APPLICATION OF WORK ZONE ROAD USER COSTS IN DETERMINING
SCHEDULE RELATED INCENTIVES AND DISINCENTIVES – A CONCEPTUAL
FRAMEWORK

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ABSTRACT

Time-related contract clauses are primarily designed to encourage contractors to complete on or ahead of construction schedule through incentives and disincentives (I/D). The I/Ds are typically devised to compensate contractors with incentive payments or disincentive charges for early or late completion, respectively. Highway agencies have gained extensive experience with the application of I/Ds. The agencies use work zone road user costs as an economic and legal basis to accelerate construction and establish I/Ds. In practice, to determine I/D, the agencies understandably apply a multiplier or discount factor to a sum of estimated work zone road user costs (WZRUC) and other owner costs. There is adequate literature available on how to estimate WZRUC and establish I/Ds; however, there are still gaps in the state-of-the practice with a particular emphasis on the selection of discount factors. While re-emphasizing the importance of adequately compensating the contractor for accelerating construction through incentive mechanisms, this study presents a conceptual framework that incorporates the concepts of costs of construction acceleration and discount factors. Instead of using a discount factor subjectively, this study proposes to view the issue of discount factor through the return of investment and risk management perspectives.

Keywords: Work zone road user costs, time-related contract clauses, incentives, disincentives, early completion, contractor costs of acceleration, schedule
INTRODUCTION
Highway construction work zones contribute about 10 percent of overall roadway congestion at an estimated fuel loss of over $700 million annually. In 2010, there were 87,606 work zone related crashes, including 576 fatalities and 37,476 injuries (1). Since the number of construction activities has been steadily increasing over the years, the adverse impacts of work zones on motorists, construction workers, local businesses, communities and the overall economy are expected to get worse. To reduce the exposure of work zone users, many highway agencies seek to accelerate construction through the use of various strategies including accelerated construction techniques, alternative project delivery methods and time-related contract clauses. Work zone road user costs provides an economic basis for quantifying these adverse impacts, which can then be used for effective decision-making to reduce work zone impacts and improve safety and mobility.

Time-related contract clauses are primarily designed to encourage contractors to complete on or ahead of construction schedule through incentives and disincentives (I/D). Examples of time-related contract clauses include cost plus time (A+B) bidding, liquidated savings, lane rental, interim milestones and no-excuse bonus. The I/Ds are typically devised to compensate contractors with incentive payments or disincentive charges for early or late completion, respectively.

Highway agencies have gained extensive experience with the application of I/Ds. The agencies use work zone road user costs as an economic and legal basis to accelerate construction and establish I/Ds. In practice, the agencies understandably apply a multiplier or discount factor to a sum of estimated road user and other owner costs to establish I/D rates. While there is ample guidance available in the literature on how to estimate work zone road user costs and establish I/Ds, there is little guidance on selecting an appropriate discount factor. This study presents a conceptual framework to address the known gaps in determining I/Ds.

WORK ZONE ROAD USER COSTS
Work zone road user costs (WZRUC) are defined as the additional costs borne by motorists and the community at-large as a result of work zone activity. The term includes monetized components of work zone impacts, such as travel delay, vehicle operating and crash costs, as well as other components that are hard to monetize, such as emissions, noise, business and local community impacts. Similarly, the term also includes both direct impacts on road users and indirect impacts on the society and environment.

There is adequate guidance available in the literature on how to compute these individual user cost components, inputs, models and cost sources, and their limitations. The AASHTO User and Non-User Benefit Analysis for Highways (2010), often referred as Red Book, provides guidance on the tools to evaluate the costs and benefits related to transportation projects (2). The FHWA report published by the authors, Work Zone Road User Costs – Concepts and Applications, provides guidance to practitioners on performing WZRUC analysis, including step-by-step procedures to calculate individual cost components, derive unit costs and their sources, and update them periodically using appropriate economic indices (3).

WZRUC is a simple aggregation of various individual cost components or impact types. These components are computed by multiplying the measured quantities of their impacts with corresponding unit costs. For instance, travel delay component of WZRUC is calculated by multiplying the estimated delays caused by the work zone to personal and truck travel by the unit cost ($/hr) of travel time. The accuracy and validity of the WZRUC estimates depend on the type of impacts considered, tools used in estimating these impacts and their unit costs.

Work Zone Impact Analysis Tools
Numerous tools are available to estimate the magnitude of impacts and/or the cost components. These tools can be broadly classified into (1) work zone traffic impact analysis tools, and (2) economic analysis tools. Generally speaking, work zone traffic impact analysis tools are primarily used to quantify work zone related mobility impacts at various stages of a project, while economic analysis tools are used to quantify the “larger picture” of benefits and costs of highway investment that also includes crashes, emissions and economic development. More information on these tools, their capabilities, advantages and disadvantages are presented elsewhere in the literature (3, 4). While highway agencies lack a “one-stop shop” standard
tool for impact analysis purposes, the tool selection can largely drive the type of impacts selected for user cost estimation and their accuracy.

**Work Zone Impact Types**

There is still a deficiency of clarity in selecting appropriate cost components or impact types for user cost estimation. What cost components should be selected? Should the impact types be selected on a project-by-project basis or as an agency’s policies? Literature suggests that there is no consistency in the way user cost components are aggregated in the computation process. For instance, some States such as Missouri and Virginia consider travel delay, vehicle operating and crash costs in the user cost computations, while others, such as Colorado and Texas, consider only travel delay costs (5, 6); however, New Jersey considers only travel delay and vehicle operating costs but does not recommend the inclusion of crash costs due to limited availability of work zone crash cost data (7). Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS), a tool that is increasingly used by other highway agencies, is limited to travel delay costs and vehicle operating costs (8). These practices thus suggest that the components to be included in user cost computations are not identified on a project-by-project basis but rather as an agency’s policies.

Another school of thought justifies the use of fewer and selective cost components, particularly the mobility impacts, because these components are assumed to be the most significant of all impact types. However, the authors recommend that the practitioners should use their discretion in selecting appropriate work zone impacts to be used in WZRUC analysis based on the results of work zone impact assessments undertaken on a project-by-project basis. The FHWA Technical Advisory T 5080.10 Incentive/Disincentive (I/D) for Early Completion, February 8, 1989, supports this perspective (9). T 5080.10 states “I/D provisions should be limited to those projects whose construction would severely disrupt highway traffic or highway services, significantly increase road users’ costs, have a significant impact on adjacent neighborhoods or businesses, or close a gap thereby providing a major improvement in the highway system.” As discussed later in this paper, selecting appropriate impact types is critical in determining discount factors. Hence, a consistent approach is required in selecting the impact types in order to capture fully the impacts of work zones as well as benefits and costs associated with highway investment.

**Unit Costs**

Highway agencies use different sources, methods and assumptions in determining unit costs and updating or indexing them annually. For example, the 2012 dollar values of time used by Missouri and Texas DOTs in the computation of travel delay costs are $10.30/hr and $20.99/hr for passenger cars and $22.7/hr and $30.65/hr for trucks, respectively. Saito et al (2005) reported that the dollar value of time (in 2004 dollars) used by 19 State DOTs in travel delay cost computations ranged from $5.08 to $17.34 for passenger costs and from $10.16 to $66.86 for trucks (12). Similarly, the agencies also appear to depend heavily on consumer price indices to index unit costs annually. Since the user cost components have deeper foundations in economic theories, a more uniform approach should be followed in determining unit costs and updating them annually with appropriate economic indices (3).

**ESTIMATING INCENTIVES AND DISINCENTIVES**

Highway agencies use time-related contracting clauses, especially in projects where the presence of work zones would cause severe disruptions, to expedite construction duration and minimize on-site work zone impacts to road users (13, 14, 15). These clauses focus on reducing the number of calendar days of construction, completing the critical project milestones within the intended timeframe, stipulating the hours and days the contractor is allowed to close the roadway lanes for work, and incentivizing the contractor to complete the project ahead of schedule. Under these clauses, the contractor is rewarded with bonus payments upon completion for completing the project ahead of a “pre-agreed” schedule and penalized with disincentive charges for late completion. The owners establishes the I/D structure by taking into account the road user costs, traffic control and maintenance costs, and construction engineering inspection costs. Similarly, the owner determines a reasonable and achievable “pre-agreed” time for completion, since an
unreasonable completion date may attract unbalanced bids, while an incentive payment to contractors is unjustified for little or no effort.

WZRUC provides an economic as well as a legal basis to determine contractor incentives and disincentives (I/D). FHWA’s Contract Administration Core Curriculum manual (2006) defines I/D for early completion as “a contract provision which compensates the contractor for each day that identified critical work is completed ahead of schedule and assesses a deduction for each day that completion of the critical work is delayed.” (16) To determine I/Ds, highway agencies often apply a multiplier or discount factor to WZRUC estimates, as presented below:

\[ I/D = DF \times WZRUC \] (1)

The value of discount factor typically ranges from 0.2 to 1.0. For example, New Jersey DOT uses a discount factor of 0.25, while California I/D guidelines typically recommend a discount factor of 0.5. A lower discount factor is typically used for projects with high RUC estimates (7, 17). The criteria for selecting of discount factor are largely non-documented and may include factors such as market conditions, confidence on the accuracy of WZRUC estimates, work zone factors, and time sensitivity of project completion. Furthermore, the selection of a discount factor may be subjective and does not consider the additional expenses incurred by the contractor for construction acceleration.

### Considering the Contractor Costs of Construction Acceleration

To be effective and well justified, the incentive payments should be adequate enough to motivate the contractor to complete the work on or ahead of schedule; in other words, the incentives paid to the contractor should be higher than the additional costs incurred by the contractor for accelerating the work. On the other hand, the disincentive charges for delivery delay should compensate the additional costs incurred by road users and the owners for construction engineering, inspection and traffic control.

McFarland et al. (1994) proposed a theoretical construct to determine the optimum construction completion time at which the owner costs and road user costs are balanced (18). This model combines the concepts of “time is money” and “time-cost trade-off” and supports the following rationale:

- Project acceleration requires additional labor, materials, and equipment and therefore costs more money.
- Delaying the project beyond the normal completion time results in increased costs due to inefficient allocation and utilization of resources.
- The longer construction takes, the greater the road user costs and owner overhead costs will be.

As presented in Figure 1, McFarland’s model presents at least three cost curves: construction costs, road user costs and construction engineering costs (combined for the presentation purposes), and total project costs. The construction cost curve represents the contractor’s cost for completing the project (assumed to include a normal profit). For every construction project, the construction cost is the lowest at the baseline duration (point \( C_L \)). Any deviation from this baseline schedule will result in increased construction costs. Expediting completion requires additional contractor effort through tighter schedules and overtime, additional resource mobilization and deployment and/or innovation, and incurs additional costs to the contractor. Extending the completion beyond the baseline duration results in penalty and misallocation and underutilization of resources, and hence incurs additional costs to the contractor. In other words, the construction costs increase with each additional day saved or delayed from the standard schedule.

On the other hand, the owner’s construction oversight cost and WZRUC increase linearly with project duration. When these indirect costs are combined with the construction costs, the resulting cost curve shifts to the left. In other words, the combined costs are lowest at an optimal duration (point \( T_L \)) shorter than the normal expected duration. Any further acceleration will no longer be justifiable, as the difference between benefits and costs would be negative. The difference between the total and construction costs will be used in determining I/Ds.
1 FIGURE 1 Relationship between project cost and duration.

The logical consequence of this model is that the contractor’s costs of acceleration (CA) and a sum of WZRUC and owner’s construction engineering costs (AGCEC) form the lower and upper limits for the incentive/disincentive amounts, respectively, and is illustrated as follows:

\[ CA \leq I/D \leq WZRUC + AGCEC \] (2)

This relationship strikes a balance between the two bounds when determining an appropriate I/D amount for the project (19).

Further studies by Sillars et al (2007), Pyeon and Lee (2012) and Shr et al (2000) built on the McFarland’s model (17, 20, 21). Shr et al (2000) proposed an empirical cost vs duration estimation model to estimate project acceleration costs based on Florida DOT cost and schedule data (21). Shr et al’s polynomial cost model developed to estimate the construction costs is presented as follows:

\[ C_c = 1.0059 \times C_o - 0.1048C_o \left( \frac{D-0.8875\times D_o}{D_o} \right) + 0.4657C_o \left( \frac{D-0.8875\times D_o}{D_o} \right)^2 \] (3)

where,
- \( C_c = \) actual project cost
- \( C_o = \) contractor bid price
- \( D = \) actual days used by the contractor
- \( D_o = \) contract time specified in the bid

Shr et al’s model has limited applications at project level as the costs of acceleration largely depend on the type of project, economies of scale, location, and use of innovative technologies.

More accurate, project-specific cost vs. duration models can be developed using detailed unit cost based estimations, standard and accelerated production rates and scenario analysis using time-cost trade-off concepts. Sillars et al (2007) proposed a framework for estimating I/D with more detailed guidance on estimating cost of construction acceleration (i.e. lower bound of I/D) (20). Pyeon and Lee (2012) developed a procedure to estimate I/Ds based on the cost and schedule estimates of the Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS) software (17).

PROPOSED FRAMEWORK

This study proposes a conceptual framework that incorporates the concepts of costs of construction...
acceleration and discount factors. In other words, the proposed framework builds on Eq.2 i.e. upper and lower bounds of I/D, while taking advantage of the discount factor concept. The proposed framework involves the following key steps:

1. Establish baseline schedule for the project using standard production rates. Baseline schedule can be established in accordance with standard agency procedures.
2. Establish WZRUC estimates for project using baseline schedule and a preferred construction or work zone management strategy.
3. Analyze the CPM schedule of baseline duration by using increased production rates for activities on the critical path. Accelerated schedule can be established in accordance with standard agency procedures.
4. Estimate the contractor’s cost of acceleration (CA = C_C - C_o) for increased production rates.
5. Select an I/D amount that is less than or equal to unit WZRUC costs but greater than the acceleration costs for the desired optimal duration.

\[
CA \leq I / D \leq \text{WZRUC} + \text{AGCEC} \quad (2)
\]
\[
I / D = CA + \text{RMF} \times ((WZRUC / ROIM) + \text{AGCEC} - CA) \quad (4)
\]
\[
I = CA + \text{RMF} \times ((WZRUC / ROIM) + \text{AGCEC} - CA) \quad \text{with } CA_{\text{max}} = CA_{\text{TL}} \quad (5)
\]
\[
D = \text{RMF} \times (WZRUC / ROIM) + \text{AGCEC}) \quad (6)
\]

where,

- \( I \) = incentive in $
- \( D \) = disincentive in $
- \( \text{WZRUC} \) = work zone road user costs in $
- \( \text{AGCEC} \) = owner’s construction engineering costs in $
- \( CA \) = contractor costs of acceleration in $
- \( CA_{\text{max}} \) = maximum allowable contractor costs of acceleration in $
- \( CA_{\text{TL}} \) = contractor costs of acceleration in $ at optimum duration in $
- \( \text{RMF} \) = risk management factor
- \( \text{ROIM} \) = return of investment multiplier

The basic tenants of the proposed framework are summarized as follows:

- When the contractor completes the work ahead of standard schedule, the owner pays for the contractor’s costs of acceleration, while shares a portion of savings with the contractor. The percent of savings that the owner is willing to share is determined by the RMF factor, which typically ranges from 0 to 1. Owner’s savings would typically include discounted amount of WZRUC and construction engineering costs resulted from shortening the construction duration.
- The CA costs paid to the contractor is capped at CA at optimum duration (T_L)
- When the contractor delays the completion of work, the contractor compensates for owner’s additional costs in terms of discounted amount of WZRUC and construction engineering costs.
- When the contractor tries to complete the work before the optimum duration (T_L), the cost of acceleration would be higher than the owner’s savings, and hence not justified. In other words, the incentive amount may not be may not be adequate enough to compensate the contractor’s additional costs. There is no motivation for the contractor to accelerate the schedule further.

The conceptual framework proposes to break the discount factor into two: risk management factor (RMF) and return of investment multiplier (ROIM). The factor “RMF” indicates the risk factor that the owner is willing to transfer, while the ROIM can be used to convert “soft dollars” into “hard dollars”. The following sections present a detailed discussion on the rationale behind the two new factors.

**Discount Factors**

As discussed earlier, the discount factors are determined subjectively by an owner’s management on a project-by-project basis by taking various factors into consideration such as project size, market conditions, magnitude and confidence on the accuracy of road user cost estimates, work zone factors, and time sensitivity of project completion. Furthermore, FHWA Technical Advisory T 5080.10 (1989) limit
maximum incentive amount at 5 percent of the total contract amount of the project on federal-aid projects, while no limits are applied to maximum disincentive amount.

Owner agencies use discount factor to reduce the dollar value of WZRUC at par with owner’s direct costs for at least two reasons: First, the discount factor is the portion of road user cost savings that an owner is willing to share with the contractor. Lower discount factors have a diminishing effect on the contractor’s I/D—in other words, at lower discount factors, the owner pays only a smaller portion of WZ RUC savings to the contractor for early completion and recovers an equal portion of the losses from the contractor for late completion. However, at higher discount factors, the owner pays a larger portion of WZ RUC savings to the contractor as incentives for early completion and recovers an equal portion of WZ RUC losses from the contractor as disincentives for late completion. Put briefly, the owner transfers a large portion of schedule related risks, including benefits and costs, to the contractor at higher discount factors, and vice versa.

Second, the owner agencies do not assign the same “dollar value” to WZRUC and I/D amounts. Often, the WZRUC are perceived as externalities or “soft” costs, since agencies do not incur them directly, whereas the I/D amounts are “hard” dollars paid by or to the owner. Moreover, the term “WZRUC” includes direct “monetary” costs to users as well as indirect, “hard to monetize” costs to the society.

**Return of Investment Multiplier**

The ROIM essentially lowers the dollar value of WZRUC to owner’s investment dollars. The ROIM is a fiscal multiplier that represents the dollar change in economic output for each additional dollar of agency spending in highway investments. For example, a multiplier of two implies that, when agency spending increases by one dollar, economic benefit rises by two dollars. A Federal Reserve Bank of San Francisco study estimated the effect of highway investment dollars on the economy in the short, medium and long term (22). This study observed that the highway investment multipliers range from 1.5 to 3 in the short term, as high as 8 in the medium term, and 2 over a 10-year horizon. Similarly, the Florida DOT’s investment multiplier is estimated at 5.5 for highway projects (23).

The concept of using ROI multiplier in discount factors is not new. Daniels et al (1999) justified the use of a default discount factor of 0.25 in I/D applications using the above concept (24). To quote “…The first way is to use the default cap of 25% of calculated RUC. This value is based on previous research that showed that the additional construction costs paid to speed up a project had an economic value roughly four times that of the savings in delay costs to road users. Maintaining the current practice of including 25% of RUC is readily defensible.” Similarly, based on their evaluation of 20 I/D projects in Missouri constructed between 2008 and 2011, Sun et al (2014) observed that for every dollar paid in incentives, Missouri saved approximately 5.3 dollars of WZRUC savings resulting from the use of I/Ds (10).

The above discussion highlights the use of ROIM determined at a macroeconomic scale. However, when applied at the project level, the authors caution that the ROIM can be highly variable. The ROIM will depend on the type and location of the project, traffic volume and composition, work zone management and construction techniques used, and the impact types or cost components considered in the benefits computations.

The ROIM values can be expected to be high especially on projects carrying heavy traffic in urban areas. For instance, on the replacement project of Fast 14 bridges on Interstate 93 in Medford, Massachusetts, the Massachusetts DOT spent an additional investment of $ 1.75 million on accelerated bridge construction to produce an user cost savings of $ 136 million at a ROIM multiplier of 77.8, whereas, on the US-6 Keg Creek project in rural Iowa, Iowa DOT spent an additional investment of $ 1.17 million on accelerated bridge construction to produce an user cost savings of $ 1.61 million at a ROIM multiplier of 1.4 (25, 26). This trend also justifies the use of lower discount factors on projects with high RUC.

Another note of caution is that the impact types used in the quantification of benefits in determining ROIM multiplier and WZRUC should be the same. Inconsistent selection of impact types may lead to erroneous or incorrect user cost estimates. For instance, if the WZRUC is estimated solely based on travel delay costs, it would not be advisable to use a ROIM multiplier that incorporates emissions, noise, crashes and local business impacts. To conclude, more research is necessary to develop a framework and determine appropriate ROIM multipliers for various locations, projects, and construction techniques.
**Risk Management Factor**

The RMF indicates the portion that the owner is willing to share or recover from the contractor. At a RMF of 1, the owner has no savings or losses in terms of WZRUC and AGCEC since the cost differentials are either paid to or recovered from the contractor through I/Ds. On the other hand, at a RMF of 0, the owner shares or recovers none from the contractor through I/Ds, while at smaller RMF, the owner shares or recovers only a smaller portion of savings or losses from the contractor. In other words, the RMF indicates the schedule related risk arrangement that the owner is willing to have with the contractor. This study hypothesizes that there is equilibrium for both the contractor and the owner in the middle, with RMFs approximately between 0.4 and 0.6.

Note that the loss to the owner is the difference between additional construction engineering and road user costs due to completion delays and the amount recovered from the contractor as disincentives, while savings is the difference between savings in construction engineering and road user costs due to early completion and the incentives paid to the contractor. Similarly, loss to the contractor is the sum of disincentive amount paid to the owner and contractor cost of delay for late completion or the negative cost differential between the incentives received from the owner and the contractor cost of acceleration for early completion, while profit to the contractor is the positive cost differential between the incentives received from the owner and the contractor cost of acceleration.

In an effort to identify the equilibrium, this study constructed a pay-off table for owners and contractors using the polynomial cost-schedule model developed by Shr et al. 2000 (21). The pay-offs indicating proportional savings and losses to the owner and the contractor were estimated at various RMFs using Eq. 5 and 6 under different construction schedule scenarios. The estimated pay-offs are presented in Table 1. The first and the second numbers in the pair indicate the pay-offs of owners and contractors. The pay-offs of -5 to +5 were used with negative and positive numbers indicating the proportion of losses and savings, respectively.

**TABLE 1 Estimated Pay-Offs for Owners and Contractors**

<table>
<thead>
<tr>
<th>Schedule Scenario</th>
<th>Low range RMF (0.1 to 0.3)</th>
<th>Mid range RMF (0.4-0.6)</th>
<th>High range RMF (0.7 to 1.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive Delay</td>
<td>(**, **)</td>
<td>(**, **)</td>
<td>(**, **)</td>
</tr>
<tr>
<td>Tolerable Delay</td>
<td>(-5, -4)</td>
<td>(-4, -5)</td>
<td>(-1, **)</td>
</tr>
<tr>
<td>Normal Time, C_L</td>
<td>(0, 0)</td>
<td>(0, 0)</td>
<td>(0, 0)</td>
</tr>
<tr>
<td>Moderate Savings</td>
<td>(3, 1)</td>
<td>(2, 2)</td>
<td>(1, 3)</td>
</tr>
<tr>
<td>Optimum Time, T_L</td>
<td>(5, 1)</td>
<td>(3, 3)</td>
<td>(1, 5)</td>
</tr>
<tr>
<td>Aggressive schedule (CA not capped)</td>
<td>(2, 1)</td>
<td>(1, 1)</td>
<td>(1, 2)</td>
</tr>
<tr>
<td>Aggressive schedule (CA capped at CA_TL)</td>
<td>(5, **)</td>
<td>(5, -5)</td>
<td>(2, 0)</td>
</tr>
</tbody>
</table>

(**) indicates very high losses

As Table 1 indicates, any delay beyond the normal completion time is disadvantageous to both owners and contractors. Schedule delays put the contractor at risk, especially at high RMF and high impact projects, since the owner transfers most of the schedule related risks to the contractor; however, this risk arrangement may result in higher bid prices from the contractor. On the other hand, pursuing an aggressive schedule is certainly not an attractive option for the contractor, as the incentives would not adequately cover contractor’s CA. When the CA is not capped, the contractor’s gains are inconsequential given the risks associated with pursuing aggressive schedule. The optimum scenario exists when the project completion is targeted for the optimum completion time, particularly at medium RMF, where both the owner and contractor share the savings. The pay-off table indicates that equilibrium exists for both owners and contractors when both parties target for optimum completion time and enter a risk sharing arrangement.
Illustrative Example

The following example illustrates the relationship between construction costs, road user costs, and duration for a hypothetical highway construction project. Assume that the contract time specified in the bid is same as the normal construction time at which the contractor’s construction costs would be lowest. For sake of illustration, the construction cost model developed by Shr et al. (21) was used in this example. The inputs are as follows:

- Road user costs (RUC) = $6000/day
- Owner’s construction engineering costs (AGCEC) = $500/day
- Normal completion time (DRoR) = 60 days
- Contractor costs at standard schedule (CRoR) = $3,000,000
- Risk management factor = 0.5 (assumed)
- ROIM = 3 (assumed)

**Case 1: Early completion**

Actual completion (D) = 56 days
Contractor costs at accelerated schedule (Cc) = $3,006,000
Contractor CA = $ 6,000
Days saved = 4
Total savings = WZRUC/ROIM+ AGCEC-CA = $6,000* 4 days / 3 + $500 * 4 – $6,000 = $4,000
Incentive I = CA + RMF * (WZRUC/ROIM+ AGCEC-CA) with CA_{max} = CA_{TL}
I = 6,000 + 0.5 *($6000* 4 days / 3 + $500 * 4 – $6,000) = $8,000
Contractor savings = $ 2,000
Agency savings = $ 2,000

**Case 2: Delayed completion**

Actual completion (D) = 56 days
Contractor costs at accelerated schedule (Cc) = $3,003,500
Contractor additional costs = $ 3,500
Days delayed = 3
Additional costs = WZRUC/ROIM+ AGCEC = $6,000* 3 days / 3 + $500 * 3 = $7,500
Disincentive D = RMF *(WZRUC/ROIM+ AGCEC)
D = 0.5 *($6000* 3 days / 3 + $500 * 3) = $3,750
Contractor losses = $ 7,250
Agency losses = $ 3,750

**SUMMARY**

Highway agencies have extensive experience with the application of I/Ds to accelerate construction and minimize on-site work zone impacts to users. Although there is adequate literature available on how to estimate WZRUC and establish I/Ds, there are still gaps in the state-of-the practice with a particular emphasis on the selection of discount factors. While re-emphasizing the importance of adequately compensating the contractor for accelerating construction through incentive mechanisms, this study presents a conceptual framework that incorporates the concepts of costs of construction acceleration and discount factors. Instead of using a discount factor subjectively, this study proposes to view the issue of discount factor through the return of investment and risk management perspectives. If applied correctly, the return of investment multiplier can be effectively used to convert “soft dollars” of user and societal costs to “hard dollars” of agency costs. Similarly, the risk management factors can be used to optimally allocate risks between the parties. This study identifies the need for a more uniform and consistent approach among highway agencies in the selection, assessment and monetization of work zone impact types. This study also
identifies the need for further research in many aspects of this practice, particularly related to the
development of a standard tool, identifying cost-benefit ratios for various practices and strategies.

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