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A Knowledge and Analytics-Based Framework and Model for Forecasting Program Schedule Performance

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Abstract

This paper discusses a mixed methodological approach to address cost and schedule delays in large-scale engineering programs (LSEP). Research has identified potential causes or factors for schedule delays, such as: ineffective human resources policies and practices, consolidation of the aerospace industry, too many stakeholders, and lack of knowledge-based acquisition practices. Current methods and tools are ineffective in helping project managers to accurately predict schedule performance during LSEP development. The authors describe research to investigate the feasibility of: (1) deriving quantitative and qualitative causal factors correlating to schedule performance during LSEP development; (2) developing a framework and a tailorable predictive model using the causal factors in a Bayesian Network (BN) model; and (3) using the resultant framework and BN model, with expert knowledge elicited from subject matter experts, to predict schedule performance and inform decision makers on actions needed to manage schedule performance. Finally, this paper discusses a version of a BN model developed by mapping a conceptualization of the framework created using a systemigram with a BN pattern that includes dependencies from causal and control factors to schedule performance. The BN incorporates a direct causal dependence of schedule performance and mitigation actions to the consequences of schedule performance.

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1. Introduction

The authors' previous research has determined significant cost overruns, schedule delays, and quality gaps are commonplace during the performance of large-scale engineering program (LSEP) development[1]. This research also identified potential causes or factors for these schedule delays, including: (1) concurrent testing and production, (2) optimistic assumptions, (3) delayed testing, (4) insufficient tradeoffs among cost, schedule, and technical performance requirements during early planning, (5) unrealistic cost and schedule estimates, (6) insufficient testing during development, (7) insufficient attention to reliability[2], (8) unrealistic performance expectations, (9) inadequate risk assessment, (10) unanticipated technological or manufacturing issues and (11) funding instability or inadequacy[3]. The authors thereby concluded that the ability of project managers to accurately predict schedule performance during LSEP development is in need of improvement. In response, the authors are performing research to investigate the feasibility of: (1) deriving quantitative and qualitative causal factors correlating to schedule performance during LSEP development; (2) developing a framework and a tailorable predictive model using the derived quantitative and qualitative causal factors in a Bayesian Network (BN) model; and (3) using the resultant framework and BN model, with expert knowledge elicited from LSEP subject matter experts (SME), to predict schedule performance and inform LSEP decision makers on actions needed to manage LSEP schedule performance[1].

With cost overruns and schedule delays commonplace during LSEP development across diverse industries, there is great value in developing a framework of methods, models, and tools to predict LSEP schedule performance such that control and mitigating activities can be planned and executed when schedule delays are predicted. Furthermore, there is great value in assessing the effectiveness and impact of proposed mitigating activities using the same framework and predictive tool. A key aspect of this research is the leveraging of expert knowledge to assess historical LSEP performance data to develop quantitative and qualitative factors with strong causal relationships to LSEP development schedule performance. The authors are modeling these correlated factors into a predictive tool using the systemigram depicted in figure 1. As such, the authors are performing research in the area of knowledge elicitation and applied predictive analytics, including Bayesian statistics, methods, and tools[1].

2. Background

The authors' review of assessments of Major Defense Acquisition Programs (MDAP) performed by the United States (US) Government Accountability Office (GAO) and the Defense Advanced Research Projects Agency (DARPA) revealed significant cost overruns, schedule delays, and quality gaps are commonplace. Review of assessments by the GAO on National Aeronautics and Space Administration (NASA) projects showed continuing cost and schedule growth associated with its major projects as well[1,4,5] . For example, a 2008 GAO report on 95 weapons systems indicated a total cost growth of $295 billion for these programs, at an average program schedule delay of 21 months. Further analysis of GAO weapon systems cost and schedule data shows that the average schedule delay in providing new war fighter capabilities was 16 months in 2000, as compared to 21 months in 2007[6].

A significant finding discovered during the authors' research is that DARPA is projecting that the US Government is rapidly approaching the time when supporting a single airplane program will require appropriating its entire defense budget[7]. DARPA's projection is based on their META program[7,8] which show the rate of growth in the time and cost to design, integrate, and test complex aerospace systems, is increasing between 8 to 12 percent per year since 1960. More importantly, META program data indicates a five times reduction in the product development lifecycle is required to become sustainable[7].

2.1. Related Research and Alternate Approaches

The authors' initial research identified related research in which the use of BNs and expert knowledge were used to enable probabilistic processes and methods for risk-informed decision making[1]. This research included work performed by the Systems Engineering Research Center (SERC) and the Stevens Institute of Technology (SIT)[9], Khodakarami[10], Xiao-xuan[11], and Kuhnert[12]. Subsequently, the authors have found additional approaches to predicting and managing project schedule performance.