Development of Pay Factors for QA/QC Concrete Compressive Strength

James Sullivan, Transportation Research Center
David Novak, Grossman School of Business
University of Vermont

VTrans Working to Get You There — Vermont Agency of Transportation

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Abstract

The ability to measure and assess "quality" is essential in building and maintaining a safe and effective transportation system. Attaining acceptable quality outcomes for transportation projects has proven difficult at both the federal and state levels, at least partially, as a result of ineffective QA/QC processes. In this project, the team developed a new QA/QC process that includes a double-bounded performance-related specification (PRS) and corresponding pay factor schedule, with both lower and upper acceptance and reward boundaries for concrete compressive strength (CCS) of in-place bridge concrete.

Historical data was used to design a variety of payment scenarios illustrating likely industry responses to the new PRS, and the single scenario that best balances risk between the agency and industry was selected. A final schedule was determined after soliciting input from the industry. The payment incentives were then converted to a pay factor schedule using a search heuristic based on achieving statistical compliance with the percent-within-limits (PWL) method.

An important finding is that, with a double-bounded asymmetrical PRS, it is not possible to represent pay factors using the simplified PWL tables currently employed in practice because each PWL value occupies two separate positions in the payment structure – one above the design target and one below it. This means that a more detailed set of pay factors must be employed, which explicitly specify the mean sample value relative to the design target.

Payment Incentive Design Approach

In this project, there were two key constraints related to the payment incentives design: 1) budgetary constraints, and 2) constraints on the payment design structure. The payment penalty / reward structure was designed with the underlying goal of shifting the mean CCS down from nearly 6,900 psi (based on historical data) toward a new design target of 4,900 psi, while simultaneously resulting in a net over-payment of 3% when compared to baseline industry payments made without pay factors. The payment structure is defined by the peak incentive location, the reward boundaries, and the acceptance boundaries (Figure 1). Rewards are shown as black bars protruding up from the 1.0 axis to the reward level and penalties are shown as black bars protruding down from the 1.0 axis to the penalty level. Note that the incentive structure is not symmetrical.

We provide an illustrative example of a "steep" and "gradual" payment structure in Figure 2. Although both payment structures result in the same net overpayment, the steeper payment structure can increase risk for both VTrans and industry.

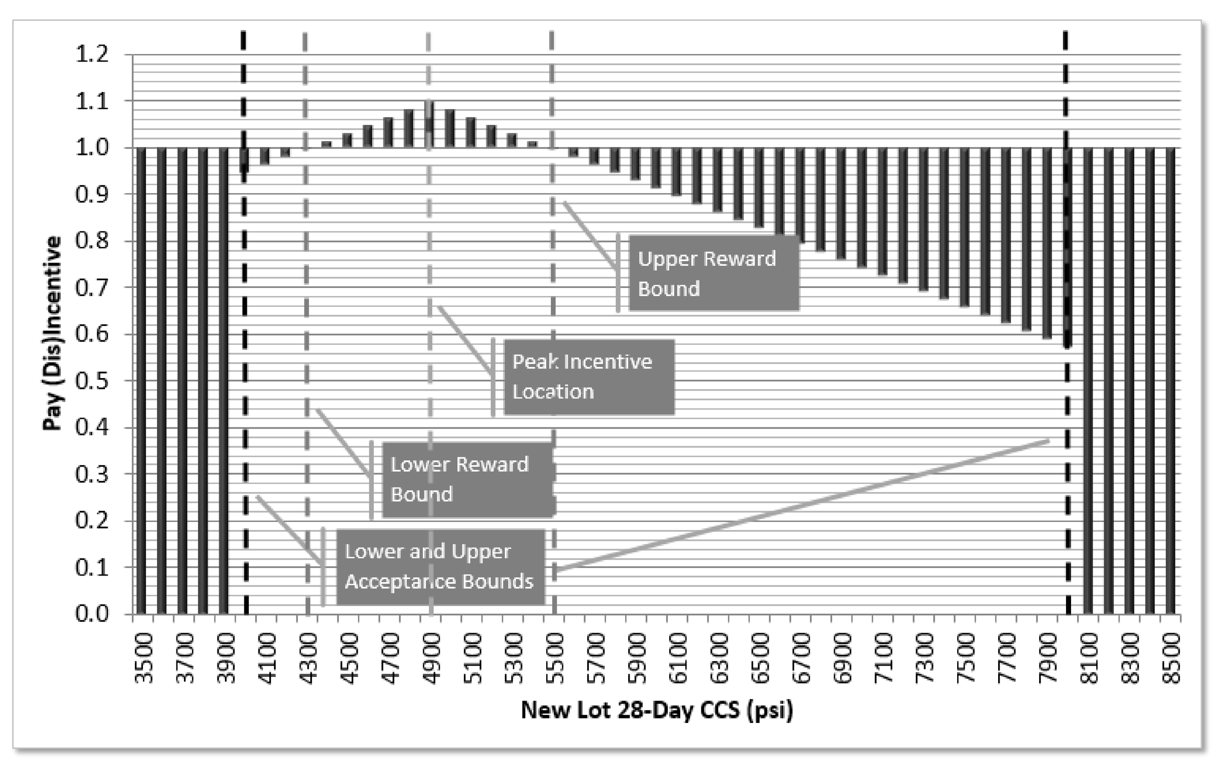

Figure 1 Hypothetical Payment Incentive Structure with Reward and Acceptance Boundaries

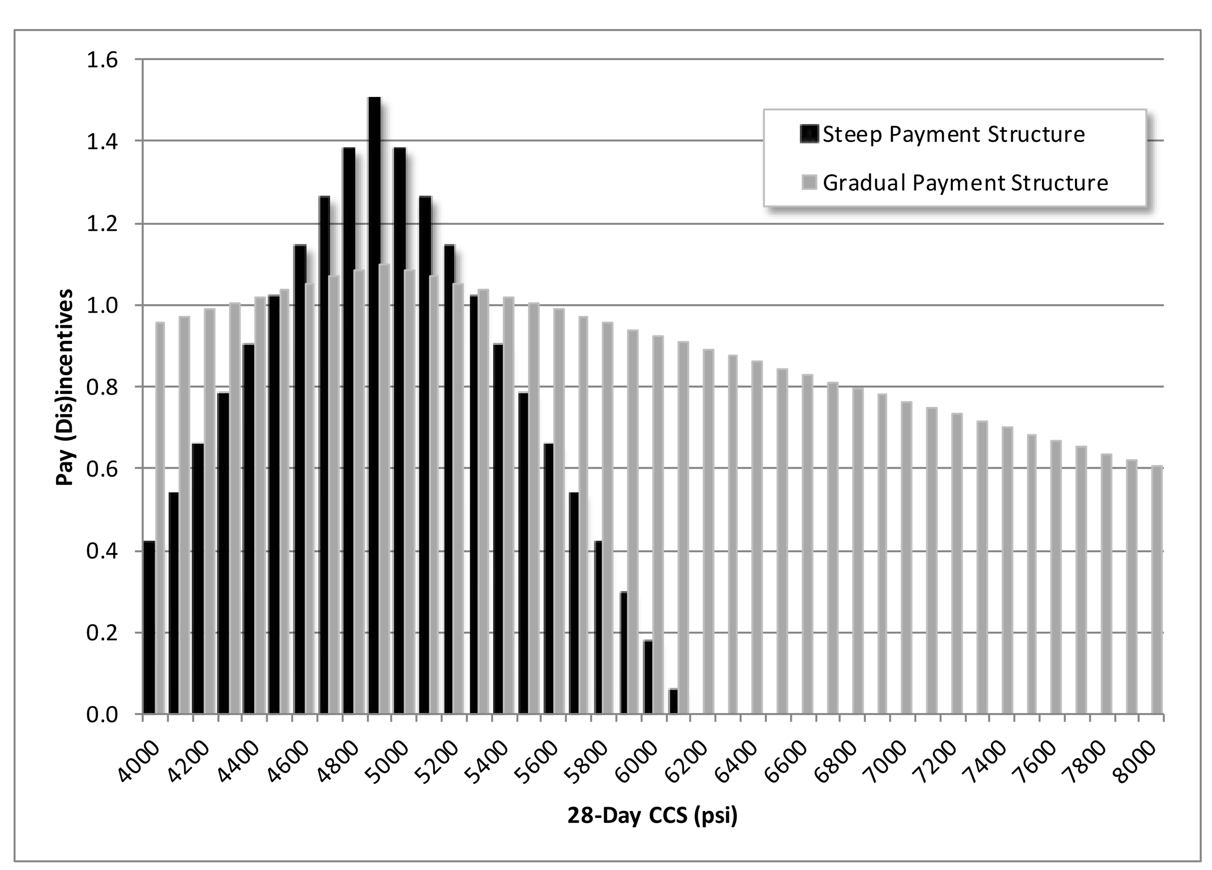

Figure 2. Example of a Gradual vs. Steep Payment Incentive Structure

Simulated Industry Responses

In order to constrain a range of possible incentive structures to the net overpayment of 3%, it was necessary to develop a set of simulated industry responses to the new pay factors. A total of 7 different "scenarios" were evaluated, each consisting of a unique simulated industry response. The 3 most realistic scenarios, denoted as F-a, F-b, and F-c, each utilized the same peak incentive location (4,900 psi), and the same upper and lower acceptance boundaries (8,000 and 4,000 psi, respectively). F-a and F-b assumed tighter distributions around the peak incentive, with standard deviations of 500 psi and 250 psi, respectively, whereas F-c assumed that the standard deviation would match the historical data (1,000 psi). F-c also relaxed the upper reward boundary slightly (5,900 psi). These three scenarios are illustrated in Figure 3.

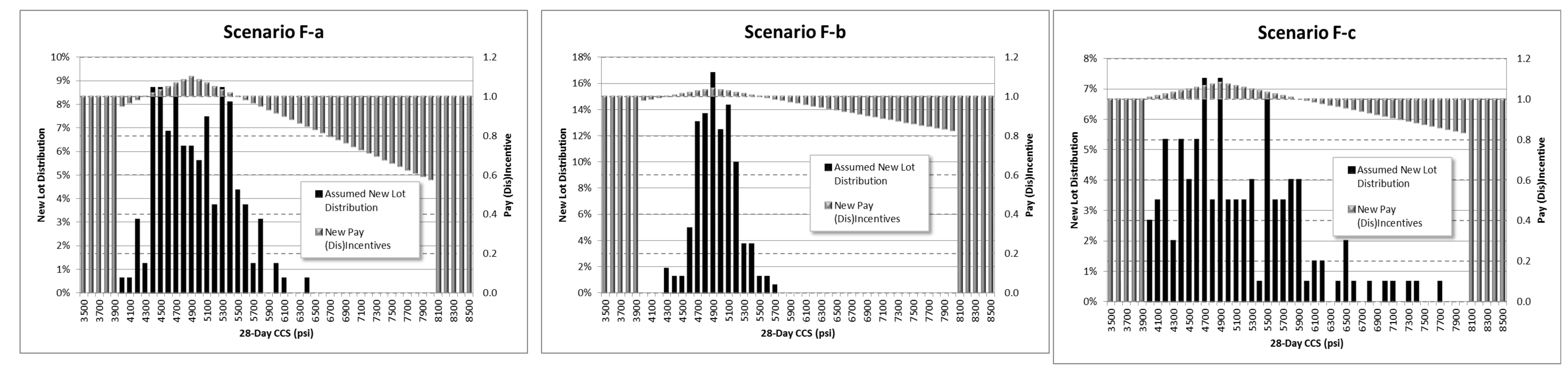

Figure 3. Simulated Industry Response and Pay Factor Design Scenarios F-a, F-b, and F-c

Final Pay Factor Design

Following a meeting with concrete industry representatives in December 2017, a final incentive design was developed based on the feedback received (see Figure 4). This final design represents a starting point for the implementation of the new PRS, with the understanding that it can evolve as the industry responds. It features a "dummy" upper acceptance boundary of 6,500 psi, above which a uniform 0.80 payment reduction factor is applied, an assumed industry response with mean of 5,000 psi and standard deviation of 500 psi.

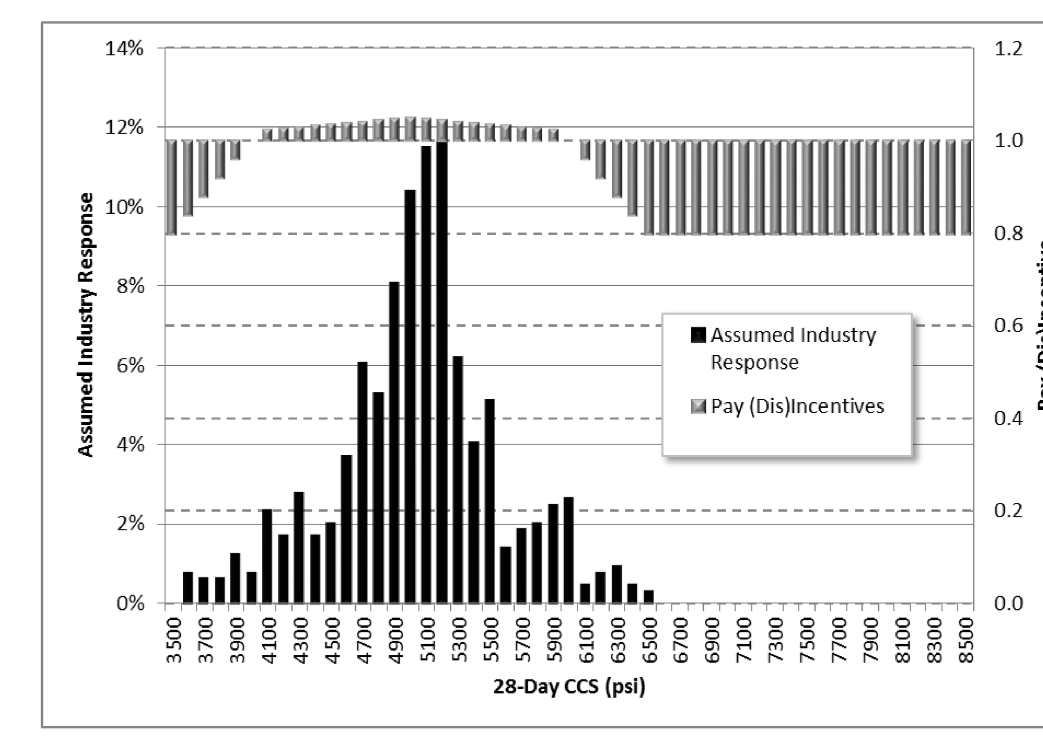

Figure 4. Final Pay Factor Design

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