Designation: E1946 – 18 (Reapproved 2023)

Standard Practice for Measuring Cost Risk of Buildings and Building Systems and Other Constructed Projects[1]

This standard is issued under the fixed designation E1946; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers a procedure for measuring cost risk for buildings and building systems and other constructed projects, using the Monte Carlo simulation technique as described in Guide E1369.

1.2 A computer program is required for the Monte Carlo simulation. This can be one of the commercially available software programs for cost risk analysis, or one constructed by the user.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E631 Terminology of Building Constructions

E833 Terminology of Building Economics

E1369 Guide for Selecting Techniques for Treating Uncertainty and Risk in the Economic Evaluation of Buildings and Building Systems

E1557 Classification for Building Elements and Related Sitework—UNIFORMAT II

E2083 Classification for Building Construction Field Requirements, and Office Overhead & Profit

E2103/E2103M Classification for Bridge Elements—UNIFORMAT II

E2168 Classification for Allowance, Contingency, and Reserve Sums in Building Construction Estimating

E2514 Practice for Presentation Format of Elemental Cost Estimates, Summaries, and Analyses

3. Terminology

3.1 *Definitions*—For definitions of general terms related to building construction used in this guide, refer to Terminology E631; and for general terms related to building economics, refer to Terminology E833.

4. Summary of Practice

4.1 The procedure for calculating building cost risk consists of the following steps:

4.1.1 Identify critical cost elements.

4.1.2 Eliminate interdependencies between critical elements.

4.1.3 Select Probability Density Function.

4.1.4 Quantify risk in critical elements.

4.1.5 Create a cost model.

4.1.6 Conduct a Monte Carlo simulation.

4.1.7 Interpret the results.

4.1.8 Conduct a sensitivity analysis.

5. Significance and Use

5.1 Measuring cost risk enables owners of buildings and other constructed projects, architects, engineers, and contractors to measure and evaluate the cost risk exposures of their construction projects.[3] Specifically, cost risk analysis (CRA) helps answer the following questions:

5.1.1 What are the probabilities for the construction contract to be bid above or below the estimated value?

5.1.2 How low or high can the total project cost be?

5.1.3 What is the appropriate amount of contingency to use?

5.1.4 What cost elements have the greatest impact on the project's cost risk exposure?

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[1] This practice is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.81 on Building Economics.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] This practice is based, in part, on the article, "Measuring Cost Risk of Building Projects," by D. N. Mitten and B. Kwong, Project Management Services, Inc., Rockville, MD, 1996.

5.2 CRA can be applied to a project's contract cost, construction cost (contract cost plus construction change orders), and project cost (construction cost plus owner's cost), depending on the users' perspectives and needs. This practice shall refer to these different terms generally as "project cost."

6. Procedure

6.1 *Identify Critical Cost Elements:*

6.1.1 A project cost estimate consists of many variables. Even though each variable contributes to the total project cost risk, not every variable makes a significant enough contribution to warrant inclusion in the cost model. Identify the critical elements in order to simplify the cost risk model.

6.1.2 A critical element is one which varies up or down enough to cause the total project cost to vary by an amount greater than the total project cost's critical variation, and one which is not composed of any other element which qualifies as a critical element. This criterion is expressed as:

$$IF\ V_Y > V_{CRIT} \tag{1}$$

AND Y contains no other element X where $V_X > V_{CRIT}$

THEN Y is a critical element

where:

$$V_Y = \tag{2}$$

$$\frac{(\text{Max. percentage variation of the element Y}) * (\text{Y's anticipated cost})}{\text{Total Project Cost}}$$

V_{CRIT} = Critical Variation of the Project Cost.

6.1.3 A typical value for the total project cost's critical variation is 0.5 %.[4] By experience this limits the number of critical elements to about 20. A larger V_{CRIT} will lead to fewer critical elements and a smaller V_{CRIT} will yield more. A risk analysis with too few elements is over-simplistic. Too many elements make the analysis more detailed and difficult to interpret. A CRA with about 20 critical elements provides an appropriate level of detail. Review the critical variation used and the number of critical elements for a CRA against the unique requirements for each project and the design stage. A higher critical variance resulting in fewer critical elements is more appropriate at the earlier stages of design.

6.1.4 Arrange the cost estimate in a hierarchical structure such as UNIFORMAT II (Classification E1557 for Buildings or Classification E2103/E2103M for Bridges; Practice E2514 provides a presentation format for elemental costs). Table 1 shows a sample project cost model based on a UNIFORMAT II Levels 2 and 3 cost breakdown for a building. The UNIFORMAT II structure of the cost estimate facilitates the search of critical elements for the risk analysis. One does not need to examine every element in the cost estimate in order to identify those which are critical.

6.1.5 Starting at the top of the cost estimate hierarchy (that is, the Group Element level), identify critical elements in a downward search through the branches of the hierarchy. Conduct this search by repeatedly asking the question: Is it possible that this element could vary enough to cause the total building cost to vary, up or down, by more than its critical variation? Terminate the search at the branch when a negative answer is encountered. Examine the next branch until all branches are exhausted and the list of critical elements established (denoted by asterisks in the last column of Table 1). Table 1 and Fig. 1 show the identification of critical elements in the sample project using the hierarchical search technique.

6.1.6 In the sample project, Group Element B10 Superstructure has an estimated cost of $915 000 with an estimated maximum variation of $275 000, which is more than $50 000, or 0.5 % of the estimated total building cost. It is therefore a candidate for a critical element. However, when we examine the Individual Elements that make up Superstructure, we discover that Floor Construction has a estimated maximum variation of $244 500, qualifying as a critical element; whereas Roof Construction could only vary as much as $40 000, and does not qualify. Since Floor Construction is now a critical element, we would eliminate Superstructure, its parent, as a critical element.

6.1.7 Include overhead cost elements in the cost model, such as general conditions, profits, and escalation (see Classification E2083), and check for criticality as with the other cost elements. Consider time risk factors, such as long lead time or dock strikes for imported material, when evaluating escalation cost.

6.1.8 Allowance and contingency, as commonly used in the construction cost estimates, include both the change element and the risk element. The change element in allowance covers the additional cost due to incomplete design (design allowance). The change element in contingency covers the additional cost due to construction change orders (construction contingency). The risk element in contingency covers the additional cost required to reduce the risk that the actual cost would be higher than the estimated cost. However, the risk element in allowance and contingency is rarely identified separately and usually included in either design allowance or construction contingency. When conducting CRA, do not include the risk element in allowance or contingency cost since that will be an output of the risk analysis. Include design allowance only to the extent that the design documents are incomplete. Include construction contingency, which represents the anticipated increase in the project cost for change orders beyond the signed contract value, if total construction cost, instead of contract cost, is used. See Classification E2168 for information on which costs are properly included under allowance and contingency.

6.1.9 The sample project represents a CRA conducted from the owner's perspective to estimate the construction contract value at final design. General conditions, profits, and escalation are identified as critical elements. Since the design documents are 100 % complete, there is no design allowance. The contingency in the cost element represents the risk element and is therefore eliminated from the cost model. There is no construction contingency in the model since this model estimates construction contract cost only. If total project cost is desired,

[4] Curran, M. W., "Range Estimating—Measuring Uncertainty and Reasoning With Risk," *Cost Engineering*, Vol 31, No. 3, March 1989.