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Identification, ranking, and management of risks in a major system acquisition

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Abstract

Risk management is essential to protect the quality of a large-scale engineering effort. It should be a well-defined process that builds on an encompassing and detailed understanding of the purpose, elements, and contexts of the system. It should accommodate qualitative and quantitative information in understanding sources of risk. In an application paper, we use hierarchical holographic modeling (HHM) to identify sources of risk in the acquisition of a large ($1 billion US) software and database system. HHM provides a framework to integrate the perceptions by managers and analysts of what could go wrong in the acquisition. In addition, we filter and prioritize the identified sources of risk based on their likelihoods and potential consequences. Finally, we generate and evaluate alternatives for risk management, focusing on potential impacts to the acquisition schedule.

Keywords: Risk management; Risk ranking; System acquisition; Risk assessment; Systems analysis and engineering; Multiobjective decision making; Technology management; Cost overrun; Schedule delay; Hazard analysis

1. Introduction

The identification and management of sources of risk to complex systems can be aided by the consideration of multiple, complementary decompositions of the problem using hierarchical holographic modeling (HHM). Identification of sources of risk can make use, in turn, of different perspectives on the system in terms of its organizational and functional hierarchical structures; the various time horizons; the multiple decision makers, stakeholders, and users of the system; and the host of institutional, legal, and other socioeconomic conditions that require consideration [6]. The contribution of this paper is the application of an HHM-based methodology for identifying, prioritizing, and managing perceived sources of risk in the acquisition of a large-scale software and database system. In Section 2, we describe some relevant literature. In Section 3, we introduce the problem of the risk management of the acquisition of a large data-management system. In Section 4, we describe the application of the HHM to identifying sources of risk. In Section 5, we address the ranking of the identified sources of risk. In Section 6, we demonstrate the evaluation of risk management options and, in Section 7, give some conclusions of the paper.

2. Literature review

It is common in decision and policy analysis to accommodate multiple decision makers and stakeholders by trying several different models of the same system. Blauberg et al. [2] propose that in order to understand and analyze a large-scale system, the fundamental principles of wholeness (representing the integrity of the system) and hierarchy (representing the internal structure of the system) must be supplemented by the principle of the "multiplicity of descriptions for any system: in order to obtain adequate knowledge about a system one has to construct a certain class of its descriptions, each of which can only cover certain aspects of the wholeness and hierarchy of the system." In hierarchical holographic modeling [5,10], multiple models represent various perspectives on the complex system. HHM recognizes that no single vision or perspective is adequate. HHM identifies and coordinates multiple, complementary decompositions of the system, where a *decomposition* is a hierarchy of the system's components, subcomponents, and sub-subcomponents that captures the structure of a particular view of the system [8,11].

The basic questions of risk assessment are [15]: What can go wrong (what are the sources of risk)? What are the likelihoods? What are the consequences? The basic

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questions of risk management are [6]: What risk management policies are available? What are the costs, risk measures, and trade-offs associated with the policies? What are the impacts of current decisions on future options? Ranking of sources of risk to complex systems has been considered by Morgan et al. [18,19], and Webler et al. [24]. Preliminary hazard analysis; subsystem and system hazard analyses; and failure modes, effects, and criticality analysis (FMECA) are described by Kales [13], Bahr [1], Kumamoto and Henley [16], and Roland and Moriarty [22] (the terms *failure scenario*, *hazard*, and *source of risk* are for us equivalent, and *source of risk* is used herein. The term *risk* itself implies the variety of measures of the probability and severity of adverse effects to performance, revenues, costs, and schedule [14,15,17]). Typically hazard analyses proceed from a single hierarchical decomposition of the functions of the system (see, e.g. Ref. [1]).

Haimes and Li [7] describe how alternate perspectives can be used to generate a more complete representation of sources of risk [7,12]. HHM has been applied to support software development [3] and global sustainable development [9]. The analytic hierarchy process, which is used below for resource allocation to risk management, and other methodology of multiattribute analysis are described by Pomerol and Barba-Romero [21] and Saaty [23]. Oliver and Smith [20] describe the methodology of influence diagrams, which are also used below, for decision and policy analysis. Grey [4] describes methodology for quantification of cost-overrun and schedule risks in project management.

3. Problem description

Managers of a large database acquisition project commissioned the authors to provide support to their risk management effort. The complexity of the project involved advanced hardware and software, translation of an immense database of text and graphics, personnel from many organizational units, transitional program phases spanning more than five years in implementation, and over one billion dollars ($1 billion US) in investment. First, a process for identification of the sources of program risk by the system managers and the analysts was needed. Next, it was important for program managers to agree on priorities to reduce the likelihood of the program failing to meet its schedule, cost, and performance objectives. A ranking methodology was developed to improve the allocation of limited resources for risk management. Lastly, alternative policies for risk management of the acquisition schedule were developed and evaluated. Numerous interviews with program managers and technical experts were conducted at the work site by the analysts. Reviews of internal documents were also essential to the process of identifying, prioritizing, and mitigating sources of risk.

4. Identification of sources of risk

Information has been collected in an integrated approach using six mechanisms:

1. Interviews at the work site with approximately twenty managers.
2. Review of requirements documents and other program planning materials.
3. Review of third-party analyses of the cost and schedule for the project.
4. Review of a list of risks prepared by program managers.
5. Consultation with a third-party management consultant familiar with the program.

Fig. 1 depicts the multiple views of the software acquisition using the HHM approach. The methodological framework for identifying sources of risk associated with the system consists of eight major perspectives as depicted in Fig. 1: (a) program consequence (technical, cost, schedule, and the user); (b) management of change (personal trustworthiness, interpersonal trust, managerial empowerment, and institutional alignment); (c) system acquisition (contractor, contract management, requests for proposal (RFPs) and contracts, and system integration); (d) temporal (design and planning, transition, steady state, and system expansion); (e) modal (external, hardware, software, organizational, and human); (f) information management (process control, information storage and retrieval, information transmission, and data analysis); (g) functional (subsystems U, V, W, X, Y and Z); and (h) geographical (primary site, secondary site, region P, region Q, and region R).

The identification of sources of risk relies on the multiple decompositions, or perspectives. After each main-level vision is introduced, a more detailed and comprehensive discussion of the underlying hierarchical structures is begun. In interviews with experts to identify new sources of risk to the large-scale technological system, an initial subset of two or more of the hierarchy's decompositions is used to formalize and structure the identification process. Later, inclusion of additional decompositions provides increased detail and focus to the identification process. For example, one vision or decomposition of the risk for the database system is the *functional* perspective, focusing on the various services that the system will provide. From a functional view, the database system is decomposed into five major subsystems. These functional areas are then evaluated for sources of risk by cross-reference to other decompositions. Another vision of the HHM relates to the acquisition process over time. Each of the overlapping stages of the system acquisition, although not sharply distinguishable, constitutes a subsystem in the *temporal* decomposition as depicted in Fig. 2. Each stage in the temporal decomposition can be viewed as a temporary fixing of the time frame, for example the design-and-planning stage, in the acquisition process. Within each fixed-time frame, risks associated with