Programmatic Examination of Missouri Incentive/Disincentive Contracts for Mitigating Work Zone Traffic Impacts

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ABSTRACT

Incentive/disincentive clauses (I/D) are designed to award payments to contractors if they complete work ahead of schedule and to deduct payments if they exceed the completion time. A previously unanswered question is, “Did the costs of the actual work zone impacts that were avoided justify the incentives paid?” This paper answers that question affirmatively based on an
evaluation of 20 I/D projects in Missouri from 2008 to 2011. Road user costs (RUC) were used to quantify work zone impacts and included travel delays, vehicle operating costs, and crash costs. Conditions during construction were compared to after construction. Delay costs were computed using the Highway Capacity Manual and crash costs were computed using Highway Safety Manual. For every dollar paid in incentives, approximately 5.3 dollars of RUC savings resulted from the use of I/D. Also, I/D projects had a higher on-time completion percentage and a higher number of bids per call than average projects. But I/D projects resulted in 4.52% higher deviation from programmed costs and possibly more changes made after the award.

INTRODUCTION

Several studies indicate that approximately 50 percent of all highway congestion is non-recurring due to work zones, incidents, weather and special events (Chin et al. 2002). Approximately 83% of work zone congestion occurs on urban freeways and 15% on rural freeways (Chin et al. 2002). Thus DOTs, being owners of such facilities, face increasing pressure to minimize work zone impacts. Efforts for reducing project delay were included in the last three transportation authorization bills, and the Federal Highway Administration (FHWA) launched in 2010 the Every Day Counts initiative aimed to shorten project delivery (FHWA 2012). A transportation authorization bill is the federal law authorizing the federal surface transportation programs for highways, safety and transit, thus these bills have great influence over highway contracting practice. Several contracting procedures seek to reduce traffic impacts by reducing project duration through the use of incentive/disincentive contract provisions (AASHTO 2001). The Code of Federal Regulations (23 C.F.R. § 635.102 (2012)) defines an incentive/disincentive (I/D) for early completion as “a contract provision which compensates the contractor a certain
amount of money for each day identified critical work is completed ahead of schedule and
assesses a deduction for each day the contractor overruns the incentive/disincentive time.”
However, there has been little effort on the part of departments of transportation (DOT) to
investigate the effectiveness of such contract provisions for mitigating work zone impacts.
The motivation behind the decision to use I/D contracts is to reduce the construction
schedule on projects that cause significant cost impacts to the public. The incentive and
disincentive amounts from I/D contracts are primarily based on road user cost (RUC). RUC is
determined by costs associated with the increased delay that drivers experience because of lower
speeds and capacities of work zones. In cases where the work requires a full-closure, the RUC is
based on the additional delay and miles driven on the detour route. When deciding to use an I/D
contract, DOT officials must weigh the potential benefits to road users versus the potential
contract administration issues. Previous studies have indicated potential issues to be possible
higher bid amounts, difficulties staying within budget, and overestimated contract times resulting
in unnecessary incentive payments. The number of variables influencing the performance of I/D
contracts makes evaluation of the effectiveness difficult. This paper aims to show how evaluating
a project’s impact on RUC can validate the motivations of the original contract method decision.
In other words, this project answers the question, “Did the costs of the actual impacts that were
avoided justify the incentives paid or did the costs that were incurred justify the disincentives
that were assessed?”

The evaluation process was performed in two steps. First, I/D contracts completed
between 2008 and 2011 in Missouri were analyzed to determine the magnitude of RUC savings
resulting from any scheduling compression. The projects included full and partial closures, and
construction in both urban and rural settings. Full-closure projects force traffic to detour around
the work zone area causing high RUC. Nine of the projects involve bridge rehabilitation or reconstruction, and five involved emergency construction in the aftermath of massive floods. The second step of the evaluation process was to analyze completed I/D contracts from 2008 to 2011 in terms of on-time completion, contract budgets, changes in final contract amounts, and number of bids per call. The Missouri Department of Transportation (MoDOT) let 27 I/D contracts in this time frame, but data required for the second step was only available for 20 of the 27 contracts. I/D contracts were compared to all contracts let by MoDOT during the same time frame. These comparisons were necessary to show how effective I/D contracts performed with respect to other contracting methods.

**PREVIOUS I/D PROJECT EVALUATIONS**

This review of I/D project evaluations is categorized into quantitative project analysis, case studies and survey-based analysis.

*Previous Quantitative Evaluations*

The quantitative analysis involves the examination of quantitative performance measures. This review shows that there has been no programmatic analysis of I/D projects for investigating work zone traffic safety and mobility impacts. Several researchers have investigated various aspects of I/D contracting, but most of these studies have emphasized project management issues and not work zone impacts. Some quantitative analyses performed have involved sample sizes of four to six I/D projects or individual case studies, but others have used much larger samples sizes. The survey-based analysis involves the examination of general perspectives and attitudes towards I/D. This literature review shows the surveys lacked quantifiable information about the impacts
of I/D contracts on work zone traffic impacts. Through their experience, the researchers in the National Cooperative Highway Research Program (NCHRP) 652 report stated that meaningful quantitative data such as project duration, relative cost comparisons, I/Ds paid or charged were limited (Fick et al. 2010). The primary factor for determining whether an I/D contract was effective was whether the contractor was able to meet the I/D milestone and was paid an incentive for early completion. The items that have the greatest potential to erode the effectiveness of I/D provisions were the frequency and impact of excusable delays and overrun and underrun quantities. The report also said that existing literature lacked quantitative data and analysis. This lack of quantitative project analysis of I/D projects was one central reason for this paper.

One study that used a large sample size of projects was performed by Choi et al. (2012). They examined the schedule effectiveness of 1,372 transportation project in California. The projects included 29 I/D with A+B (cost + time) projects and 58 A+B projects. The comparison between pure A+B and I/D with A+B showed that pure A+B suffered from underestimates on the B portion while I/D with A+B resulted in achieving or surpassing early project completion goals.

A recent National Bureau of Economic Research publication discussed the results of quantitative analysis of 490 sample highway construction project from Minnesota (Lewis and Bajari 2011). But this project focused on lane rental projects only and did not evaluate any I/D projects. The authors performed a simple delay analysis using Google Maps on a subset of 99 projects, but no meaningful traffic analysis was performed.

Strong (2006) evaluated design-build, lane-rental and A+B contracting methods by considering administration costs, project costs, management complexity, disruption to third
parties, RUC, innovation, product/process quality, and funding flexibility. The methodology used both a survey of national experts and a review of projects. The reviewed projects included three A+B, one lane rental and one design-build. The three A+B and one lane rental projects were analyzed through a cost comparison of the following: first cost, final cost, bid durations, final durations, and approximate internal administrative costs as function of total project cost. The authors cautioned the reader about the significance of the results because of the small sample size of four projects. The authors also raised the issue that the effects of incentive clauses were difficult to separate from the effects of A+B contracting.

Previous Case Studies

The Minnesota Department of Transportation (Mn/DOT 2006) examined six I/D projects between 2000 and 2005 with two of them involving liquidated savings. For each project, Mn/DOT examined the engineer estimates, low bid, maximum incentive amounts and the amount of incentives paid. For the incentive projects, Mn/DOT stated that contractors used extra effort to complete projects early in order to obtain bonuses which strained Mn/DOT oversight staff. But there was not enough data to determine if contractors were adjusting bids in anticipation of obtaining bonuses to offset costs. The contractors did not appear to expedite construction for liquidated savings projects.

State’s uses of I/D provisions have shown to effectively reduce the time frame of construction projects that have a serious impact on traffic. Arditi et al. (1997) studied a number of projects for the Illinois Department of Transportation and found that 93.3% of projects that used I/D provisions finished on time or ahead of schedule compared to 41.4% that did not use I/D provisions.
Even though previous case studies provided detailed examples of I/D projects, it was difficult to compare the studies with each other in order to derive general conclusions. Some case studies involved California freeways such as I-15 (Lee and Thomas 2007) and I-710 (Lee et al., 2006). Another study was of I-95 in Delaware (FHWA 2004). For some of these studies, the authors performed traffic impact assessment of the project by monitoring closures and comparing the closure traffic with historical traffic data from the same location. Thus the authors sought to investigate whether the accelerated rehabilitation project resulted in tolerable traffic impact, but the authors did not seek to examine whether the incentive amounts earned corresponded to the traffic and safety impacts avoided. Such issues were not the focus of previous case studies, but are the main focus of the current paper.

*Previous Survey-Based Evaluations*

In terms of survey-based methods for evaluating I/D contracts, NCHRP 652 obtained surveys from thirty-two states and in-depth investigations of six states (Fick et al. 2010). In terms of safety, the authors discussed the significant challenges that exist in evaluating the safety impacts of I/D contracts. The authors even stated that in their judgment, it was nearly impossible to conduct a safety comparison between contracts that incorporate acceleration clauses and those that do not. And no one interviewed was aware of any attempt to conduct such an analysis. And the chapter entitled, “Evaluating I/D Effectiveness”, only discussed the need for adequate metrics to be developed for I/D effectiveness evaluation. This report again validates the need for conducting research on evaluating I/D projects using quantifiable metrics.

Other survey-based studies examined I/D contracts together with A+B. One study concluded that A+B project increased bid price by 7.5% when compared with non-I/D projects.
Gillespie (1998) suggests that acceleration provisions, especially when combined with A+B bidding, tend to produce more innovative bids from contractors in order to compete in the bidding market and have the opportunity to earn the maximum incentive. A drawback to I/D provisions is that bid prices could rise due to the increased risk transferred to the contractor. As shown by Arditi et al. (1997), most I/D projects pay incentives, and the final cost of the project could be unnecessarily high if a completion date is too generous.

Some studies examined a broad range of techniques for construction and acceleration, including I/D. NCHRP Synthesis 413 examined several construction techniques in congested urban areas (Warne 2011), and surveyed states to discover how and why they used various contracting elements. A NCHRP domestic scan discussed DOT survey results on the topic of best practices for construction acceleration (Blanchard et al. 2009). Another NCHRP Synthesis project surveyed states on the selection and evaluation of contract acceleration techniques (Anderson and Damnjanovic 2008). The synthesis examined I/D along with four other alternative contracting methods and found that I/D does not substantially increase or decrease costs. Anderson and Ullman (2000) surveyed 44 states on the broad spectrum of techniques aimed at reducing lane closures. They found 94% of 40 surveyed agencies use I/D which was higher than A+B (76%) and lane rental (52%). In conclusion, even though there is a significant collection of I/D literature, there has not been a study that directly linked incentive/disincentives to a reduction in work zone traffic impacts.

DATA COLLECTION

MoDOT has used various forms of contracting to accelerate construction including I/D. MoDOT contracts with I/D provisions include the Job Special Provision (JSP) Liquidated
Damages/Liquidated Savings Specified. This JSP explicitly states that amounts received or charged for completion time are based on costs to the traveling public. After a search of MoDOT’s database from 2008 to 2011, all contracts with this JSP were found. The years 2008 to 2011 were chosen because detailed data prior to 2008 was either incomplete or altogether missing.

This resulted in 27 contracts. Out of those, 20 contracts had the necessary data for further analysis. It should be noted that these contracts did not use cost plus time bidding (A+B), thus the effect of A+B bidding was not included. MoDOT uses I/D provisions to encourage early completion of construction projects. According to MoDOT’s Engineering Policy Guide (EPG), the suggested criteria for I/D use are: completion of milestones are critical to future work, there is a critical completion date, long detours, public or worker safety concerns, and contract time is lengthy or short (MoDOT 2012a). Information on why a specific I/D provision was included in each of the contracts and how the maximum number of incentive days was determined were unavailable.

Table 1 shows some details for the 20 contracts. The column are identification number, original amount, description of the type of work, work zone volumes, maximum incentive period in days, I/D rate per day, maximum incentive allowed (total) and maximum number of incentive days. The average contract days were around 173 days and varied between 25 and 759 days. The average contract amount was approximately $3.5 million per contract and ranged from $105,000 to $15 million. The average I/D rate was around $8,000/day and varied between $2000/day to $15,000/day. The maximum incentives allowed averaged almost $120,000, which corresponds to an average of around 14 days per incentive period a daily incentive could be earned.
Each contract had a critical milestone or completion goal requiring the contractor to open the road to normal traffic. If the time when critical work begins to the reopening were less than the incentive period stated in Table 1, then the contractor would earn the I/D rate for each day less than the incentive period. The contractor could not earn more than the maximum incentive allowed no matter how early the road was opened to traffic. The contracts are a mix between completion date and calendar day contracts. The I/D projects used in this study were spread across the state and involved different types of road construction. Of the twenty projects, eleven were in rural areas and nine were in urban areas. The urban projects were located mostly in the Kansas City and St. Louis metro areas as shown in Figure 1. There were five emergency construction projects and nine bridge rehabilitation/replacement. Full closure of a roadway segment existed on fifteen of the twenty projects. Three projects had intersection access closures and two projects involved only partial closure or lane reductions.

WORK ZONE IMPACT METHODOLOGY

The primary way I/D contracts minimize work zone impacts is through schedule reductions. To show the impacts that a reduced schedule has on RUC, twenty MoDOT I/D projects were analyzed in detail. It was beneficial that eighteen projects involved some sort of a full closure, because existing literature have mostly focused on partial closure or reduced capacity work zones. Whether a project is in a rural or an urban area, a full closure project will significantly impact road users costs.

Typically, I/D rates are set as a percentage of the actual RUC. This insures that the traveling public receives a favorable cost/benefit ratio (FHWA 1989). In order to determine how much the schedule reduction benefitted the road users for each project, the RUC must be
computed. For this analysis, three typical cost components were used to quantify RUC: travel delay costs (TDC), vehicle operating costs (VOC), and crash costs (CC). In other words:

\[ RUC = TDC + VOC + CC \]

TDC is the value of additional travel time incurred because of the delays resulting from a work zone. Delays result from the congestion near the work zone taper, the use of detours, and/or a reduction in the speed limit. Delays caused by congestion or queuing effects were estimated with the MoDOT Work Zone Impacts Analysis Spreadsheet (MoDOT 2012b). This spreadsheet was developed based on the Highway Capacity Manual (TRB 2010) methodology. Delays from detours were estimated by finding the difference between the detour and normal travel times. Partial-closure work zones also included a delay caused by reduced speed limits. This was estimated by finding the travel times through a road segment with a work zone present and under normal conditions. The travel delay is then monetized by multiplying by the unit value of time (VOT) according to Equation 1. The value of time for passenger cars and trucks were obtained from the MoDOT Work Zone Impacts Analysis Spreadsheet, which is used to estimate queuing and traffic delays. These values are specific to Missouri.

\[ TDC \left( \frac{\text{$/day}}{} \right) = \text{DELAY} \times AADT \times (VOT_{cars} \times \%_{cars} + VOT_{trucks} \times \%_{trucks}) \]  

(1)

Where,

- \( \text{DELAY} \) = additional travel time caused by work zone, (hr/veh)
- \( AADT \) = Annual average daily traffic of work zone, (veh/day)
- \( VOT_{cars} \) = Value of time for passenger cars, ($/hr); $10.30/hr
- \( VOT_{trucks} \) = Value of time for trucks, ($/hr); $22.70/hr
- \( \%_{cars} \) = Percentage of AADT that is passenger cars (%)
- \( \%_{trucks} \) = Percentage of AADT that is trucks (%)
For projects with partial closure or lane reductions, there is another component of TDC caused by the speed reduction through the work zone. Work zone speeds were found within the project plans. This component of TDC can be seen below.

\[
TDC \left( \frac{S}{day} \right) = AADT * \left( \frac{L}{s_{wz}} - \frac{L}{s_N} \right) * (VOT_{cars} * %_{cars} + VOT_{trucks} * %_{trucks}) \tag{2}
\]

Where,

\( L \) = Length of the work zone (mi);

\( s_{wz} \) = Work zone speed limit (mph);

\( s_N \) = Normal speed through the roadway segment (mph).

VOC are the mileage dependent expenditures caused by operating a vehicle. Cost items such as fuel use and vehicle wear and tear are included in VOC. For full closures, VOC are the additional costs due to the extra miles driven along the detour compared to the mileage of the normal route. Equation 3 shows how the VOC is calculated. The unit VOC are taken from AAA (2012) and Trego and Murray (2010) for passenger cars and trucks respectively.

\[
VOC \left( \frac{S}{day} \right) = MILES_{added} * AADT * (VOC_{cars} * %_{cars} + VOC_{trucks} * %_{trucks}) \tag{3}
\]

Where,

\( MILES_{added} \) = length of detour – length of normal route, (miles/veh)

\( VOC_{cars} \) = unit VOC for passenger cars, ($/mile); $0.403/mile

\( VOC_{trucks} \) = unit VOC for trucks, ($/mile); $0.818/mile

Crash costs for the various projects were calculated differently depending on the type of closure for the work zone. The method for calculating change in crash frequencies for detour
traffic compares crash frequencies of both the detour and normal routes and is based on the Highway Safety Manual (HSM) (AASHTO 2010). For projects with rural detours, the expected change in crash frequencies was calculated using chapter 10 of the HSM. The risk of additional crashes is due to the extra mileage driven by the detoured traffic and is directly proportional to the AADT and length of detour. For projects with urban detours, the expected change in crash frequencies was calculated using chapter 12 of the HSM. The frequencies of five different crash types were calculated for urban detours. These crash types are multiple-vehicle non-driveway, single-vehicle, multiple-vehicle driveway-related, vehicle-pedestrian, and vehicle-bicycle.

Variables needed to calculate crash frequencies along an urban roadway are AADT, detour length, type of roadway segment, number of driveways, and classification of those driveways. For projects with partial-closure or lane-reduction work zones, a method from Khattak et al. (2002) was used. Khattak’s research was used in the HSM to calculate crash modification factors (CMF) for work zones. The method compares crash frequencies of a work zone segment compared to pre-work zone.

A composite cost per crash was estimated using historic crash data from MoDOT and HSM methodology. All work zone crashes from 2009 to 2011 were classified by severity. The 6749 total work zone crashes were composed of 2.70% fatal, 0.52% disabling, 21.11% evident injury and 75.67% Property Damage Only (PDO) crashes. According to HSM methodology, all crash costs were adjusted to 2011 values. The human costs were adjusted using the Consumer Price Index and the non-human societal costs were adjusted using the Employment Cost Index from the Bureau of Labor Statistics. The unit crash cost of a work zone crash in Missouri in 2011 was $172,221. The crash cost, $CC$, is estimated using

$$CC \left( \frac{\$}{day} \right) = \frac{N_{sfp \, rs}}{365} \times 172,221$$

(4)
Where,

\[ N_{spf rs} = \text{predicted additional annual crashes, (crashes/year)} \]

**RESULTS**

For each of the twenty I/D projects used in this analysis, the RUC were calculated separately as shown in Table 2. The RUC savings from the 20 I/D projects benefitted the traveling public favorably. For a contractor to start earning incentives, the work zone must be reopened to traffic. Seventeen of the twenty contractors were able to open the road early and earn incentives. The other three contractors finished on time but did not earn any incentives. No contractor was assessed disincentives for any project. In Table 2, the number of days the contractor was able to reduce from the incentive period is shown in the third column. The fourth and fifth columns show the calculated daily RUC and the total RUC saved because of the early completion. The net RUC savings is the incentives paid subtracted from the RUC savings.

< Insert Table 2 here>

Table 2 shows the total impact from the 20 I/D projects as 214 days reduced, around $8.9 million in RUC saved, around $1.7 million in incentives paid, and around $7.2 million in net RUC saved. On average, in terms of RUC components, VOT accounted for 35% of the total, VOC for 50% and CC for 15%. The acceleration of the projects also resulted in almost 9 million VMT (vehicle miles traveled) saved for the detour traffic. This was calculated by multiplying together AADT, mileage difference of detours, and days reduced. The incentives were paid out as follows: seven contractors finished exactly on the day in which the full incentive could be earned, seven contractors finished earlier than the maximum number of incentive days (earned maximum incentive), three contractors earned partial incentives, and three contractors finished at
the original contract time. The row entitled, “Target”, represents the total amounts if all contractors finished on the day to earn maximum incentives and is used as a reference point for comparison. Note that this does not imply that meeting the maximum number of incentive days was the most important goal. Table 2 shows 77% of the contracted RUC savings were realized, 72% of contracted incentives were paid and 79% of the net savings were realized. It is arguable what the ideal percentages should be, but the values indicate that MoDOT received close to the upper limit of their expected results. On average, the return on investment of $1.00 of incentives is $5.30 of RUC savings.

EFFECTS OF PROJECT CHARACTERISTICS

Table 3 below shows how various characteristics affected the outcome of I/D contracts. Of the twenty projects, eleven were rural which included five emergency projects. There were no urban emergency projects. The fifteen full closure projects include five urban projects and ten of the eleven rural projects, including all five emergency projects. The urban projects include the five full-closure urban projects as well as two with access-restricted intersections and two with partial closure of the roadway.

Table 3 below shows that the rural, non-emergency projects resulted in the smallest savings and only netted about one-third of the actual RUC saved. Although not shown in Table 3, all of the projects combined netted 81% of RUC with a target of 80% (calculated from Table 2). Also, the rural, non-emergency projects reduced the fewest number of target days. The lower performance was partly due to the low average daily RUC of $18,786. Presumably because of this, the incentives were set closer to the actual RUC to motivate the contractor to accelerate construction. Proportionally, even at the target number of days, rural, non-emergency contracts
paid the most incentives compared to the RUC savings. The fact that only 23% of the target RUC savings was realized indicates that rural projects may not be the most suitable for I/D provisions.

The nine urban projects reduced 16 more days than the target. This is the result of four of the contracts finishing earlier than the maximum incentive day. Interestingly, these extra days did not result in total RUC savings higher than the total target RUC savings. This is due to projects, which did not finish beyond the target, having a greater influence on the RUC savings. The project with the highest RUC ($104,134/day) only reduced 3 of 14 possible days.

Altogether, the urban projects netted 80% of the RUC saved which was the same as the target percentage. At 90% RUC savings, nearly the entire target RUC savings was realized which indicates I/D was successful in accelerating construction for urban projects.

Three-quarters of the twenty projects used were full-closure projects. Because of the larger sample size, the results might be more reliable than the results for other subcategories of projects. These full-closure projects netted 86% of the RUC savings, which was a higher percentage than the target of 84%. A total of 142 days were reduced, which was 63% of the target number. Reducing the target number of days is beyond actual expectations for I/D projects so reducing 63% of the target days is considered a success. The 63% of days reduced along with 73% of the target RUC saved indicates that the I/D rate and the maximum I/D cap are being set at appropriate values, balancing the contractor’s ability to accelerate construction and the agency’s desire to minimize RUC.

The five emergency projects are the only subcategory to save more RUC than the target value. This occurred even though only 82% of the target days were reduced. Two projects that had the highest RUC finished ahead of the target causing the 108% RUC savings. The fact that
93% of the RUC savings was realized cannot be used to compare to the other project characteristics fairly because of the unique circumstances of emergency contracts. Nonetheless, all indications are that the inclusion of the I/D with these emergency contracts saved considerable RUC at a relatively low cost to MoDOT.

**COMPARING I/D PROJECTS AGAINST ALL PROJECTS**

In addition to the analysis of individual projects in the previous section, a programmatic comparison between I/D projects and all MoDOT projects was also conducted. MoDOT publishes a quarterly Tracker report (MoDOT 2012c). The purpose of the Tracker is to measure the performance of tangible goals set by the agency. So far MoDOT has not published measures specifically for I/D contracts. The following measures, currently recorded in Tracker, are areas where I/D contract performance could be compared to other contracting methods. By including I/D performance measures into a results-based data tracking system like MoDOT’s Tracker, it will be possible to set and achieve goals based on the motivations behind using I/D contracts.

The data for the overall MoDOT construction program was obtained from the Tracker, while the I/D project data was computed using the data described in previous sections. The following four measures were used for programmatic analysis: the percentage deviation of programmed cost versus final cost, the percentage of projects completed on time, the percentage of contract change and the number of bids per call.

The necessity for a project to stay on budget is becoming increasingly important as funding for transportation struggles to meet demand. Early in the development of a project, program costs are estimated, which become the project’s budget according to MoDOT (2012). The Tracker reports the programmed project cost as compared to the final project cost to
measure the budget performance. Ideally, the deviation in programmed versus final cost should be 0%. Negative numbers indicate the final cost was lower than the programmed cost. Five out of the twenty I/D projects were not used for this measure due to the lack of data on program estimates. Four of those five projects were emergency flood repairs and thus were not programmed in advance. For the period between 2008 and 2011, the deviation in cost was -7.30% for all MoDOT projects and -11.82% for I/D projects. The higher I/D percentage deviation indicated, perhaps, that I/D projects had much greater uncertainty and required more conservative programmed costs. Maximum incentives were only 2.98% of programmed estimate or $2.10 million. Therefore it was not just the difficulties of budgeting for unknown incentive payments that were to blame. It could be possible that MoDOT assumed that the I/D provision would result in higher bids from contractors due to more risk transferred to the contractor.

The ability of a project to stay on schedule is another important measure of performance. Figure 2 compares the on-time performance of I/D projects versus all MoDOT projects for the years 2008 to 2011. Figure 2 shows both unadjusted and adjusted data. The adjusted data reflects actual contract changes negotiated between MoDOT and the contractor. Figure 2 shows that I/D projects were completed on-time 100% of the time while all projects ranged from 91% to 97% if adjustments were taken into account. For unadjusted values, I/D projects had an 83% on-time completion in 2010 and 2011, which was still higher than all projects.

The percentage change for finalized contracts represents the percentage difference of total construction payouts to the original award. This reflects changes made to the project after they were awarded to the contractor. Figure 3 shows percentage change in original award amounts for four years of I/D versus all MoDOT projects. Positive values reflect overruns while
negative values reflect underruns. MoDOT had a target of keeping the percentage below 2%. At first glance, I/D projects appear to require more changes. However, there were some outliers in the I/D data. The 2008 data was skewed by a project with a slope failure near the end of construction, and the 2011 data was skewed by an emergency contract with additional work added to the project after receding floodwaters showed more damage to the road than expected. When the outliers were removed, the I/D Selected data shows that I/D projects all fell within 2%.

One concern with I/D contracts is that the innovation required for accelerating projects might reduce the number of capable bidders. This is because acceleration could involve the use of multiple shifts, night shifts, newer technologies and flexible scheduling. This concern was not realized in actual project data. Figure 4 compares the average number of bids per call for all MoDOT projects as compared to I/D projects. Except for 2010, there were more bids received per call for I/D projects than all projects. Assuming that all bidders were qualified to undertake accelerated projects, this result shows that the potential for incentive bonuses overcame any problems associated with acceleration.

CONCLUSION
Project acceleration has become a national focus. The newly enacted transportation bill, Moving Ahead for Progress in the 21st Century, emphasizes accelerated project delivery and innovation (FHWA 2012). Innovative contracting techniques such as incentive/disincentive contracting could be one tool for ensuring the timely delivery of transportation projects. This study reports the results from an examination of completed I/D projects in Missouri from 2008 to 2011. Data shows that I/D projects reduced both mobility and safety road user costs. The average days saved
was around 11 days and the average total RUC savings was over $444,000 per project.

Contractors appeared to be aggressive in pursuing incentives and avoiding disincentives. No contractors were assessed disincentives while fourteen of the twenty contractors obtained the maximum incentive amount. In total, I/D projects saved around $8.9 million in road user costs while only paying a little less than $1.7 million in incentives. The savings corresponded to a reduction of 214 days in construction. The RUC savings and schedule reduction were achieved with an average I/D rate discounted to 16.7% of the daily RUC and a maximum incentive of 3.4% of the original contract amount. Since the sample size of projects from existing literature is limited, this study included a much larger sample size of twenty I/D projects let by Missouri over a four-year span. The results show that I/D contracting is successful at mitigating work zone impacts.

The effectiveness of I/D for various project characteristics was analyzed. Urban projects, full-closure projects and emergency projects all seemed to be good candidates for I/D provisions. The net RUC savings was 80% for urban projects, 86% for full-closure projects, and 93% for emergency projects. Rural, non-emergency projects effectively saved RUC but not at the same level as other projects, only netting 33% of RUC savings.

A programmatic evaluation of all MoDOT projects showed that I/D projects deviated more than other projects from the programmed costs. However, such deviations (-11.82%) were not primarily produced by the I/D payouts since incentive payments only accounted for 2.32% of final contract costs. I/D projects were completed on time more often than other projects, which indicates that I/D contracts successfully reduce construction time. I/D projects also had a higher percentage change of award amounts to final amounts, but this change could be skewed by two projects. The concern that I/D contracts could reduce the number of qualified bidders due to
contractor capabilities and the innovation required did not materialize. In fact, the average number of bids per call was higher for I/D than other projects. This result is important for understanding the competitiveness of the market.

Since this project only examined I/D contracts in the state of Missouri, to what extent are the conclusions from this project transferable to other states? There are three main factors that affect transferability. The first factor is the characteristics of the DOT in terms of the contracting process, contracting language, statutory authority and rules, use of acceleration techniques and construction management practices. The legal characteristics are especially significant, because local contracting practice is heavily dictated by a state’s contracting laws and regulations. The second factor is the local heavy construction environment and characteristics of contractors such as the number of contractors and the capability of contractors for acceleration and innovation. The last factor is the local transportation system, demand and land-use. For example, a different level of congestion in metropolitan areas in D.C. or Los Angeles could result in much higher RUCs. Despite its limitations, this project presented the only examination of work zone traffic impacts associated with I/D project to date and included the use of one of the largest datasets on I/D projects. Similar studies conducted in other states will help to build a larger knowledge base and examine how significant are each of the three aforementioned factors.

ACKNOWLEDGMENT

The authors gratefully acknowledge the assistance from the following individuals: Natalie Roark, Danica Stovall, Jeremy Kampeter and Jeff Campbell of the Missouri Department of Transportation (MoDOT) for their expertise on contracting and project cost estimation; John Miller and Myrna Tucker of (MoDOT) for their assistance with traffic and safety data; Tracy
Scriba of FHWA for her help in discovering relevant experts and sources; and Jerry Ullman of TTI for his aid to the project through the TRB Work Zone Traffic Control Committee.

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Note: Projects may be included with one or more characteristic.