Lecture 86

Cost Risk Analysis Methods for Defence Acquisition Projects

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Abstract

Cost risk analysis is a fundamental process in defence acquisition projects. It allows analysts to examine the impact of individual risks on overall project cost and to estimate the contingency budget amount needed for a desired level of confidence. Different methods for conducting cost risk analysis in defence acquisition projects have been developed in the literature. This paper provides a comprehensive historical review of the predominant research developments in risk analysis from a cost perspective. The paper discusses the underlying assumptions of the different cost risk analysis approaches, their methodologies, and how they can be used to estimate the contingency allowances.

1. Introduction

Military assets are generally appraised at the acquisition stage on the basis of their total life cycle costs. Cost estimates for major defence acquisitions are usually accompanied by a formal risk analysis. Indeed, point estimates (median or average expected cost) of these acquisitions have frequently underestimated the true cost by a wide margin. The reasons for this include changes in the specifications or requirements as the program progresses, optimistic estimates of advances in technology, funding instability, price/cost escalation, and schedule slippage. Although a formal analysis of cost risk will not necessarily reduce the risk inherent in a program, it will help program managers understand the nature of the risks involved, and quantify and display the uncertainty associated with cost estimates. The result is a more realistic assessment of the funding required for a project and of the likelihood of exceeding reported point estimates.

Cost risk analysis is a fundamental process in project management. It provides a means to examine the impact of individual risks on the overall project cost, to determine the likelihood of finishing the project on budget, and to estimate the requisite contingency reserve needed for a desired level of certainty about achieving the cost plus reserve. Cost risk analysis can also identify the most important risks to project cost so risk mitigation can be effective. The analysis of cost risk can be conducted in the project's conceptual development phase as soon as there is a notional budget, and should be updated periodically throughout project execution as the estimate is refined and additional risks are identified and quantified.

The objective of this paper is to provide a comprehensive historical overview of the evaluation of risk assessment methodologies and to highlight recent research developments in risk estimation techniques. It also offers guidelines for applying appropriate statistical and operational research techniques in cost risk assessment.

2. Evolution of Cost Risk Assessment Methodologies in Defence Acquisition Projects

The existing literature on project cost risk analysis has primarily focused on the estimating techniques. Many researchers have contributed to the development of an overall framework. The range of its fields of application includes the environment, finance, project management, and cost estimating (Arena et al. 2006). The military use of cost risk analysis can be traced back to the early 1950s after the end of World War II. Three main periods can be distinguished in this history: the multidisciplinary approach period (1950-1959), the econometric techniques period (1960-1980), and the stochastic simulation period (1990 to present).

2.1 Multidisciplinary approach period (1950-1959)

In the 1950s, scientists were mainly using a multidisciplinary approach including descriptive statistics, probability theory, and mathematical tools to analyze the equipment cost overrun factors (Marshall and Meckling 1959). Over this decade, the most influential event was the introduction of the Program Evaluation Review Technique commonly abbreviated PERT. This statistical tool was developed by the United States Navy in 1957 to analyze the involved tasks in completing large and complex projects. Uncertainty is caused by scheduling a given project without having the details of all the activities. It can be reduced by better understanding of dependencies and improved scheduling of activities (Morris 1994).

2.2 Econometric techniques period (1960-1989)

In the period 1960-1989, cost overruns on many high-visibility public projects started to shed light on the importance of cost risk analysis (Morris 1994). Probabilistic risk analysis started to be recognized as an approved part of policy analysis (National Research Council 1983). During this period of transition, the American Society for Risk Analysis has expanded to become an international organization. The advancement of statistical techniques and the growth of computing power led to more-refined techniques of cost risk analysis.

One of the econometric techniques is the cost growth technique. This technique applies econometric techniques to the costs of a set of historical projects to derive a cost growth factor. The difference between the revised and the estimated costs and the width of the confidence intervals are used as measures of the overall cost risk (Bolten et al. 2008). Dienemann (1966), for example, treated the future cost of a system as a random variable. This random variable is characterized by its probability density function. Integrating this variable between its lowest possible value and some value of interest gives the probability that the final cost will be at or below that value.

2.3 Stochastic simulation period (1990 to present)

In the period 1990 to the present day, personal computers and software packages became widespread and their power continued to increase rapidly. This made the use of stochastic simulation methods for proactive decision making in project evaluation possible. Simulation uses mathematical models, probability distributions, and random sampling to draw instances of results.

There are two main stochastic simulation methods for cost risk analysis (Hulett 2012): Cost driver and risk driver methods. The cost driver method uses a cost breakdown structure of a project and represents each cost line item by a probability distribution indicating the variability in the cost estimate. The risk driver method addresses the weaknesses of the cost driver method by using a risk breakdown structure instead of a cost breakdown structure to perform cost risk analysis. The cost driver method has three main limitations: (1) A cost element may be influenced by several different risks and a risk may impact multiple cost elements. (2) Correlation between cost elements exists in most projects. Using the cost driver method requires the specification of correlation coefficients to represent this phenomenon. These correlation coefficients are particularly difficult to obtain. (3) The method focuses on the impact of risks rather than the risks themselves. It particularly ignores the probability that a risk project event may or may not occur.

A growing body of literature has begun to recognize simulation and convolution as approved methods for proactive decision making in military project evaluation (Arena et al. 2006, US Air Force 2007, NASA 2008, NATO 2012, Maybury 2014). Sokri and Solomon (2014), for example, used a probabilistic risk assessment to portray the major factors of uncertainty and estimate the Next Generation Fighter Capability (NGFC) project cost contingency. The authors showed that the single-figure expected value approach yields a higher predictable value of cost contingency than Monte Carlo simulation.

This period also saw the widespread development by the International Cost Estimating and Analysis Association (ICEAA) of new standards in terminology and application of analysis techniques. The Scenario-Based Method is one of the techniques that ICEAA published in its official professional journal (Garvey et al. 2012).

In parallel to all the developments mentioned above, three simplified approaches have usually been used: The percentage addition method, the expected monetary value, and the qualitative methods. The percentage addition method determines contingency as a percentage addition on the base estimate of a project. This subjective value is sometimes at the 100th percentile guaranteeing enough funds for any upward random variation in project cost (Sokri and Solomon 2014). The expected monetary value estimates contingency as probability times consequence. Kaplan and Garrick (1981) found that the expected monetary value view reduces risk to the expected value of damage. They concluded that this viewpoint alone is not able to express the idea of risk. Qualitative methods use subjective judgments and ordinal scaling techniques to prioritize risks. Risk probability and risk impact are generally described in non-numerical terms such as low, moderate, and high (Hulett 2012).

3. Major limitations

The key decision point in selecting a cost risk method over another is the availability of reliable and relevant data that will be used to assess cost risk. A multidisciplinary approach including a qualitative cost risk analysis would be appropriate early in the project life cycle when there is no or little information about the project. An econometric approach would be appropriate early in the project life cycle when some historical data and limited project information are available. Use of a simulation approach would be recommended when sufficient data on risk drivers or a detailed design specification is available (NASA 2008).

The multidisciplinary approach evaluates each risk to determine how likely it would affect the project cost if it occurs. A major critical consideration of this approach is that it does not take into account the potential correlations among the cost risk drivers. Such a correlation may exacerbate or dilute the aggregated incremental cost. The qualitative part of this approach is based on subjective judgments to prioritize risks. This qualitative analysis should be thought of as a quick and temporary evaluation that should be reviewed as soon as new information is available.

A major limitation of the econometric approach is that it requires a valid relationship between cost and the different risk drivers. The accurate and homogenous historical data required for a formal econometric analysis is not always accessible. The lack of a significant similarity between historic systems and the new one is another major disadvantage of this method.

The level of similarity is generally based on subjective judgement made by analysts.

While both the stochastic simulation and convolution methods can be used to generate a new aggregate probability distribution of the project cost estimate and what is known as an S-curve, they present different benefits and limitations. Convolution involves solving analytical formulas to derive closed-form solutions. Three main approaches are used to combine distributions analytically: manipulation of integrals, moment generating functions, and characteristic functions. The moment generating function, for example, does not always exist. Sometimes its integral does not converge. Simulation can combine all input distributions to generate a possible distribution of the outcome, but it is still unable of determining other aspects of cost risk such as the identification of the most likely risk tolerance level and the determination of the residual risk (United States Government Accountability Office 2009).

4. Conclusion

Cost risk analysis is a fundamental process in defence acquisition projects. It examines the impact of individual risks on the overall project cost and estimates the contingency amount needed for a desired level of certainty. Different methods for analyzing cost risk in defence acquisition projects have been developed. Their military use can be traced back to the early 1950s. These techniques can be separated along historical lines into three main periods: the multidisciplinary approach period (1950-1959), the econometric techniques period (1960-1989), and the stochastic simulation period (1990 to present).

In addition to a comprehensive historical review of these techniques, this paper discusses their underlying assumptions, and describes their limitations. The paper mainly showed that the most difficult step in assessing a risky project is to combine the distributions of different risk factors. There are two major approaches to aggregating risk distributions: stochastic simulation and analytical approach. The simulation approach is very flexible and provides detailed quantitative analysis. The analytical method is very difficult and not practical for most uses and users. Further efforts should be undertaken to address other aspects in cost risk analysis. Any methodology used for the derivation of the estimate should be able to determine a specific risk tolerance and evaluate the remaining risk after mitigation.

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