Summary

An Integrated Real Options Framework for Model-based Identification and Valuation of Options under Uncertainty

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Abstract

Complex systems and enterprises, such as those typical in the aerospace industry, are subject to uncertainties that may lead to suboptimal performance or even catastrophic failures if unmanaged. This work focuses on flexibility as an important means of managing uncertainties and leverages real options analysis that provides a theoretical foundation for quantifying the value of flexibility. Real options analysis has traditionally been applied to the valuation of capital investment decisions by considering managerial flexibility. More recently, real options have been applied to the valuation of flexibility in system design decisions. However, different applications of real options are often considered in isolation.

This thesis introduces an Integrated Real options Framework (IRF) that supports holistic decision making under uncertainty by considering a spectrum of real options across an enterprise. In the context of the IRF, enterprise architecture is described in terms of eight views and their dependencies and modeled using a coupled dependency structure matrix (C-DSM). The objective of the IRF is to leverage the C-DSM model in order to identify and value real options for uncertainty management.

The contributions of this thesis are as follows. First, a new characterization of a real option as a *mechanism* and *type* is introduced. This characterization disambiguates among 1) patterns of mechanisms that enable flexibility and 2) types of flexibility in a system or enterprise. Second, it is shown that a classical C-DSM model cannot represent flexibility and options. The logical C-DSM model is introduced to enable the representation of flexibility by specifying logical relations among dependencies. Third, it is shown that in addition to flexibility, two new properties, optionability and realizability, are relevant to the identification and analysis of real options. Fourth, the logical C-DSM is used to estimate flexibility, optionability and realizability metrics. Methods that leverage these metrics are developed to identify mechanisms and types of real options to manage uncertainties. The options are then valued using standard real options valuation techniques. The framework is demonstrated through examples from an unmanned air vehicle (UAV) project and management of uncertainty in surveillance missions.

Introduction

The goal of decision making under uncertainty is to make decisions that manage the risks that arise from uncertainty while simultaneously enabling the pursuit of opportunities. Uncertainties facing complex systems, system of systems or enterprises may be managed through flexibility. A real option gives the decision maker the right, but not the obligation, to exercise an action or decision at a later time, thereby capturing the essence of flexibility. An important motivation for framing flexibility as a real option is to utilize algorithms for quantitative valuation of options in order to value flexibility. Real options valuation has traditionally been applied to the valuation of

business investment decisions under uncertainty. More recently, real options methods have been applied to value flexibility in the context of system design. Although real options analysis has been applied to different domains, such as strategic investments and product design, there is no integrated framework that enables systematic exploration of real options. The objective of this research is to develop a model based framework to systematically identify and value: 1) what type of flexibility, if any, is desirable to manage uncertainty? 2) how to enable flexibility? and 3) where to enable flexibility in a complex system or enterprise?

Summary of Chapter 2 – Modeling Enterprise Architectures using C-DSM

This chapter presented research at the intersection of enterprise architecture and knowledge representation using the coupled dependency structure matrix (C-DSM). The first part of this chapter presented background on enterprise architecture and a holistic framework of describing an enterprise through eight views and dependencies. The second part of the chapter discussed representation frameworks for enterprise architecture and engineering systems, focusing in particular on the C-DSM framework that is amenable for dependency modeling and analysis of complex systems. The C-DSM representation was then adapted to an Enterprise C-DSM for holistic modeling of enterprise architecture through eight views and dependencies within and among these views. Scalability of the C-DSM representation and the scalability of the methodology for constructing the C-DSM through abstraction, distribution and automation were discussed.

The Enterprise C-DSM modeling is the first step of the integrated real options framework (IRF). Given that the Enterprise C-DSM model forms the basis for identifying real options to manage uncertainty, limitations of existing C-DSM based methods for analysis of real options and flexibility were discussed. An important is that the C-DSM model cannot represent flexibility and options.

Summary of Chapter 3 – Real Options: Mechanisms and Types

This chapter focused on the intersection of real options and enterprise architecture. The first section presented background on options as a formal framework for modeling flexibility to manage uncertainty. Specific challenges in the real options domain were then discussed, including the isolated applications of real options and varying senses of the real options terminology in the literature. A new characterization of a real option was introduced to distinguish among the mechanisms and types of real options, which represent the sources of flexibility and types of flexibility, respectively. The distinction among mechanisms and types of options becomes increasingly important for complex systems and enterprises where various interactions among sources and types of flexibilities emerge. The relations among mechanisms and types of options were presented. It was shown how the mechanism and type characterization enables a more holistic exploration of real options.

The link between the new real options model and the eight views framework of enterprise architecture, as described in Chapter 2, was established through a generalized mapping of mechanisms and types of options to the enterprise views. This mapping was verified through

examples of deployed mechanisms and types of options in various domains. Examples of generalized patterns of mechanisms that enable flexibility were also presented.

Summary of Chapter 4 – Metrics for Identifying Mechanisms and Types of Options using Logical C-DSM

This chapter focused on the intersection of real options and C-DSM, with the goal of using the C-DSM to identify mechanisms and types of real options. It was shown that the traditional C-DSM model does not have the expressivity to model flexibility and choice. The logical C-DSM was introduced to enable the modeling of options by specifying logical relations among dependencies. Three properties: flexibility, optionability and realizability were defined in the context of real options. Flexibility was defined as the ability to exercise types of options to manage uncertainty. Optionability was defined as the ability to enable types of options. Realizability was defined as the ability to implement a given type of option. The logical C-DSM was then used to estimate flexibility, optionability and realizability metrics, in order to support the identification and analysis of mechanisms and types of real options.

Summary of Chapter 5 – Integrated Real Options Framework

This chapter focused on the intersection of real options, C-DSM modeling and enterprise architecture. The logical C-DSM and metrics introduced in Chapter 4 were used in an integrated method for identifying the mechanisms and types of real options that encompass the enterprise views. Alternative uses of the flexibility, optionability and realizability metrics to analyze the interactions among mechanisms and types of options were discussed. An expanded method was introduced to incorporate the creative identification of options that encompass the enterprise views. The framework was demonstrated through application to the management of uncertainties in surveillance missions and to specific examples from an unmanned air vehicle (UAV) project.

Conclusion

The integrated real options framework enables holistic identification, synthesis and analysis of mechanisms and types of real options for managing uncertainties facing complex systems and enterprises. The characterization of a real option as <mechanism, type> should be adopted to emphasize sources of flexibility and support integration of real option silos. Mapping of mechanisms, types of options and their relations to enterprise views is a generalized classification that encompasses many others and can promote systematic thinking about flexibility. Finally, the logical C-DSM should augment classical C-DSM for modeling flexible systems and choice to support systematic analysis of options.