STOCHASTIC MODELING FOR QUANTIFYING OPTIMAL INCENTIVE AMOUNTS OF EARLY PROJECT COMPLETION

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ABSTRACT: An effective Incentive/Disincentive (I/D) rate should fall above what a contractor needs to turn a profit by exceeding Contractor's Additional Cost (CAC) for expediting construction and below the total cost saving by the agency. However, determining this type of I/D rate has been extremely challenging because of contractor's reluctance to disclose pertinent CAC data and state transportation agencies' lack of a systematic method for determining I/D rates, resulting in frequent misapplications and substantial losses in public resources. The objective of this study is to develop an effective method for determining I/D amounts for high-impact infrastructure projects. To achieve its objective, this study employs an integrated analysis to capture schedule, CAC, and total savings concurrently by combining an existing scheduling simulation with a stochastic analysis. A regression analysis is performed to predict the CAC growth rate by analyzing the relationship between CAC and the agency's specific schedule goal. A stochastic model that accounts for heterogeneity of drivers' value of time is developed to estimate the total savings achieved by early completion. The robustness of the proposed model is then validated through a case study.

***Keywords**: Infrastructure, Rehabilitation, Innovative Contracting, Incentive/disincentive, Decision-support Model, Stochastic Modeling, Road User Cost*

1. INTRODUCTION

In an effort to motivate contractors to complete construction projects early on critical transportation infrastructures, State Transportation Agencies (STAs) have often used Incentive/Disincentive (I/D) contracts. These reward contractors with bonuses for early completion of projects and levy fines for delays. The practice is in common use – a preliminary analysis of innovative contracting projects completed by the Ohio Department of Transportation from 2004 to 2007 revealed that 95 of 196 used incentive contracts for projects with average costs of $6.1 million – and I/D contracts have shown to be effective in satisfying the public's expectation for early project completion.

The amount of compensation specified in I/D contracts not only affects contractor project performance, but it also reflects how an STA spends taxpayer money. To encourage competitive contractors to bid on projects, an agency must offer I/D amounts greater than the Contractor's Additional Cost (CAC) while keeping overall costs low enough to prevent strains on project budgets. In practice, STAs have mostly determined I/D rates by their impacts on road user cost, as measured as savings or in delays. However, this has often resulted in frequent misapplications and substantial losses of public resources. Determining I/D rates that promote early completion of projects, exceed

CAC, but are below the total cost savings realized by the agencies, is extremely difficult. Contractor reluctance to disclose pertinent CAC data is part of the problem, but the larger issue is that there is no systematic method and tool for helping STAs determine effective I/D rates.

The primary objective of this study is to develop a new decision-support model for determining the most realistic and economical I/D dollar amounts for critical high-impact highway improvement projects. To achieve its objective, this study employs an integrated analysis including project schedule and the lower and upper bounds of the I/D contract. The lower bound is the contractor's additional cost of acceleration, and the upper is the total savings to road users and to the agency. Using these parameters, an existing scheduling simulation is combined with a stochastic analysis. First, schedule simulations using an innovative software tool called Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS) are conducted to create data that demonstrate the tradeoff between contractor schedules and costs. Second, using the tradeoff data, a regression analysis is performed to predict the CAC growth rate by analyzing the relationship between CAC and the agency's specific schedule goal. Third, a stochastic model that accounts for heterogeneity of drivers' value of time is developed to estimate the total savings achieved by early completion. The proposed new methods recognize driver's value of time as heterogeneous and incorporate it as a variable factor along with project schedule, contractors' additional costs, and uncertainties in other key parameters. Lastly, to determine the most appropriate I/D rate for a given project, a Bayesian approach is applied by jointly modeling I/D as a function of road user cost, CAC, and other uncertain variables. The robustness of the proposed model is then validated through several case studies.

The model and recommendations made through the study will assist STAs engineers and decision-makers to establish more accurate budgets for I/D (i.e., not overestimating the I/D rate) and also significantly reduce the agency's expenses in the time and effort required for determining I/D dollar amounts. Critically, use of the model will directly impact current ad-hoc practices for determining I/D rates. When completed, it will provide a reliable method that STAs can use to determine the most economical I/D dollar amount for a given project – an optimal value that allows agencies to stay within budget while effectively motivating contractors to complete projects ahead of schedule. The integrated Bayesian approach to determining an appropriate I/D rate will provide a scientific justification of the I/D rate from a cost-benefit perspective. A more effective I/D rate can contribute significant monetary savings to the agency, which translates to better use of public funds.