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Evaluating real options for mitigating technical risk in public sector R&D acquisitions

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Abstract

Government acquisitions requiring R&D efforts are fraught with uncertainty. The risks are often mitigated by employing a multi-stage competition, with multiple vendors funded initially, until a single successful vendor is selected. While decision-makers recognize they are using a real options approach, analytical tools are often unavailable to evaluate optimal decisions. We present an efficient stochastic dynamic programming approach that public sector acquisition managers can use to determine optimal vendor selection strategies in those competitions where Technology Readiness Levels (TRLs) are the measure of progress. We then use examples to demonstrate the proposed approach and provide illustrative numerical results.

Keywords: Real options; Management of science/technology; Project management; Optimization; Public sector public acquisition; Dynamic programming

1. Introduction

Virtually all government acquisition activities possess some elements of risk and uncertainty. However, the acquisition of new capabilities is particularly perilous, especially when the desired capabilities are significant advances beyond current levels of technology, as is often the case in many modern defense acquisitions. These acquisitions frequently require significant research and development (R&D) programs to provide the basic research or technology development and maturation required to produce operational products that deliver the desired capability. In addition to the various cost, schedule, and programmatic risks all government acquisitions face, R&D intensive acquisitions must contend with a higher degree of technical risk. This additional risk is due to broadly defined initial capability or threshold performance levels, changing performance targets during the course of the acquisition as requirements change, insufficient technological maturity to produce the desired capability, or uncertainty regarding the feasibility of any given technological approach. The successful management of technical risk in such long duration, one-of-a-kind R&D acquisitions is crucial for these projects' success [1].

Government acquisition managers often mitigate the technical risk associated with R&D acquisitions through a combination of formal milestone decision points and multi-source, parallel development acquisition strategies [2–4]. For example, consider the Department of Defense's DOD 5000 acquisition process presented in Fig. 1. After the DoD has determined the new capability desired, multiple vendors are initially awarded technology development and maturity contracts to perform the R&D required for successful development of the desired capability. At predetermined decision points, Milestones A and B, resulting

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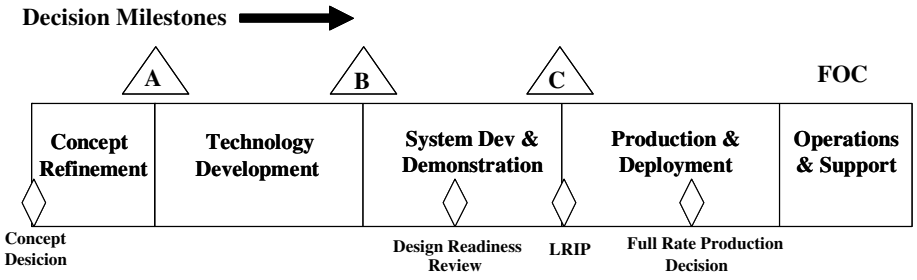

Fig. 1. DOD 5000 acquisition process.

technologies are evaluated to determine which, if any, vendors are selected to continue R&D and capability development efforts. Milestone C decisions will typically evaluate finished prototypes and result in a final down-select to a single winning vendor to commence a low rate of initial production (LRIP) of the fielded capability. It is important to note that the winning vendor may be selected for criteria other than obtaining the highest or most robust technological maturity, such as possessing the technology with the lowest expected total cost or development schedule, or having the highest probability of successful implementation conditional upon their current level of technological maturity.

While these multi-stage, multi-vendor competitions have proven useful for mitigating technical risk, acquisition managers must address a number of key questions to efficiently employ this strategy: How many vendors should be initially funded? How many stages? How should funding be spread between stages? Which vendor should be funded after each decision point? The answers to these questions present difficult tradeoffs that must be faced. For example, are more vendors, theoretically increasing the range of technical alternatives, or fewer, better-funded vendors more likely to increase the probability of successfully acquiring the desired capability on time and within budget? Should more funds be spent in the R&D phase, ensuring a more robust technological solution, or in the product development phase, increasing the likelihood of a smoother implementation? Should the high-cost, mature technology vendor be selected over the low-cost, less mature technology vendor as the winner? Of course, the answers to these questions depend upon the precise nature of the given acquisition program. However, a lack of formal models to address the optimal design of these competitions typically leads to *ad hoc*, qualitative solutions to these questions.

Real options valuation techniques provide an analytical framework to find optimal solutions to these problems. In fact, acquisition managers often recognize that they are employing a real options approach by structuring such a competition [1], [5]. The contribution of this paper is the formulation of a stochastic dynamic program that public sector acquisition managers can use to determine optimal vendor selection strategies in such multi-stage, multi-vendor competitions. Though stochastic dynamic programming is a standard method of evaluating decisions under uncertainty, our paper is unique in the kind of decisions that we consider. Real options models typically demonstrate the increased benefits of managerial flexibility that can be achieved through the inclusion of additional options. This makes these models an ideal approach for evaluating the dynamic investment decisions in R&D portfolios, where the numbers of distinct options grow over time as R&D projects progress. However, the vendor selection problem is quiet different in that the acquisition manager starts with many different options and then chooses to potentially reduce the number of options as the project progresses. This decreasing options problem has been ignored by the literature and the suggested solution methodology constitutes a useful, practical approach for devising optimal vendor selection strategies. Moreover, using our approach, acquisition managers may find optimal strategies that would not likely have been considered without formally modeling the acquisition's options.

2. Public sector R&D acquisitions

Unfortunately, while there exists a robust literature on the use of real options to manage uncertainty in R&D projects [6–14], this literature fails to account for the peculiarities of public sector R&D acquisitions. This is not to imply that the technical risks in public sector R&D projects are somehow different than those encountered in private sector R&D efforts. For example, the likelihood that a specific, scientific breakthrough occurs or whether developmental subassemblies can be successfully integrated according to the system's initial design are common to both the public and private sectors. Rather, it is the relative rigidities of the public sector acquisition process that influence the available approaches for mitigating the various technical risks that may occur during an R&D project. Commercial R&D projects are largely internal to the firm with direct management oversight to guide and direct as technical issues arise. While a portion of public sector R&D is performed in government facilities, a majority of the R&D required for new capabilities is either sourced to private vendors or simply embedded within the contracts issued for the completed capability. This significantly reduces the public sector's ability to directly mitigate technical risks as they occur, subject to the provisions incorporated and