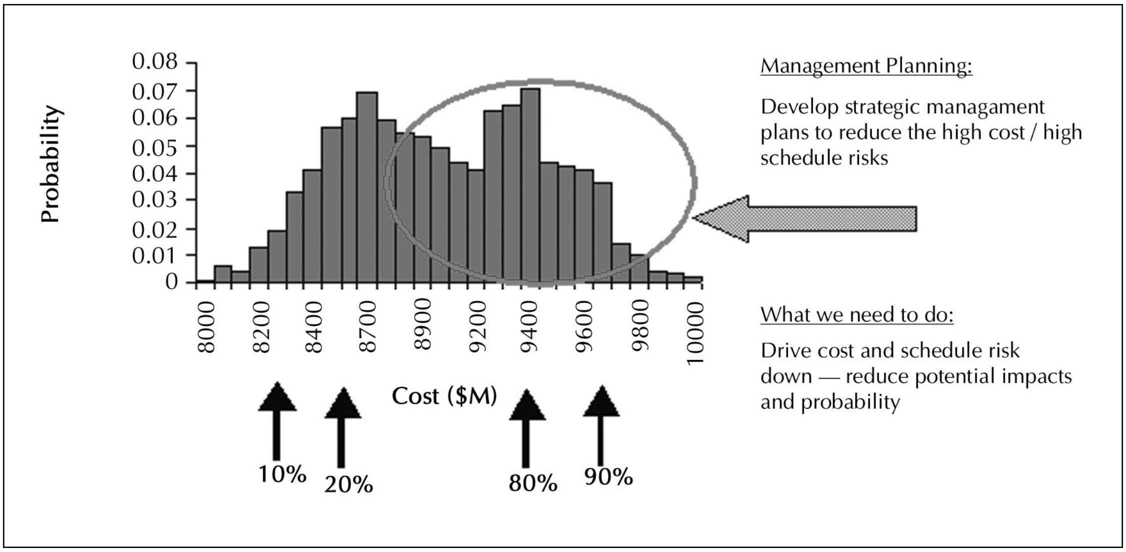



**FIGURE 4. The general risk management approach after CEVP.**

## Risk Management Planning

Early and strategic risk management has been referenced as one of the most important tools for managing the cost and schedule of complex infrastructure projects. It was noted for London's Jubilee Line Extension (which had a cost overrun of 67 percent) that "time and cost overruns could have been minimized with a more established strategy at the very beginning of the project."[11] But how can a viable, more established strategy be determined at the very beginning of the project?

One of the not-so-incidental benefits of CEVP is that it provides an explicit quantification of potential risk and opportunity events that could impact the project's cost and schedule. From this quantified risk profile, risk management plans can be developed earlier in the project life-cycle (see Figure 4). Risk management procedures are well understood and many references are available.[8,9,12]

## Cost Ranges (Probability Mass Diagrams)

Any probability mass diagram or histogram, such as CEVP uses, can be described in more detail to represent important characteristic values of the distribution. As illustrated in Table 2, WSDOT found that representing a few key values, or the range of cost between them, to be very effective in communicating with the public and the legislature about a particular project. Typical of the WSDOT tabular summary of evaluation statistics, this table outlines the mean, the standard deviation, and percentiles, usually ranging from 10 to 90 percent in current dollars, future dollars and duration in months. It has been helpful to have the information in both graphical and tabular formats.

As illustrated in Table 2, the 10 percent probable cost ($268 million) represents that there is a 10 percent chance that the final project cost, in future dollars, will be less than this number. Similarly, there is a 90 percent chance that the project will cost no more than $335 million (there is a 10 percent chance that it could cost more). Especially interesting to the public was understanding that there is, for the current example, an 80 percent chance that the final project, in year of expenditure dollars, will cost between $268 and $335 million. WSDOT's effective communication strategy in reporting the results of the initial CEVP results in June 2002 made extensive use of such values and ranges. Even though some doubted that the public would grasp the concept of cost ranges and probabilistic mass diagrams, experience has shown that this worry did not become a problem and that a uniform image, the probabilistic mass diagram, was used consistently.[13,14]

**TABLE 2.**
**Tabulation of Characteristic Values (Hood Canal Bridge)**

| | Total Project Cost (Future $M) | Total Project Duration (Months After 4/02) |
|---|---|---|
| **Mean** | 311 | 65 |
| **Standard Deviation** | 26 | 5 |
| **Percentiles** | | |
| **10** | 268 | 63 |
| **20** | 278 | 63 |
| **30** | 312 | 63 |
| **40** | 317 | 63 |
| **50** | 320 | 63 |
| **60** | 323 | 63 |
| **70** | 325 | 63 |
| **80** | 329 | 63 |
| **90** | 335 | 75 |

## Requirements for a Valid CEVP Cost Estimate

CEVP requires specific skills, personnel and resources. In general, WSDOT has found that the process requires:

- A knowledgeable and committed owner who wants to know an objective "potential cost";
- A well shaped, complete project estimate and schedule for each scenario to be assessed, with sufficient information about the estimated costs and schedule to be able to separate base data from allowances and contingencies;
- Available/involved team members, including project team members, internal and external SMEs, qualified cost and risk group leaders, and an administrative workshop team;
- A sufficient level of external validation/review;
- Sufficiently good interaction/cooperation of project team and CEVP team members;
- Sufficient process and expertise to "validate" base costs and schedule (if validation cannot be achieved, the result is a "cost-risk assessment");
- Suitable risk modeling technology and experience with uncertainty theory and models for a sufficiently precise probabilistic risk assessment;
- Sufficient expertise to understand the issues involved in a "first-order" analysis and the limitations therein;
- The ability to develop a sufficiently precise range suitable for the design level of the project being considered; and,
- Sufficient time and available resources (personnel, funding and information).

## Facilitating Improved Communications

CEVP avoids false precision when discussing the range of probable costs. False precision can be as big a problem as early optimism because it sends a message of confidence when, by its very nature, an estimate of future costs is sketchy at best.

CEVP also helps manage expectations for budget and schedule. CEVP data allow more informed decision-making by political representatives, agency managers and other involved personnel and this form of communication supports a more informed discussion with the public.

CEVP demonstrated to the public, media and political decision-makers WSDOT's commitment to — and investment in — full, continuous and transparent presentation of its cost estimating process and the results for its projects.

Using the initial CEVP results, updates based on project changes (many in response to the initial results) provided an iterative tool to allow alternatives to be evaluated in the same transparent public process and to be communicated in a predictable manner.

WSDOT clearly understood that the new process and the results needed to be well communicated. Extensive, but simple and understandable documentation was prepared and presented on June 3, 2002, in both printed and web formats.[13] Briefings were given to the public, political decision-makers and the media. Initial results were predictable. One newspaper article latched onto the "overruns."[15] However, subsequent editorials were more gratifying. In an editorial, the *Seattle Post-Intelligencer* stated that "shocking or not, the Department of Transportation has performed an unprecedented public service with these latest cost estimates. It is a much-needed dose of fiscal reality. The department offered realistic cost-range estimates. Giving citizens a range of costs, including full disclosure of the variables, 'is not only politically smart, but it's common sense.'"[16]

The results for each project, or project alternative in some cases, were presented by WSDOT in a uniform one-page format with the key fact of the project and the CEVP results clearly and simply summarized (see Figure 5 on the next page).

## Key Factors to CEVP Success

CEVP, as implemented by WSDOT at this level, is unique in the United States although the component techniques, such as the risk process, have been used widely in other industries.[8-10] Subsequently to CEVP's introduction, there has been enormous interest at the federal and state levels because of its clear approach, and better methodology, to help resolve a chronic problem that has been plaguing the infrastructure industry.

Several key factors were important to the initial success of CEVP in Washington State:

- Cost and schedule assessment or validation procedures, together with risk analysis procedures, were developed based on leading techniques and best practices available from the national and international community.
- Intensive peer engagement in the workshops both engaged and challenged the professional expertise of the workshop teams. This cooperation created an environment conducive to a critical evaluation of the project and its characteristics as well as provided a way to identify new opportunities that could be addressed immediately by the project or in a subsequent value engineering workshop.
- An early and continuous commitment to a uniform CEVP report format that could be clearly understood and useful to non-engineers (including the press, political decision-makers and the public) provided WSDOT with a means to clearly communicate the information and better inform the public. As a result, the media, the public and political decision-makers responded positively to both the reports and the strides toward accountability and the more reliable cost and schedule information that WSDOT was making available.

## Fundamental Lessons Learned

Every project is unique, particularly in the uncertainties and risks to which its eventual "cost to complete" will be subjected as it goes through the stages of concept design, preliminary design, environmental analysis, design, bidding and construction.

The individual elements of a project are subject to different levels and origins of risk that affect cost and schedule, depending on the project's unique circumstances. For example, the risk that costs will be dramatically and unpredictably affected by right-of-way costs are much higher in a corridor like SR 167 (which is planned to be built through a rapid-

**SR 167, Tacoma to Edgewood New Freeway Construction**

**Project Description:**

The project completes SR 167 from Puyallup to the Port of Tacoma.

The new facility provides a six lane freeway including HOV lanes from SR 161 near Puyallup to Interstate 5 and four lanes between Interstate 5 and SR 509 near the Port of Tacoma.

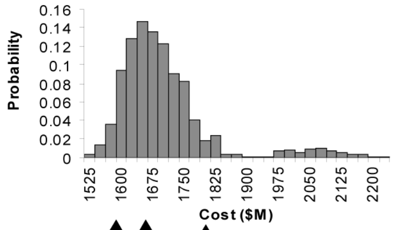
**Project Schedule:**

Estimated Construction Start: 2005

Estimated Completion: 2012 - 2013

*Inflation escalation is to year 2008, the approximate mid-point of construction.*

**CEVP Profile/Result:**




**Best Current Cost Range (BCCR)**

There is a **10%** chance the cost is less than **$ 1.59 Billion**

There is a **50%** chance the cost is less than **$ 1.67 Billion**

There is a **90%** chance the cost is less than **$ 1.78 Billion**

**Benefits this project would provide:**

- Completing this freeway link will help relieve congestion in the lower Puget Sound region by offering commuters, travelers, and shippers an alternative to Interstate 5, especially providing a key link for movement of freight to and from the Port of Tacoma.
- SR 167 will reduce congestion and improve safety on local roads while providing system continuity between the SR 167 corridor and Interstate 5.

**Some events that could impact project cost or schedule:**

This project requires the acquisition of large amounts of property in a corridor where land is rapidly developing. Delays in acquiring new properties will result in significant cost increases to the project.

This project will be constructed near the Puyallup River, Hylebos Creek, Wapato Creek, wetlands and wildlife habitat. Environmental permitting and mitigation requirements may change significantly between now and construction, tending to increase costs and cause delays.

This project includes a major new interchange where Interstate 5 and SR 167 connect. The design of this interchange assumes Federal Highway Administration (FHWA) approval of a number of design features. If not approved by FHWA, changes in the design would result in increased cost and time for the project.

Only a few contractors are qualified to pursue construction projects this large. Less competition may result in higher contractor prices and thus higher project costs.

If all identified risks occur, the cost of the project will be on the high end of the probability curve.

Washington State Department of Transportation

**FIGURE 5. A CEVP one-page summary.**

ly developing area of Pierce County) than for a different project such as the Hood Canal Bridge replacement project through a less-populated area.

Risk identification forces more strategic, early risk management attention and earlier development of risk mitigation approaches, based on quantified and explicit risk information. For example, CEVP helped the project team strategize where to best focus its work to develop a better risk mitigation plan for the Hood Canal Bridge Replacement Project. This risk mitigation plan led to the development and construction of a WSDOT graving dock, which reduced bidding, schedule and environmental risks. It also led to expediting permitting coordination to avoid delay risks. Finally, it led to development of a marketing program to attract bidders to compete for the project.

One of the identified risks in a revised scenario (Scenario B, Port Angeles with Market Conditions) included a risk — "graving dock cultural conditions" — which was given a 10 percent chance of occurrence and was ranked seventh in potential risk impact. No sooner had construction begun on this project than this risk eventuated with the discovery of Indian burial remains in the middle of the project construction site. This discovery led to a significant delay and increased cost to the project.

CEVP, like the best of programs, is not perfect. The graving dock cultural conditions risk was listed, but at a low probability and impact. Of course, other identified risks are equally likely not to eventuate, perhaps balancing the impact of that risk. Any opinion regarding the accuracy the final CEVP result for the Hood Canal Bridge Replacement Project must wait until the completion of construction.

It will take some time and completion of several projects for the accuracy of CEVP to be calibrated. For the Hood Canal Bridge Replacement Project, the contractor's bids were reasonably close to the lower end of the WSDOT CEVP range, as published on the WSDOT website. This occurrence may represent good work, a good CEVP or good luck — or all of these possibilities.

## Concerns & Cautions

The initial WSDOT CEVP application was clearly described as a new and experimental procedure, albeit one that had significant potential to provide better results than historic cost estimates for large, complex projects. In particular, CEVP results are not a warranty that the estimates are perfect, for it is true that the final costs of a project are known only when the project has been finally completed. In some cases, CEVP was applied to projects that were very early in their project development cycle, which led to the result that the CEVP range of costs for such projects was predictably large. Results to date have shown that this range narrows as the project designs are developed.

If a cost-risk assessment is not done correctly, errors can lead to misleading results. For example, if the validation of the base cost estimate is not done well, or the risks are not assessed using expert judgment, the resulting cost and schedule range will be skewed. The quality of the ultimate output reflects the quality of the input. As WSDOT is working to extend CEVP and other cost-risk assessments into its standard business practices, it is challenged with the balancing act of having a tool that is flexible enough to be helpful with many projects, while consistent enough to ensure reliable results and to maintain the integrity of the process.

It is important to use CEVP as intended, which is as an engineering and communication tool. While it may be tempting, and dangerous, to get caught up "tweaking the model," it is more important to focus on what key messages the results express, and to use those messages as information to help make good project management decisions. That being said, it is also important that the project team understands and buys into the results, thus ensuring that the intended risk/opportunity impacts and consequences were determined reasonably and will be managed effectively.

Reporting CEVP results in the form of a range creates several difficulties even though it is a more accurate and meaningful representation. The public may be inclined to focus on the extreme possible (but unlikely values) that might make the project appear too expensive or unrealistic. This reaction may have been the case with some CEVP work, such as the Alaskan Way Viaduct and Seawall Project, which was described as potentially costing up to $11 billion (which was at the extreme end of a conservative range for a project in very early development).

It is also difficult (impossible to date) to gain legislative endorsement on a project with a range estimate. Eventually, a single number is necessary for the legislative planning of a statewide budget. CEVP should at least condition legislators with regard to the limitations of a single-number approach and the "expected unexpected events" that may cause budgets to have to be revised. WSDOT has therefore used the 90 percent range number for legislative approval and budgeting.

A risk-based cost estimate, such as CEVP, must be done carefully and reasonably and must be well communicated. WSDOT recognizes that there are still many unknowns, but it has found that potential risk events that could drive up project costs can be communicated fairly and reasonably to the public. In addition, the early identification of a risk creates management opportunities to minimize the potential of additional project costs associated with those risks. WSDOT has also learned some things about its related current practices. The external peer review provided WSDOT with an evaluation report, which suggested improving their estimating processes, complemented by a standard method of communicating the cost estimate ranges. As a result, from the lessons learned early on with CEVP, WSDOT has taken steps to refine and develop its estimating practices, its overall risk management approach and its strategies for public communications.

## Current Developments

CEVP provides a way to better determine and communicate ranges of probable costs and schedules, and the specific risks and potential variability for large, complex projects very early in the public process. With this disclosure comes better information that the public, and elected officials, can use to make sound decisions, and that engineers can use to better manage their projects.

WSDOT initially applied CEVP to ten projects. WSDOT staff are now gaining so much familiarity with it that in transportation and political parlance in Washington State, "CEVP" [see-vip] has now entered common usage as both a noun and a verb. (Early in the development of the program, thought was given to coining a catchier acronym, and many were suggested, such as CARE for "cost and risk evaluation." These acronyms were rejected by WSDOT. A cost estimating validation process was what WSDOT was seeking to develop, and CEVP it was, from that day forward.)

The cost of the CEVP work itself (not including project team costs) was $1.5 million (approximately 0.006 percent of the projected project costs). Including the project team costs would approximately double this number.

The hallmark of the process was the close and useful collaboration of WSDOT's project teams and the CEVP team members, both external consultants and WSDOT personnel.

CEVP focuses early attention on the significant cost and schedule risks for any project. This emphasis provides an explicit, quantified basis to manage and control cost and schedule early in a project, and then to monitor and manage risk through the life of a project through a risk management plan.

CEVP creates a better mechanism to allow open communications with the public. It also provides a framework to respond to public questions quantitatively and openly. The process allows a more intuitive (to the public) discussion that better relates to "what people already know." For example, the public already knows that projects change and costs usually increase, just like what happens to them when they get an estimate for a car repair or a kitchen remodeling.

If engineering and planning professionals are open and transparent about cost estimating processes and their explanation, it will be possible to embark on a more relevant cost discussion with the public that can be sustained and defended through votes, through project development, through media scrutiny and, ultimately, through project delivery.

WSDOT recognized the value that cost validation and risk assessment provides. WSDOT also recognized that CEVP is not a "magic bullet" or a "quick fix." WSDOT therefore made a commitment to improve its cost estimating process by implementing the CEVP program on a state-wide, long-term basis by using the process extensively and by training its staff. This implementation will revise and standardize WSDOT's cost estimating procedures across departments and regions, and will provide updated tools such as estimating manuals, risk databanks, cost-risk assessment (CRA) services and procedures, CEVP services and other related actions.

CRAs for smaller projects have been implemented, with a simplified process, generally relying mostly on WSDOT staff. CEVP has been scaled appropriately for these projects. To accommodate this development, WSDOT is currently training staff around the state to serve as region or subject matter experts for the CRAs. WSDOT is also working to define the best times, over the life of a project, to conduct a CRA or CEVP, and is experimenting with applicable uses of the CRA and CEVP results.

ACKNOWLEDGMENTS — *Douglas MacDonald and Michael McBride thank Ria Convery at the MWRA for her assistance with this paper. CEVP and its successful application would not have been possible without the commitment and expertise of personnel drawn from WSDOT and its consultants. The initial question, in Washington State of "why can't WSDOT make better cost estimates" was asked of Secretary Douglas MacDonald by State Senator Daniel McDonald. The initial response to Senator McDonald was by Michael McBride, who brought the MWRA cost validation experience from the MWRA's MetroWest Water Supply Tunnel Project into the Washington State setting, and then by John Reilly who suggested other management possibilities, including the inclusion of uncertainty (risk and opportunity) in cost estimates. The initial guideline document for the new process was then developed by John Reilly and Michael McBride with WSDOT managers David Dye (Urban Corridors [UCO] Administrator) and Cliff Mansfield (UCO Design Engineer). The decision to proceed and, importantly, to fund the work was made by David Dye; John Conrad, Assistant Secretary for Engineering and Regional Operations; and Douglas MacDonald. The initial application of CEVP to the ten large, complex highway projects was managed by Cliff Mansfield with initial implementation assistance from John Reilly, Michael McBride, Bill Roberds and Keith Sabol, and, subsequently, from the full specialized consultant team. Facilitation of CEVP and its subsequent implementation and development was managed by Jennifer Brown (currently it is managed by Monica Bielenberg). Important in the initial application and development was the leadership and assistance of the core team consultants, including Bill Roberds, Dwight Sangrey and Travis McGrath of Golder Associates (risk and decision analysis); Keith Sabol of Parsons Corporation (cost assessment); Art Jones of KJM Associates (cost estimating); the National Constructors Group led by Paul Silvestri and his associates (market and bid conditions, construction processes); and Keith Molenaar, Jim Diekmann and Richard Rast of the University of Colorado (process assistance and documentation). The WSDOT project teams and their consultants rose admirably to the challenge of a new process that questioned established ways of doing business and thinking about their projects. This effort required extraordinary dedication and persistence. The authors appreciate the hard work of all the persons mentioned above, including the many unnamed members of the WSDOT project teams, the specialized consultants and the SMEs. CEVP has been registered by WSDOT to recognize its sponsorship of its development and to ensure that the term is not loosely applied in other settings to cost review procedures that contain less than all the tools and controls that have been incorporated into the process used at WSDOT. For further information see www.wsdot.wa.gov/projects/cevp/default.htm, www.true-cevp.com or www.JohnReillyAssociates.com.*

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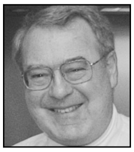

DOUGLAS MACDONALD *has been Secretary of Transportation for the State of Washington since April 2001. He holds degrees from Harvard College and Harvard Law School. He practiced in law firms in Chicago and Boston and also served as the general counsel of Boston-Logan International Airport. He spent nine years as Executive Director of the MWRA, leading a $6 billion program to build new sewage treatment and drinking water delivery systems serving sixty communities in greater Boston.*

JENNIFER BROWN *has worked with WSDOT since 2001, until recently as Manager of the Cost-Risk Estimating and Management Office. Building on her background in organizational change, she was an integral part of the development of CEVP, and was responsible for the integration of CEVP and other cost-risk methodologies into WSDOT's standard business practices.*

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