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INNOVATIVE METHODS FOR REDUCING CONSTRUCTION TIME OF TRANSPORTATION PROJECTS IN URBAN AREAS

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ABSTRACT
In today's highway construction industry, the focus of work has shifted from building new transportation facilities to Rehabilitating, Resurfacing, and Restoring (3R) of those already in existence. In this type of project, traffic must be maintained with lane and shoulder restrictions while construction takes place, As a result, traffic flow is disrupted seriously and creates major inconvenience to the public. Reducing the construction time and thereby minimizing the inconvenience to the traveling public has become one of the primary missions for State Highway Agencies.

In recent years, a few innovative contracting methods have been introduced into the USA These innovative contracting methods are not entirely new ideas but have not been used substantially in the past. These methods intend to reduce construction time and thereby minimize traffic disruptions during the construction periods. These innovative contracting methods motivate the contractor to work faster and encourage better construction planning and work management.

This paper will introduce the results of analyzing 100 projects that have been constructed in the USA using these innovative methods. The statistical analysis has shown substantial reductions in construction time (up to 50%) as compared to similar projects using conventional methods. The paper will also present the parameters affecting time reduction, such as project type, location, and other parameters.

KEYWORDS
Procurement, Time Unit Cost, Road User Cost, Bidding Methods, Transportation Projects

1. INTRODUCTION

Contract time, which can be defined as the maximum time allowed for the contractor to complete all the work, as specified in the contract documents, is one of the most important aspects of the entire construction process. Not only do these time calculations affect the areas such as budgeting, resource planning, local economies, and claims issues, but reasonable contract time may avoid higher bid costs as well as decrease the possibility of disputes between the contractor and the contracting authority (Hancher and Rowings, 1981).

Today's highways have become such an integral part of our daily lives that over 90% of America's total transportation needs are met by these systems (Highway, 1992). Unfortunately, this heavy traffic has had an undesirable effect of decreasing ability of each motorist to effectively utilize this country's transportation network. In the past two decades, the number of vehicles on our roadways has increased by more than 75% while the total mileage of new highway systems has increased by only 4% (Highway, 1992). As a result, the traveling public inevitably faces heavy traffic congestion, especially in the metropolitan areas. Therefore, increasing usable roadway lanes for vehicular traffic has become one of the top priorities of all state highway agencies (SHAs) across the nation.

To effectively meet the growing need for additional usable highways, attention is shifting from the building of new transportation facilities to the resurfacing, rehabilitation and restoration (3R's) of those already in existence. Typically, these projects are undertaken in heavily urbanized areas, causing extreme traffic congestion during the construction period. This slowdown of the traffic flow not only poses severe inconvenience to the traveling public, it also negatively impacts the business community. With such a premium placed on construction time, many of this country's SHAs have begun to implement alternate construction procedures in an attempt to reduce project duration. A variety of contacting and bidding methods have been introduced in the United States over the last several years that specifically address reduction of construction times by "buying time". The four most popular of these methods presently being utilized are:

- Bidding on cost/time
- Incentive/disincentive (I/D)
- Bidding on cost/time combined with incentive/disincentive
- Lane rental

Each of these four innovative methods considers the value of the time. Due to the significant influence of time value, schedulers will have to become much more proficient in estimating construction times. It is therefore a necessity for the successful practitioner to become familiar with the basic principles and procedures of these developing contracting methods.

2. TIME VALUE

2.1 Unit time value

Each of the innovative procurement methods addressed in this paper is based on the principle of cost reimbursement to the contractor for contract time reduction. To ascertain these costs, the owner has to calculate what is the value of the time. For example, if a contractor reduces construction time by 40 calendar days, the owner has to determine what is the value of the 40 calendar days of time reduction. In this case the owner is a "time seller".

Calculation of time value is based on a parameter defined as "unit time value" (UTV), which represents the value of a time unit to the owner. In most cases, the UTV will include the direct cost resulting from construction delays, such as temporary facilities, moving costs, and another alternate solutions. Indirect cost items encompassing both job overhead and general overhead can also be considered in the UTV calculation. A variety of other general costs involving losses to the business community, reduction of potential profits and even hardship to the owner, though harder to quantify, can also be incorporated into the final calculations. The measurement of UTV can be in any unit that the owner chooses, such as hours, days, weeks or months. The total value of the time to be sold is calculated using the following formula:

TOTAL TIME VALUE = (UNIT TIME VALUE) x (TIME)

2.2 Calculation of Daily Road-User Cost

UTV calculations in the highway construction industry are typically expressed as a cost per day. This variable, evaluated by SHAs throughout the country, is commonly referred to as the "daily road-user cost" (DRUC). For example, if a new road has to be built, a feasibility study will be conducted by the SHA to determine the economic impact of the new facility. A calculation of the DRUC will be part of this analysis, and will include such items as travel time, travel distance, fuel expense, as well as other related components.

Although DRUC calculations have been performed routinely by SHAs for many years, no formal computational procedures have been instituted nationwide. Therefore, many states have developed their own procedures. One of the major differences in DRUC calculations among the various SHAs is the way in which they approach indirect costs. Many states, in fact, due to regulatory constraints and hard-to-quantify values, do not even consider indirect costs in their DRUC calculations. This is a critical issue because the indirect cost items can be very significant, especially for projects constructed in heavily populated areas. For instance, on a major highway reconstruction project resulting from the earthquake damage in California, the DRUC was estimated at $200,000/day based on direct costs only. Preliminary evaluations by California DOT indicated that had they included indirect costs, this figure could have been increased substantially. Since UTV and DRUC calculations are the basis for determining time value in all innovative procurement methods, the importance of the establishment of standardized procedures for these calculations cannot be stresses enough.

3. INNOVATIVE PROCUREMENT METHODS

3.1 Generalities

The utilization of innovative procurement methods has increased substantially in recent years. The evaluation of these nontraditional techniques has been performed by the authors researching dozens of case studies of projects constructed under one of these contracting strategies. To be able to compare and contrast these methods, the reader needs to be familiar with the basic principles of each method. This section is devoted to describing concepts and procedures associated with each of the three most popular innovative procurement methods used in today'' highway construction industry.

3.2 Bidding on Cost/Time (A + B)

Until recently, bidding on cost/time, also referred to as the A+B method, has been employed very sparingly in the United States. However, after this approach was recommended by the federal highway agency, its use has steadily increased among various SHAs.

The first step in this procedure is for the owner to establish the DRUC and incorporate it into the bid documents. Next, every contractor who participates in the bidding process will be required to calculate two values: A- the estimated construction cost for the project; and B – the estimated project duration for construction completion. The successful bidder is the contractor who submits the lowest total combined bid (TCB) using the following formula:

TCB = ESTIMATED CONSTRUCTION COST + (DRUC) x (EPD)

The feedback from those SHAs who have implemented the bidding on cost/time method has been very positive (Harp 1990; Taricone 1993). Herbsman and Ellis (1992) analyzed data obtained from 14 case studies of projects contracted using the bidding on cost/time method. The results of this analysis indicated that for the most part, substantial time reduction was achieved with little or no increase in overall construction costs.

The bidding on cost/time method has been gaining acceptance among many of the country's SHAs. A list of 16 states that currently use this method is presented in Table 1. Of the SHAs surveyed that have contracted projects under the A + B method, only Texas DOT has met with any adverse consequences.

Table 1: The "A + B" Contracting Project Status in United States

Location	No. of projects	Results
Arkansas	1	Favorable
California	3	No results to report
Delaware	3	First two had favorable results, third had problem unrelated to A+B bidding
District of Columbia	2	Favorable
Idaho	1	No results to report
Kentucky	1	Favorable
Maryland	Several	Favorable
Michigan	2	Too early for results
Mississippi	2	Favorable
Missouri	Numerous	Favorable
Nebraska	1	Favorable
North Carolina	10	Favorable
Pennsylvania	2	Favorable
Texas	2	Unfavorable results, A+B created friction between State and the contractor
Utah	3	Favorable
Virginia	1	No results to report

The most important advantage of this method is that time reduction is achieved through competition between contractors rather than direct monetary payments. A study of the bid results from a large number of projects has revealed that when bidding on cost/time, contractors do not appreciably raise their unit prices with respect to the unit prices of comparable projects bid using conventional methods.

The main disadvantage to notice are the problems that may arise under this method when contractors are too eager to get the job and may underestimate the construction time in order to increase their chances of being the successful bidder. When the contractor realizes that the original estimated project duration is unattainable, he might be tempted to “cut corners” in an attempts to limit financial losses. At this point, the quality of the work might suffer, and the contractor will most likely be looking to change orders and claims as a means for recouping losses.

3.3 Incentive/Disincentive

The incentive/disincentive (I/D) approach of motivating general contractors to reduce overall contract duration is probably the most established of the three innovative contracting methods being analyzed in this paper. In this method, the contract time is determined by the owner and presented as part of the bid documents. If the contractor is able to complete the project ahead of schedule, this contractor would then be entitled to a bonus (incentive fee). If, on the other hand, the contractor finishes the project behind the schedule, the owner then assesses a penalty (disincentive fee)

As was the case with the bidding on cost/time (A + B) method, the DRUC is also an integral part of the I/D method. Most SHAs calculate the DRUC and apply this value as their daily incentive/disincentive fee. Table 2, based on a study conducted by the Iowa DOT, illustrates the distribution of I/D fees for various transportation agencies across the United States. According to the SHAs surveyed, over half of all I/D contracts let by these agencies had an I/D fee in the range of $2,500/day to $5,000/day

Table 2: Daily I/D Fees used by SHAs

I/D rates ($/day)	Percent of SHAs
0-2,500	11.4
2,501-5,000	54.4
5,001-10,000	25.7
10,001-25,000	5.7
>25,000	2.8

The data of the Table 2 indicate that at the time of the survey, only 2.8% of the I/D contracts were mandating fees in excess of $25,000/day. However, as the trend for more urban highway rehabilitation continues, the magnitudes of the I/D fees are expected to increase profoundly as greater significance is placed on the value of time. Already, there are a few rehabilitation projects under way in major metropolitan areas, where DRUC calculations have yielded values in the range of hundreds of thousands of dollars per day. In one recent California emergency transportation project, DRUC estimates were used as the basis for contractual establishment of a $200,000/day I/D fee. The contractor on this particular project finished 73 days ahead of schedule and received 14.6 million dollars in incentive fees.

Although most states are using the DRUC as a basis for determining appropriate I/D fees, there are some states using different parameters for establishing I/D fees. One of the alternate approaches is to calculate the I/D fee as a percentage of total project cost. Table 3 is a schedule of I/D fees as utilized by the New Jersey DOT. For example, projects in which total construction costs are expected to be between $1,500,000 and $5,000,000, the I/D fees will be set at $5,000/day. For projects whose costs are to exceed $500,000,000 the I/D fees will be 0.03% of the total project cost.

Table 3: Schedule of Daily I/D Fees Utilized by New Jersey DOT

Total project cost (in millions of dollars)	Daily I/D rates
0-.05	$1,000
0.5-1.5	$2,000
1.5-5.0	$5,000
5.0-10.0	$6,000
10.0-15.0	$8,000
15.0-20.0	$10,000
20.0-30.0	$13,000
30.0-40.0	$16,000
40.0-50.0	$17,000
50.0+	0.03% of total project cost

Most states that are using the I/D method apply the same value for both the incentive and disincentive fee. An Iowa DOT study, indicates that of the 35 states surveyed using the I/D method, 28 (80%) had an I-fee equal to the D-fee (I = D). Four states (11.4%) said that no systematic relationship existed between I/D fees and, they varied from project to project. Two states (5.7%) reported that their I-fee was higher than their D-fee (I > D), while one state (2.9%) had an I-fee smaller than its D-fee (I < D). One state (2.9%) indicated that they do not even assess a D-fee.

Many states have implemented limits to the maximum amount of incentive fees that will be paid out and the disincentive fees that will be assessed to the contractor. These limits, also known as caps, have been set by some states as a percentage of the total construction cost. According to a Iowa DOT study, the maximum percentage cap reported in 1991 was 10% (Missouri), while the majority of those SHAs that limited I/D fees by means of a percentage cap used a value of 5% of the total construction cost. Other states are restricting the maximum amount of I/D fees to a flat-rate dollar amount. For example, New Jersey DOT has mandated that total I/D fees on any one project cannot exceed $100,000. Only one state surveyed, Arizona, had a limiting cap in terms of time rather than dollars (±30 days). Several of the SHAs that responded varied their cap amounts depending on the project. At the time of the survey, some states did not have any restrictions on the cap rates, but most indicated that they were considering some sort of limitations for the future.

According to the survey conducted by the Iowa DOT, the utilization of the I/D contracts achieved construction time reductions in almost every case. In over one half of the projects studied, the contractor was able to achieve the maximum compensable time. Another advantage of the I/D contracting strategy is its flexibility in enabling SHAs to adjust their financial exposure by utilizing flat rate or percentage caps for I/D fees. It has also been reported that on projects that used the I/D approach, as compared to the A + B method, the relationship between the owner and contractor tended to be much less adversarial. This aspect is apparently related to the fact that the contractor typically receives some amount of incentive payments.

The major disadvantage of the I/D method lies in the fact that the fees are based on the engineer's time estimates, as established by the SHAs. Today, in the United States, most transportation departments determine contract time based on the performance (production rates) of the average contractor. This practice of establishing contact times creates a situation whereby a good competitive contractor can reduce contract time with little or no additional commitment of resources. In other words, the same time reduction could essentially be achieved, free of charge, by reducing the original engineer's time estimates. This opinion is supported in several states where, in recent years, original engineer's time estimates have been reduced, and contractors were still able to complete projects on time.

3.4 Lane Rental

Introduced in the United States in 1990, the lane-rental method has been used extensively by the British Department of Transportation (BDTp) since 1984. This method was defined as a way of providing financial incentives to general contractors and others to shorten the overall time required for lane closures (Report 1989).

To utilize the lane-rental method, the transportation agency in charge of managing the project must set contract times, as well as determine the cost of lane closures under various working conditions. Each bidder is required to submit their cost estimate of the work to be performed, along with the amount of time needed for lane closures during the construction period. The total cost of the project is the sum of the cost estimate of the work to be performed plus the cost of all essential lane closures. The lowest total aggregate cost estimate will determine who will be the successful bidder. Upon commencement of construction, whenever lane closures are required, the contractor will pay to the owner those charges in accordance with a predetermined schedule of lane closure fees.

An example of a schedule of lane closure fees for a four-lane roadway construction project 2.4 Km (1.5 mi.) long is presented in Table 4. Referring to Table 4, if a contractor elects to close one lane of traffic from 9:00 a.m. to 3:00 p.m. on weekdays for a total of 20 days, a cost item of $120,000 ($6,000/day x 20 days) should be included in the bid. If on the other hand, this contractor decides to close one lane from 6:00 p.m. to 6:00 a.m. during weekdays for the same amount of days, then an add of only $20,000 ($1,000/day x 20 days) would be required in the bid.

In order to avoid the payment of excessive lane closure fees, the contractor will strive to minimize construction work during the peak traffic hours. Bondar (1988) found that the contractors seem to better manage the construction work, as well as the material deliveries, thus maximizing productivity during lane closure periods, again in an effort to pay the lowest fees possible. Hence the contractor is highly motivated to minimize lane closures, and when such occurrences do arise, every effort is made to undertake these lane closures during off-peak hours. The net effect to the traveling public of this innovative contacting method is therefore a substantial reduction in the disruption to the normal traffic flow.

Table 4: Schedule of Lane Closure Fees ("Lane rental" 1990)

Work time	Work duration	Lane-closure fee
Weekdays	9 a.m. to 3 p.m.	$ 6,000/day for each lane closed
Weekdays	6 p.m. to 6 a.m.	$ 1,000/day for each lane closed
Weekends	Friday 6 p.m. to Monday 6 a.m.	$10,000 for each lane closed
Weekends	Friday 6 p.m. to Monday 6 a.m.	$50,000 for whole project detour

Although the lane-rental method has been utilized on a few projects in the United States (Colorado and North Carolina), this contracting strategy is still in its infancy. Due to the continued rate of success that this approach enjoys in the United Kingdom, some practitioners feel that lane-rental method may become an established part of our highway construction industry. Maggs (1985) stated that "Lane-rental contracts for motorway reconstruction have been successful in demonstrating the scope for reducing the time needed for completion". According to Bondar (1988), lane rental favors the more efficient firms who are able to provide careful thought for work planning. Analysis of the cost benefit of projects that were contracted using the lane-rental method shows these cost savings to be very significant. As a case in point, the BDPp has reported that during the first three years of using the lane-rental method, the equivalent dollar value of cost savings due to reduction in delays was worth approximately $40,000,000 (1986 value).

The BDTp is pleased with the results they have had using the lane-rental method. The savings in cost and time have been substantial. According to the BDTp, the average reduction of construction times realized utilizing this method is approximately 25% (Srinivasan and Harris, 1991). The main advantage of this method, is that it allows the contractors freedom to choose the best work patterns for construction (day, night, weekend, one lane closed, two lanes closed, detour, and so on). In addition, the contractors are strongly motivated to reduce the construction time because they actually pay out (real money) to the owner for the lane closure.

The BDTp reported that the main disadvantage associated with the lane-rental was the tendency for contractors to "cut corners" when faced with the prospect of unanticipated lane-closure fees due to construction delays. Just as it is in the United States (A + B method), this situation could lead to poor quality and strained contractor/owner relationship.

4. CASE STUDIES

Many specific case studies have been examined in detail. The major objective of this review has been to find the mean and method that contractors use when they participate in bidding process. The major conclusions from analyzing these case studies shows that the low bidding time was estimated and achieved by better organization, better scheduling and planning, better use of resources and not by raising the cost. However, when contractors were able to earn high incentive fees, they then invested more resources, switched to night or 24-hour day shift work, etc. In this case, it becomes pure economic calculation, if the contractor can gain a $200,000/day incentive it would be worthwhile for him to invest more in order to gain this significant sum.

4.1 Case study 1

An example of a highway bid tabulation from a construction project in North Carolina (Table 5) is presented. Since this project was contracted utilizing the A + B method, each contractor participating in the bid submitted an estimated construction cost, column 2 and the estimated project duration required to complete this project, column 4.

Table 5 illustrates that the estimated construction costs submitted by the five bidding contractors range from $19,371,550 to $21,138,086, while the estimated project duration vary from a low of 642 days to a high of 762 days. Although contractor B ranked second in both the estimated construction cost and the estimated project duration, this contractor was awarded the project by virtue of the lowest total combined bid of 424,222,537. The calculation of the total combined bid of contractor B is as follows:

$19,518,537 + 672 days x $7,000/day = $24,222,537

Upon further analysis of the bid results from Table 5, one can argue that the North Carolina DOT overpaid $146,987. This amount represents the difference between the lowest estimated construction cost of contractor A ($19,371,550) compared to that of contractor B ($19,518,537), by selecting contractor B over contractor A.

However, from the general public's point of view, the state of North Carolina obtained a project with a 90-day reduction in construction time. This time is calculated by subtracting the estimated project duration of contractor B at 672 days from the engineer's time estimate of 762 days (762 days – 672 days = 90 days). According to the North Carolina DOT's DRUC calculations, this savings of 90 days is valued at $630,000 (90 days x $7,000/day). Therefore, the net savings realized by the citizens of North Carolina utilizing the A + B method was $483,013 ($630,000 - $146,987). It should be noted that the savings to the general public will actually be much higher because the North Carolina DOT did not consider any indirect costs in their DRUC computations.

Table 5: Bid results utilizing the Bidding on Cost/Time (A+B) Method

Contractor	Estimated Construction Cost		Total Time Value			Total Combined Bid (A + B)	
	Dollar value(A)	Rank	Estimated project duration (d)	Rank	Dollar value[a] (B)	Dollar value	Rank
A	19,371,500	1	762	4	5,334,000	24,705,550	4
B	19,518,537	2	672	2	4,704,000	24,222,537	1[b]
C	19,734,919	3	702	3	4,914,000	24,648,537	2
D	20,198,158	4	642	1	4,494,000	24,392,158	3
E	21,138,086	5	762	4	5,334,000	26,472,086	5

Note: engineer's cost estimate (A) = $20, 568,042; engineer's time estimate: 762 days
[a]Equals column 4 x DRUC ($7,000/day).
[b]The successful bidder.

4.2 Case study 2

After the Northridge (California) earthquake, the California DOT (CALTRANS) had to reconstruct a few bridges (over crossing) which caused enormous problems (delays, loss to the business community, etc.) to the public. CALTRANS decided to use the A + B plus I/D as the best method to reduce construction time.

In Table 6 information provided by CALTRANS on the Santa Monica Freeway reconstruction project is presented. The contractor did a very detailed schedule – worked 24 hours/day, 7 days/week, and used extensive resources to reduce the time. For example, construction materials have been brought from east. The management of the project was also very intense. It is interesting to note that the contractor' cost estimate was much less ($6,300,000) than the engineer's cost estimate.

Table 6: Santa Monica freeway bridge reconstruction project

Item	**Data**	**Item**	**Data**
Date: Budget(engineer's cost estimate):	April 1994 $21,341,839	Contractor' s time estimate	140days
Engineer's time estimate:	140 calendar days	I/D fee	4200,000/day
RUC:	$200,00/day	Completion time	66 days
Contractor' s cost estimate:	$14,904,275	Incentive fee, 74 days x $200,000	$14,800,000

As for the public reaction, the California trucking association reported that "operating the freeway early will save their commercial operators more than $250 per truck trip or %500,000 per day" in trucking cost (Carr 1994). This figure demonstrates the enormous value of damages to the business community caused by this type of project (3R). CALTRANS based their calculations of the RUC only on direct cost, so they arrived at the value of $200,000. If indirect costs, such as losses to the business community, were taken into consideration, the RUC value would have been much higher.

5. CONCLUSIONS

This paper presents three innovative procurement methods that all share a common goal of reducing project duration, but each has a very different approach for achieving this common objective. The authors have analyzed a great deal of data from case studies, as well as from numerous interviews with practitioners who have been involved in innovative contracting projects. The research results indicate that the three methods can be divided into two major areas. In the first category, that includes the bidding on cost/time (A+B) method, time reduction is achieved by competition between bidding contractors. In the second category, time reduction is encouraged by financial rewards and time delays are discouraged by penalties. The incentive/disincentive (I/D) method and the lane-rental method are included in this category.

The main conclusion reached from analysis of all available research data was that each of the three methods was successful in reducing construction time. This success rate was measured against engineers' time estimates calculated as if the projects were contracted under conventional methods. Time reductions of 20-50% were achieved in comparison to similar projects using conventional contracting methods.

The most economical methods of the three is bidding on cost/time (A+B), since the time reduction is achieved through competition rather than monetary payments to the contractor.

The use of the incentive/disincentive method was determined to be less effective and more expensive than the A+B method. This would explain the decline in the number of I/D contracts let in the United States over the last few years.

The new approaches represented by the lane-rental method as well as a combined method (A+B plus I/D) are promising, however more data from additional case studies must be collected for further analysis. More studies need to be done in developing standard procedures for calculating the value of time (DRUC), especially in the area of determining what indirect cost items have to be included in the final calculations.

Additional research should be conducted with the goal of establishing an acceptable methodology for computing "reasonable" contract determination. The application of knowledge-based expert systems in this area has shown some promising results, and more research could yield valuable data.

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