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Abstract

Incentive/Disincentive (I/D) provisions are used by state highway agencies as a contract method when early completion is needed for a highway construction project. I/D can provide encouragement for contractors to complete highway construction projects by giving them incentives to finish ahead of the required schedule. The incentive amount should be enough to encourage contractors to accelerate their schedules while, at the same time, making up for any cost incur when doing so. Additionally, in order not to waste tax payers' money, the incentives should be limited to a reasonable amount. Setting a cap for incentive is one of the most important procedures that Departments of Transportation (DOTs) undertake when drafting I/D contracts. This study evaluates different methods that have been used to set incentive and disincentive amounts for I/D contracts. The advantages and disadvantages of these methods are then examined and analyzed.

Keywords: Incentive/Disincentive Contracting, highway construction, I/D amount

Evaluation of Incentive/Disincentive Contracting Methods for Highway Construction Projects

Since the 1990s, state highway agencies have begun to implement incentives and disincentives (I/D) contracts that aim for early completion of highway construction projects (Ellis and Pyeon 2005). Various I/D contracting plans include schedule-based I/D for early completion of work, cost-based I/D for reducing project costs, and performance-based I/D for improving project quality and safety. The design and implementation of schedule-based I/D are relatively easy and inexpensive (AbuHijileh and Ibbs 1989).

Among these three I/D methods, early completion has been the most popular I/D plan for transportation construction projects. Its original design awarded the contractor with financial incentives to accelerate a schedule, and then decreased any user costs resulting from the inconvenience of the construction. On the other hand, if a project completion was delayed, financial disincentives would be collected from the contractor to make up for the loss of user costs. Thus far, I/D have been limited to only a few highway construction projects because of the increased effort involved. I/D contracts do not come without a price. I/D provisions require increased administration to determine when project targets have been reached (Jaraiedi, Plummer and Aber 1995). Also, the DOT staffs need to evaluate and decide if the amount of the incentive, as well as the amount of the disincentive, cap setting, and all relative provisions in the contracts is appropriate. Generally, I/D contracts are limited to those projects whose execution would severely disrupt highway traffic or highway services, significantly increase road user costs, considerably affect adjacent neighborhoods and businesses, or complete a gap in the highway system to provide a major improvement (FHWA 1989). I/D are assessed on a daily basis and can be used to achieve specific milestones within a project or to encourage timely completion of the total contract (FDOT 1996–1997, 1997–1998).

Because of the inherent character of the I/D contracting methods, both DOTs and contractors are cautious when selecting and dealing with them. This directed project will list, analyze, and summarize the methods proposed in the existing literature and documentation on setting incentive and disincentive amount for highway projects. Recommendations will be given based on the analysis.

Statement of Problem

I/D has been used in highway construction for more than 20 years, but it is still not a common highway contracting method. DOTs will only choose I/D when the projects need urgently to be finished.

When setting the cap incentive amount for a project, the DOT needs not only to make the amount sufficient to compensate for the energy that the contractors will spend on scheduling acceleration, but also to make sure the cost of the incentive is less than the public cost of delay caused by the construction. In other words, the DOT needs to provide a reasonable amount for the incentive to make sure it is attractive enough to motivate contractors to accelerate their schedules, while at the same time not wasting tax payers’ money. Therefore, when choosing I/D as the contracting method, one of the DOT’s essential assignments is to set an appropriate amount of incentive for the contract.

Significance of Problem

Although setting cap incentive amounts is an important process in I/D contracting, there is no official regulation or rule to guide DOTs on how to actually do this. While the basic concept of using the I/D is simple, there is some variation (Shr and Chen 2004). The bottom line for determining I/D rates is that the rates should reflect the cost of savings/delays to the public and the savings/extra administrative costs to the DOTs (Herbsman 1995). The I/D amount should include various costs such as (1) safety of the users; (2) the loss of user time due to construction; (3) an increase in gasoline consumption; and (4) the increased administrative and monitoring associated with the use of an I/D contact (Jaraiedi 1995). Most DOTs employ the daily road user cost (RUC) as the basis for determining an appropriate I/D amount (Herbsman 1995). Some states, however, count on other parameters. DOTs are free to choose their own methods of determining incentive and disincentive amounts. Nevertheless, they do need some guidance to help them decide how to set these amounts.

Statement of Purpose

This directed project reviews the literature and summarizes different methods used for setting the incentive and disincentive amounts for I/D contracts. It also provides a comparison of different methods for setting incentive amount by examining selected case studies. Finally, the study concludes by identifying advantages and disadvantages of different methods and then providing some recommendations on how to choose an appropriate method for a specific contract.

Definitions

- *Incentive/Disincentive contracting method*: A highway construction contracting method that awards the contractor with incentives for accelerating the schedule and then decreases users' costs caused by the inconvenience of construction. It also collects the disincentives from the contractors to make up for the losses for users' costs if a project's completion is delayed (Ellis and Pyeon 2005).

- *Road User Cost (RUC):* The estimated cost to the general public resulting from travel delays due to construction work or other incidents that impede traffic.
- *Cost of acceleration*: The additional cost a contractor incurs due to expediting the delivery of a contract. This includes direct and indirect costs, profit, and additional markup.
- *Liquidated damages*: A monetary component included in some construction contracts to encourage completion of the project or a segment of the project by a specified date.

Assumptions

This directed project is based upon the following assumptions:

1. DOTs need some guidance to help them set incentive and disincentive amounts for I/D contracts;
2. There should be at least one method among the different methods used for setting incentive and disincentive amounts that is better suited for a specific I/D contract than other methods;
3. The data that is used in the case study of this project is historical data of Florida DOT obtained from Shr and Chen (2004) published report. The unknown or inaccessible part of the data, which is necessary for calculation, is assumed as the normal situation (roadway project type and normal market conditions).

Delimitations

This directed project includes the following delimitations:

1. The methods indicated and analyzed in this study are the ones that exist and have been detailed in prior literature;
2. All of the I/D contracting plans mentioned in this study, except the ones that have been specified, are schedule-based I/D and linear I/D;
3. This study is focused on research done within the United States. Relevant issues that involve some locale other than the US will not be discussed in this study;
4. This study aims to provide a guide that can be referred to by DOTs whenever necessary. It does not aim to set standards for I/D contracts.

Limitations

This directed project involves the following limitations:

1. Methods that likely exist and have been used by some DOTs but have never appeared in published literature are not included in the analysis of this study;
2. The analysis and conclusion of this study are based only on the assumptions, data, and results of the case studies included within and, as much, may not be suitable for all situations.

Literature Review

The I/D contracting method usually implements I/D clauses to the typical low bid method. The DOT pays incentive fees to the contractor, based on each day that the contractor can complete the project ahead of schedule. Likewise, each day beyond the completion date will cost contractor a disincentive fee. The FHWA Technical Advisory

(1989) proposes that daily incentive rates and daily disincentive rates should be equal. If different rates have been set for incentives and disincentives, it is recommended that the daily incentive rate should not exceed the daily disincentive rate.

The DOT also sets a cap for the total incentive fee, which means the contractor can earn no more than this amount by accelerating the schedule. The cap incentive amount is usually set at a certain percentage of the contract amount, a certain dollar amount, or a set number of days that will be paid (Sillars 2007). Most DOTs choose a cap of five percent of the total contract amount. According to FHWA Technical Advisory, a cap for disincentive should not exist, though some DOTs set equal caps amount for both the incentive and disincentive (Anderson and Russell 2001). The existence of cap for incentive denotes that when the completion date is ahead of schedule, and at some point the DOT pays the incentives, both the DOT and the contractor will benefit from the schedule acceleration; however, when the completion date is either beyond the schedule or it is before the ‘incentive days’, the benefit to either the DOT or the contractor, or both, will be decreased.

For highway construction projects that are in critical need of early completion, I/D has effectively led to positive outcomes. Although the percentage of cases using I/D as a contracting method is relatively small when compared to those using other contracting methods, the use of I/D remains promising. A fairly high ratio of cases using I/D has ended with the early completions expected by the owners. Arditi, Khisty and Yasamis (1997) state that, of the 28 highway construction projects conducted by Illinois DOT during 1989 and 1993, 79% received full incentives and 21% received partial incentive payments. Rister and Wang (2004) note that, between January of 1999 and December of 2002, 32 highway construction projects in Kentucky were selected to use I/D contracting methods (including both entire contracts and partial contracts). Among the 32 projects, approximately $10,868,395 has been paid out in incentive fees, and $21,500 has been collected in disincentive fees.

Background

Although there is no official standard for setting incentive amounts, it has been accepted and implemented by most DOTs that the incentive amount should be between Road User Costs (RUC) and the extra acceleration cost to the contractors (Herbsman, Glagola 1995). Sillars (2007), in his report for the Oregon DOT, formulated an equation, $CA \leq I / D \leq RUC$ to express the relationship of I/D. The lower boundary of the equation is the contractor's cost caused by acceleration (CA), which should be less than incentive amount; otherwise there is no reason for the contractor to accelerate the schedule if the incentive cannot cover the cost. The upper boundary of the equation is Road User Costs (RUC), which should be greater than the incentive amount; otherwise, it is meaningless to accelerate the schedule, since an incentive amount greater than RUC will cost the public even more than if no acceleration were to happen. As DOTs decide the incentive amount, they should, at minimum, ensure that it complies with Sillars' equation.

According to Sillars (2007), the estimation of the equation's upper boundary RUC has been performed, and its method has now been accepted widely by most agencies. For the estimation of the equation's lower boundary CA, however, there are few working-level techniques and no commonly accepted method.

Incentive/Disincentive Amount Setting Models

There are several models provided in the literature that can be applicable to DOTs when deciding the amount of the incentive/disincentive. They are as follows:

Shr and Chen's model.

Shr and Chen (2004) have developed a model that can determine a reasonable incentive amount for construction projects. Based on the data collected from Florida DOT, this model provides a method for determining the optimum incentive days and incentive amount by putting the incentive/disincentive factor into a functional relationship between the construction cost and the project duration.

Based on the historical data collected from Florida DOT, the fitted model of regression appears as:

$$[(C-C_0)/C_0]=0.03214+0.10481[(D-D_0)/D_0]+0.46572[(D-D_0)/D_0]^2 \quad (1)$$

where C=Final Construction Cost

D=Days Used

C_0=Award Bid

D_0=Final Contract Time

Perform the procedures of shifting: (1) determine (D_0,C_0); (2) Determine the functional relationship between construction cost and time duration by using the set of (D_0,C_0) and Eq. 1; (3) Locate the point of minimum construction cost (D_1,C_1);(4) Calculate the distance between (D_0,C_0) and (D_1,C_1); (5) Shift the functional relationship between the construction cost and the time duration using the distance obtain in the last step and let (D_1,C_1) match (D_0,C_0). After shifting, Equation 2 is developed as:

$$C=1.0059C_0+0.1048C_0\ [(D-1.1125D_0)/D_0]\ +0.4657C_0\ [(D-1.1125D_0)/D_0]^2 \qquad (2)$$

In Eq. 2, it is assumed that every project has an internal relationship between the construction cost and project duration. The functional relationship between the two is determined at the same time as (D_0, C_0) is decided.

Due to the procedure of I/D contract, Incentive/Disincentive relationship is defined as:

$$T= (I) \times (D-D_1) \qquad (3)$$

where T=The Anticipated Maximum I/D Amount

I=Daily Linear I/D Amount

D=Construction Time

D_1=Contract Time

Put Incentive/Disincentive relationship into Eq. 2:

$$C=1.0059C_0+0.1.48C_0\ [(D-1.1125D_0)/D_0]\ +0.4657C_0\ [(D-1.1125D_0)/D_0]2+ (I) \times (D-D_1) \qquad (4)$$

where D_0=Construction Cost Estimate

D_1=Contract Time Estimate

Before the bid, there is no way to obtain D_0, so it is set that $D_0=D_1$.

$$\text{Construction Time } (D) =D_0-1.0736\times\ [(I\times D_0^2)/C_0] \qquad (5)$$

Finally, the anticipated maximum days for incentive and the anticipated maximum incentive will be:

Anticipated Maximum Days for Incentive= $(D_1\text{-}D)$ (6)

Anticipated Maximum Incentive=I $(D_1\text{-}D)$ (7)

This model is only appropriate for the estimation of linear I/D contracts. The authors suggest that an engineer's cost and time estimates can be used to run this model. After bidding, the contractor's award bid and contract time can be also used to run this model and calculate the anticipated maximum days for incentive and the anticipated maximum incentive.

Though this model is developed according to the historical data from Florida DOT projects, it can be adopted by any state DOT for a similar situation. However, the functional relationship between the construction cost and duration needs to be developed by the client based on construction type, location, and economic factors. Additionally, it should be noted that this model is project-dependent only.

Sillars and Riedl's model.

Sillars and Riedl (2007) conclude that the previous incentive amount setting methods usually consider one of two factors: (1) uses of RUCs; and (2) broad analysis of the cost of time changes to the contractors, using global bid result information. However, the congestion and the RUCs for a given segment of highway could continue to be increased along with growth in population and urbanization. Therefore, considering only the RUCs for incentive amounts given to contractors could cause the amount to be substantially higher than what is required to accelerate the work. Thus, Sillars and Riedl's model is based on the reflection of contractors' project economics.

This model is divided in two stages. In Stage 1, the profit of the project and the proportion of construction project cost categories (e.g., labor, material, equipment, etc.) are worked out. In Stage 2, the proportion established in Stage 1 is adjusted for the I/D amount according to experts' engineering judgment, and the estimated I/D amount is calculated according to the adjustment of the proportion.

Aside from the total cost of a project, the profit of the project may also be relevant to the project type and the market conditions. Based on Carr and Beyor's (2004) formula and exploration of Oregon DOT, a formula of predicted highway construction project profit has been articulated as followed:

$$P= f / [\log (C)^{m}] \tag{8}$$

where P= forecasted profit at bid time

f=factor representing project type

C=estimated total project cost

m=factor representing the market condition.

The value of f-factor and m-factor are shown in Table 1 and Table 2 below.

Table 1

f-Factor Used in Incentive Determination Model

Project Type	Description	*f*-Factor
A	Roadway	1
B	Interchange	1.1
C	Bridge	1.25
D	Complex	1.35

Table 2

m-Factor Used in Incentive Determination Model

Market Condition	Description	*m*-Factor
AA	Busy	1.4
BB	Normal	1.5
CC	Slow	1.6

The authors came up with a broad breakdown of the total costs of a project (see Table 3 below). The purpose of this breakdown is to provide a starting point for the calculation of a particular project, for which the user needs to adjust the proportion based on the original one, according to the engineering judgment and reflection of the accelerated segment. Then, the user must estimate the impact of acceleration to cost (i.e., percentage impact of acceleration to each element of the cost), based on engineering judgment. At this point, the acceleration cost is obtained from calculation. This acceleration cost is the lower boundary (CA) of the incentive amount, and RUC is the upper boundary. Based on engineering judgment, the user decides upon a final incentive amount that falls between these two boundaries.

This model provides a method that focuses on a particular project's unique characteristics, instead of relying on a one-size-fits-all algorithm. Due to the secretive nature of the highway bidding process, the using of engineering judgment is vital.

Percentage as maximum incentive amount (PMI) method.

The method most commonly used by DOTs to decide daily I/D amount and cap amount is Percentage as Maximum Incentive Amount. It is simple to use and requires no complicated calculation or historical data collection/analysis. As a result, this method has been widely accepted as the regular approach to setting I/D amounts. DOTs have different ways of setting the maximum percentage used in this method, but 5% is commonly used. Under special circumstances, the fixed percentage amount set by the DOT may be exceeded after approval by a relative agency. This study will use 5% as the default percentage when calculating for this method.

The daily I/D amount is calculated by dividing 5% of the total contract amount by the I/D time, which is the number of days that the contractor can use to accelerate a project. According to WVDOT (2003), the I/D time is usually decided by the following process: (1) The number of days of a normal schedule is the total working time in hours divided by a selected normal number of working hours (such as eight hours per day for five working days per week); (2) The number of days of an accelerated schedule is the total working time in hours divided by a selected accelerated number of working hours (such as 16 hours per day for six working days per week); (3) Subtracting the number of days of the normal schedule by the number of days of the accelerated schedule equals I/D time, which is the maximum number of days the contractor can save by accelerating the schedule.

It should be noted that, to avoid making the incentive days too long, the calculation of the normal number of working hours sometimes uses an aggressive pace of work, such as ten working hours per day multiplied five working days per week.

After the above calculation is performed, justification is sometimes necessary. A process must then conducted to verify that the I/D amount falls between the CA and the RUC.

Conclusion

There is a modest amount of literature on the various I/D amount-setting models that are applicable to this study and thus can be used as references when a DOT is trying to set a reasonable I/D amount for highway construction project using the I/D contracting method. The principles of these methods may vary, but nearly all are based on the relationship of $CA \leq I/D \leq RUC$. However, the application, effectiveness, and practical use of these models still needs to be verified.

Table 3

Sub-element Breakdown of Project Costs

Element[a]	Sub-element[b]	Value			
		Roadway	Interchange	Bridge	Complex
Direct cost		82%	78%	79%	77%
	Labor	25%	30%	30%	33%
	Materials	45%	35%	30%	37%
	Equipment	30%	35%	40%	30%
Indirect cost		6%	9%	8%	9%
	Supervision	2%	3%	2%	4%
	Time-related facilities	1%	1%	1%	1%
	Non-time-related facilities	1%	1%	1%	1%
	Mobilization/demobilization	3%	5%	5%	5%
	Insurance and taxes	1%	1%	1%	1%
Markup		12%	13%	13%	14%
	Risk	3%	5%	5%	6%
	Home Office G&A	8%	8%	8%	8%
	Profit (Calculated Separately)				

[a] Stated as a percentage of total project cost.
[b] Stated as a percentage of total direct cost

Analysis of the Models

The I/D amount setting methods discussed in this study are analyzed both qualitatively and quantitatively.

Shr and Chen's Model

Shr and Chen's model's equation is based on historical data and used regression analysis. By only knowing the contract amount and the contract time of a particular project, the anticipated maximum days for incentive can be predicted. Then, by calculating the daily RUC, the anticipated maximum incentive for the project can be obtained.

The traits of Shr and Chen's model are:

1. It can only be used for the prediction of the maximum days for incentive or maximum incentive for I/D contracts;
2. It is easy to use. Simply put in the data (construction duration and construction cost) of a particular project at an exact stage (DOT's estimate, contractor's bid or final data at the end of the project) to run the model, and the result will be obtained;
3. As stated above, this model can be used many times during different stages of the project to adjust the days of incentive and the corresponding daily incentive amount whenever needed;
4. The model depends on other resources to obtain the daily RUC, which is needed in the process of calculation;
5. The original data that has been used to obtain this equation is from FDOT projects. Therefore, the equation provided by Shr and Chen's research is only suitable for the

use of FDOT project. However, this model can be adopted by other DOTs. The functional relationship of construction cost and construction duration in the equation needs to be developed by other DOTs' own historical projects. Thus, the functional relationship developed by the exact DOT suits for the location, construction type, and economic factors in the exact area well.

Sillars and Riedl's Model

Sillars and Riedl's model does not require the support of historical data. It involves breaking down the construction costs, estimating the contractor's cost of accelerating the work (CA), and then adding incentive profit to obtain the final incentive amount for a project.

Through analysis, the traits of Sillars and Riedl's model are:

1. It does not employ a one-fits-all algorithm. It focuses more on the particular project that is being estimated. Therefore, the model could possibly estimate one project possibly more accurately.
2. It takes account of an array of factors (project type, project size and market condition) that comprise a particular project. This makes the model more accurate to estimate the incentive amount.
3. The process of using this model to estimate the incentive amount is relatively difficult. Unlike other models designed for the same aim, Sillars and Riedl' model cannot be used by simply inputting the data in an equation and then getting a result by solving the equation. This model requires a fair amount of analysis and calculation, which makes the result more accurate for a particular project's estimation.

4. Apart from analysis and calculation, the model also requires an engineer's judgment when estimating the changed percentage in each sub-element caused by the acceleration. Though it has not been specified particularly in the article, additional engineering judgment might be needed at the beginning of stage two when using this model. The percentage of each segment from the original breakdown is used as starting point and needs to be adjusted according to the specific project by the engineer's judgment.
5. The number of days that could be used for acceleration is not provided through the calculation of this model. It needs to be determined manually.
6. The final result from this model may need to be verified by the equation that expresses the original relationship of I/D amount: $CA \leq I/D \leq RUC$.

Percentage as Maximum Incentive (PMI) Amount Method

Percentage as maximum incentive amount method is widely used by DOTs as incentive amount setting method. The use of this method does not have a standard or specific procedure. DOTs decide how to conduct the calculation when using this method. The method does not have much reasoning or equations for back up, and depends upon the accumulated experience from prior historical projects and rules set by DOTs.

Through analysis, the traits of PMI method are:

1. When using the method, DOTs have different default amount for their incentive amount setting. As listed in Table 4 below, DOTs cap rates can be decided by fixed percentage of contract amount, fixed dollar amount, and various negotiable ways.

2. The method does not contain any complicated calculation, nor require an engineer's judgment. Therefore, once the fixed percentage or dollar amount is decided, it is relatively simple to use.
3. While simple to use, it lacks of a solid scientific foundation, and therefore, lacks the accuracy of the previous two models.
4. The final results may still need to be verified by using the equation: $CA \leq I / D \leq RUC$.

Table 4

Incentive/Disincentive Cap Rates for Various State Highway Agencies (Herbsman, Chen and Epstien 1995; Shr and Chen 2004)

State	Cap
Alabama	None
Arizona	±30days
Arkansas	None
California	Dollar Amount[a]
Colorado	None
Delaware	None
Florida	Varies
Georgia	None
Idaho	Varies
Illinois	None
Indiana	Dollar Amount[c]
Iowa	None
Kansas	Dollar Amount[a]
Maine	Dollar Amount[c]
Maryland	5%
Massachusetts	None

Michigan	5%
Minnesota	None
Missouri	10%
Montana	Varies
Nevada	Varies
New Hampshire	None
New Jersey	Dollars 100,000
New York	10%
North Carolina	Varies
North Dakota	5%
Ohio	5%
Pennsylvania	5%
South Dakota	None
Tennessee	None
Utah	Dollar Amount[c]
Virginia	Dollar Amount[b]
Washington	5%
Wisconsin	Varies
Wyoming	6-8%

[a] Fixed.

[b] Fixed except the A+B contracts.

[c] Fixed or negotiated not available.

Conclusion

As stated above, the three models discussed in this research have apparent differences, as well as some common attributes. These are summarized in Table 5 below.

Table 5

Comparison of the Incentive Amount Setting Methods

	Incentive Amount Setting Method		
	Shr and Chen's Model	Sillars and Riedl' model	Percentage as maximum incentive amount method
Whether Used Widely	Not Sure	Not Sure	Yes

Engineer's Judgment Involved	Yes	Yes, a lot	No
Simple to Use	Yes, once the equation is given	No	Yes
Whether Have Reasoning Process	Yes	Yes	No
Based on CA ≤ I / D ≤ RUC	Yes	Yes	Yes
Need Daily RUC in the Calculation	Yes	Yes	No

Case Study

Due to the limited accessibility of DOT's historical data and information, some of the information used in this study is assumed according to the normal situation (roadway project type and normal market conditions).

Case Study 1: FDOT Project FM210623

Project FM210623's award bid and contract time, as estimated by FDOT, are \$9,213,000 and 650 days, respectively. The daily RUC for that portion is \$5,992. The following sections show the outcomes for running each model with the data of Project FM210623.

Shr and Chen's model.

When applying the Shr and Chen's model to Project FM210623's data, (650, 9213) is given as (D_0, C_0) and 5.992 is given as I in Equation 5 and Equation 6. The specific calculation is as followed:

$$\begin{aligned} D &= D_0 - 1.0736 \times [(I \times D_0^2)/C_0] \\ &= 650 - 1.0736 \times [(5.992 \times 650^2)/9213] \\ &= 650 - 295 \end{aligned}$$

= 355 (days)

The maximum days for incentive= 650-355=295 (days)

The maximum incentive = $5,992 × 295= $ 1,767,640

Sillars and Riedl's model.

When applying the Sillars and Riedl's model to Project FM210623's data, $9,213,000 is given as total project estimate and, based on the result of running Shr and Chen's model above, 295 is used as reasonable number of acceleration days (at the very least, it can be said that 295 is a reasonable number of days that cannot be exceeded by incentive days). It is assumed that Project FM210623's project type is roadway and its market conditions are normal. So the factor *f* and factor *m* can be read from Table 1 and Table 2 respectively, and the values are 1.00 and 1.50 respectively. Also, the breakdown percentage of roadway is applied to Project FM210623's stage I value.

The basic information of Project FM210623 is summarized in Table 6 below.

Table 6

Project FM210623 Input Value

Project FM210623	
Type	A (Roadway)
Market Condition	BB (Normal)
Total Project Estimate	$9,213,000
Reasonable Acceleration Days	290 Days
Estimated Daily RUC	$5,992

The value of *f* (1.00) and *m* (1.50) and the project value ($9,213,000) are inserted into Equation8 to calculate the profit value. The result is $1.00/[\log(\$9{,}213{,}000)^{1.50}]$ = 9.0%. The percentage breakdown of roadway from Table 3 is used as the stage I value, and 9.0% is inserted as the stage I value of profit. The result of this process is shown in Table 7 below.

Table 7

Project FM210623 Stage I Value

Element[a]	Sub-element[b]	Stage I Value
Direct cost		82%
	Labor	25%
	Materials	45%
	Equipment	30%
	Subcontract	0%
Indirect cost		6%
	Supervision	2%
	Time-related facilities	1%
	Non-time-related facilities	1%
	Mobilization/demobilization	3%
	Insurance and taxes	1%
Markup		12%
	Risk	3%
	Home office G&A	8%
	Profit	9.0%

[a] Stated as a percentage of total project cost
[b] Stated as a percentage of total direct cost

After the starting point of the breakdown percentage is provided, the percentage is adjusted to better reflect of the reality of the actual project. According to Table 7 above, the starting point percentage of labor for roadway project is 25%. However, the need of acceleration may result in a higher percentage of labor being requested. It is assumed that the user increases the labor percentage value to 30%, and then the percentage values of material and/or equipment are decreased for the purpose of maintaining the total cost at 100%. The same process of adjustment is carried out for each percentage of the sub-element in the table. According to the adjusted percentage value, the portion specific value is obtained. The percentage adjustment and portion specific value for each part is shown in Table 8 below.

Table 8

State II Adjustment of Project FM210623

Element[a]	Sub-element[b]	Stage 1 Value (%)	Project Specific Value (%)	Portion Specific Value ($)
Direct cost		81%	76%	**7,001,880**
	Labor	25%	25%	1,750,470
	Materials	45%	45%	3,150,846
	Equipment	30%	30%	2,100,564
	Subcontractor	0%	0%	0
Indirect cost		6%	8%	**770,207**
	Supervision	2%	2%	140,038
	Time-related facilities	1%	1%	70,019
	Non-time-related facilities	1%	1%	70,019

	Mobilization/demobilization	3%	5%		350,094
	Insurance and taxes	1%	2%		140,038
Markup		12%	15%	**1,715,461**	
	Risk	3%	5%		350,094
	Home office G&A	8%	10%		700,188
	Profit	9.0%	9.50%		665,179
Total			100%	**9,487,547**	

[a] Stated as a percentage of total project cost
[b] Stated as a percentage of total direct cost

Once the actual percentage of each sub-element is estimated, the percentage increase (or decrease) of each sub-element caused by the acceleration is estimated through project knowledge and engineering judgment. It is assumed that double shifting is necessary for the acceleration, and the labor element is assumed to increase by 20%. From Table 8 above, the portion specific value for labor is $1,750,470. So, the acceleration cost for labor is $1,750,470 × 20% = $350,094. Except the profit portion, the same process of acceleration impact estimation is carried out for each sub-element. The result of acceleration impact estimation and the calculation of acceleration cost are shown in Table 9 below.

Table 9

Acceleration Impact of Project FM210623

Element[a]	Sub-element[b]	Portion Specific Value ($)	Acceleration Impact (+/-%)	Acceleration Cost (+/- $)	
Direct cost		7,001,880	8%	**465,625**	
	Labor	1,750,470	20%		350,094

	Materials	3,150,846	5%		157,542
	Equipment	2,100,564	-2%		(42,011)
	Subcontractor	0	0%		-
Indirect cost		770,207	1%	**10,503**	
	Supervision	140,038	10%		14,004
	Time-related facilities	70,019	-5%		(3,501)
	Non-time-related facilities	70,019	0		-
	Mobilization/demobilization	350,094	0		-
	Insurance and taxes	140,038	0		-
Markup		1,715,461	12%	**175,047**	
	Risk	350,094	50%		175,047
	Home office G&A	700,188	0%		-
	Profit	665,179			
Total		9,487,547	8%	**651,175**	

[a] Stated as a percentage of total project cost
[b] Stated as a percentage of total direct cost

According to Table 9 above, the total cost caused by the acceleration is $651,175. This value is actually the total contractor's cost caused by acceleration (CA). The incentive should include some profit besides the CA. Sillars and Riedl provide a method for calculating the profit's neutral value (i.e., the lowest point of reward to the contractor as an incentive profit). The profit neutral value is the result of direct cost's acceleration cost ($465,625) times the project specific value of profit percentage in Table 8 above (9.5%). So the profit neutral value is $465,625 × 9.5% = $44,234. The actual profit that is offered to the contractor should be higher than the neutral value to encourage acceleration. It is assumed that the profit is three times that of the neutral value, which in this case is

$44,234 × 3= $132,702. According to the calculation, the final incentive amount is $651,175 + $132,702 = $783,877. The whole process of calculating Project FM210623's incentive amount using Sillars and Riedl's model is shown in Table 10 below.

Percentage as maximum incentive amount (PMI) method.

When applying the percentage as maximum incentive amount method to Project FM210623's data, it is assumed that the percentage value is 5%. Therefore, the incentive amount for Project FM210623 is $9,213,000 × 5% = $460,650. It is assumed that the normal schedule uses an aggressive pace of work (ten working hours per day multiplied by five working days per week), and the accelerated schedule uses an accelerated pace of work (16 working hours per day multiplied by six days per week). The calculation of incentive days using the percentage as maximum incentive amount method is as follows:

The total weeks of normal schedule = 650days/7days = 93 weeks

The total hours needed = 10hours per day × 5days per week ×93 weeks = 4650hours

The working hours per week of accelerated schedule = 16hours per day × 6days per week = 96 hours per week

The total weeks of accelerated schedule = 4650hours/96hours per week = 48 weeks

The total days of accelerated schedule = 48weeks × 7days per week = 336days

The maximum incentive days = 650days – 336days = 314 days

Summary of Case Study 1.

The results of calculating Project FM210623's incentive amount and incentive duration using the three models are shown in Table 11 below. According to the values obtained from the calculation of each model, there are differences among the results from the three models. The incentive amount calculated by the Shr and Chen’s model ($1,767,640) is the largest among the three. Theoretically, it can be set as the maximum incentive amount which is used more for the purpose of controlling the incentive amount under the total RUC, rather than as the final specific incentive amount value. The incentive amount calculated by PMI method ($460,650) is the smallest among the three. The amount could save the most capital for the DOTs. However, it might not have enough encouragement for the contractors to accelerate the schedules. Moreover, compared with the result calculated by the Sillars and Riedl’s model, it is very probably under the reasonable contractor’s cost caused by acceleration (CA). The incentive amount calculated by Sillars and Riedl’s model ($783,877) is more reasonable compared with the other two results, and it can be set as the specific incentive amount value, not the maximum incentive amount. The comparison of the incentive amount calculated by each method is shown in Figure 1 below.

As to the calculation of incentive duration by each model, only the Shr and Chen’s model and the percentage as maximum incentive amount method have included the calculation of incentive duration. The results of the two models are close to each other. The result of the percentage as maximum incentive amount method (314 days) is 6% larger than the result of the Shr and Chen’s model (295 days). Before the calculation of the Sillars and Riedl’s model, a reasonable number of acceleration days needs to be given. So, the calculation of the Sillars and Riedl’s model might need to depend on another model.

Table 10

Sillars and Riedl's model Incentive Determination User Screen of Project FM210623

Project	FM210623
Type	Roadway
Market Condition	Normal
Total Project Estimate	9,213,000
Total Project Direct Cost Estimate	7,001,880
Reasonable Acceleration Days	295
Estimated RUC/Day	5,992

Element[a]	Sub-element[b]	Stage 1 Value (%)	Project Specific Value (%)	Portion Specific Value ($)	Acceleration Impact (+/-%)	Acceleration Cost (+/- $)
Direct cost		81%	76%	7,001,880	8%	**465,625**
	Labor	25%	25%	1,750,470	20%	350,094
	Materials	45%	45%	3,150,846	5%	157,542
	Equipment	30%	30%	2,100,564	-2%	(42,011)
	Subcontractor	0%	0%	0	0%	-
Indirect cost		6%	8%	770,207	1%	**10,503**
	Supervision	2%	2%	140,038	10%	14,004
	Time-related facilities	1%	1%	70,019	-5%	(3,501)
	Non-time-related facilities	1%	1%	70,019	0	-
	Mobilization/demobilization	3%	5%	350,094	0	-

	Insurance and taxes	1%	2%	140,038	0	-
Markup		12%	15%	1,715,461	12%	**175,047**
	Risk	3%	5%	350,094	50%	175,047
	Home office G&A	8%	10%	700,188	0%	-
	Profit	9.0%	9.50%	665,179		
Total			100%	9,487,547	8%	**651,175**

Acceleration Cost	651,175
I/D Incentive Profit	132,703
Total Incentive Amount	783,878

[a] Stated as a percentage of total project cost

[b] Stated as a percentage of total direct cost

Table 11

Comparison of Incentive Amount and Incentive Duration of Project FM210623 Calculated by Three Models

Model	Incentive Amount ($)	Incentive Duration (days)
Shr and Chen's Model	1,767,640	295
Sillars and Riedl's Model	783,877	-
PMI Method	460,650	314

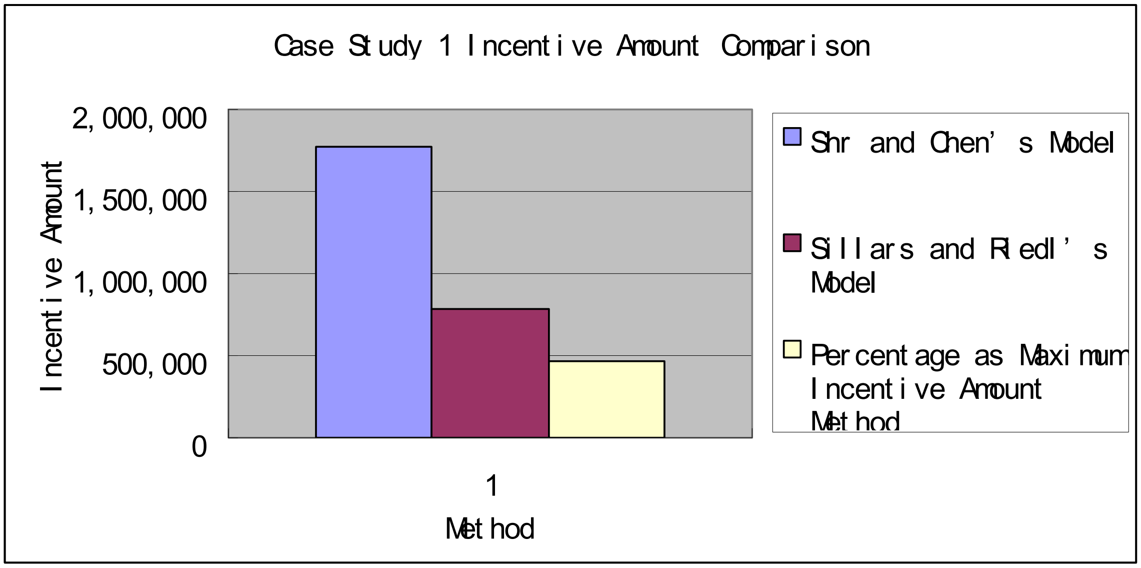

Figure 1. *Case Study 1 Incentive Amount Comparison*

Case Study 2: FDOT Project FM229629

Project FM229629's award bid and contract time estimated by FDOT are $3,849,000 and 485 days, respectively. The daily RUC for that portion is $2,700. The following sections show the outcomes of running each model using the data of Project FM229629.

Shr and Chen's model.

Using (485, 3829) as (D_0, C_0) and applying Equation 5 and Equation 6, the process of calculation is shown below:

$D = D_0 - 1.0736\times [(I\times D_0^2)/C_0]$

$= 485 - 1.0736\times (2.7\times 485^2/3829)$

$= 485-177$

$= 308$ (days)

The maximum days for incentive= 485-308=177 (days)

The maximum incentive amount= $2,700 × 177 days=$477,900

Sillars and Riedl's model.

The same assumptions (project type, market condition, specific sub-element percentage breakdown, acceleration impact, and how many times I/D incentive profit value is more than the neutral profit value) are made when applying Sillars and Riedl's model to Project FM229629. The calculation result of Project FM229629's incentive amount using Sillars and Riedl's model is shown in Table 12 below.

The calculation of Sillars and Riedl's model shows that Project FM229629 has an acceleration cost of $272,047, and an incentive profit of $55,441. The total incentive amount of Project FM238320 is $327,488.

Percentage as maximum incentive amount (PMI) method.

When applying the PMI method to Project FM229629's data, the same assumptions (percentage value of incentive amount, normal schedule pace of work and accelerated schedule pace of work) are made as the ones applied to Project FM210623 when using the other two methods. So the incentive amount for Project FM229629 is \$3,849,000 × 5% = \$192,450. The calculation of incentive days using the percentage as maximum incentive amount method is as followed:

The total weeks of normal schedule = 485days/7days = 69 weeks

The total hours needed = 10hours per day × 5days per week ×69 weeks = 3464hours

The working hours per week of accelerated schedule = 16hours per day × 6days per week = 96 hours per week

The total weeks of accelerated schedule = 3464hours/96hours per week = 36 weeks

The total days of accelerated schedule = 36weeks × 7days per week = 253days

The maximum incentive days = 485days – 253days = 232 days

Summary of Case Study 2.

The results of calculating Project FM229629's incentive amount and incentive duration using the three models are shown in Table 13 below.

The differences among the results calculated by three models are similar with those in Case Study 1. The Shr and Chen's model has the largest incentive amount (\$477,900), while the percentage as maximum incentive amount method has the smallest result of incentive amount (\$192,450). The result of the Sillars and Riedl's model falls in between the results of other two models. The comparison of the incentive amount calculated by each method is shown in Figure 2 below.

Table 13

Comparison of Incentive Amount and Incentive Duration of Project FM229629 Calculated by Three Models

Model	Incentive Amount ($)	Incentive Duration (days)
Shr and Chen's Model	477,900	177
Sillars and Riedl's Model	327,488	-
PMI Method	192,450	232

The incentive durations of the Shr and Chen's model and the percentage as maximum incentive amount method are not as close to each other as that in Case Study 1. The incentive duration calculated by the percentage as maximum incentive amount method (232 days) is 31% larger than that calculated the Shr and Chen's model (177 days).

Table 12

Sillars and Riedl's model Incentive Determination User Screen of Project FM229629

Project	FM229629
Type	Roadway
Market Condition	Normal
Total Project Estimate	3,849,000
Total Project Direct Cost Estimate	2,925,240
Reasonable Acceleration Days	177
Estimated RUC/Day	2,700

Element[a]	Sub-element[b]	Stage 1 Value (%)	Project Specific Value (%)	Portion Specific Value ($)	Acceleration Impact (+/-%)	Acceleration Cost (+/- $)
Direct cost		81%	76%	2,925,240	8%	**194,528**
	Labor	25%	25%	731,310	20%	146,262
	Materials	45%	45%	1,316,358	5%	65,818
	Equipment	30%	30%	877,572	-2%	(17,551)
	Subcontractor	0%	0%	0	0%	-
Indirect cost		6%	8%	321,776	1%	**4,388**
	Supervision	2%	2%	58,505	10%	5,850
	Time-related facilities	1%	1%	29,252	-5%	(1,463)
	Non-time-related facilities	1%	1%	29,252	0	-
	Mobilization/demo	3%	5%	146,262	0	-

	bilization					
	Insurance and taxes	1%	2%	58,505	0	-
Markup		12%	15%	716,684	12%	**73,131**
	Risk	3%	5%	146,262	50%	73,131
	Home office G&A	8%	10%	292,524	0%	-
	Profit	9.5%	9.50%	277,898		
Total			100%	3,963,700	8%	**272,047**

Acceleration Cost	272,047
I/D Incentive Profit	55,441
Total Incentive Amount	327,488

[a] Stated as a percentage of total project cost

[b] Stated as a percentage of total direct cost

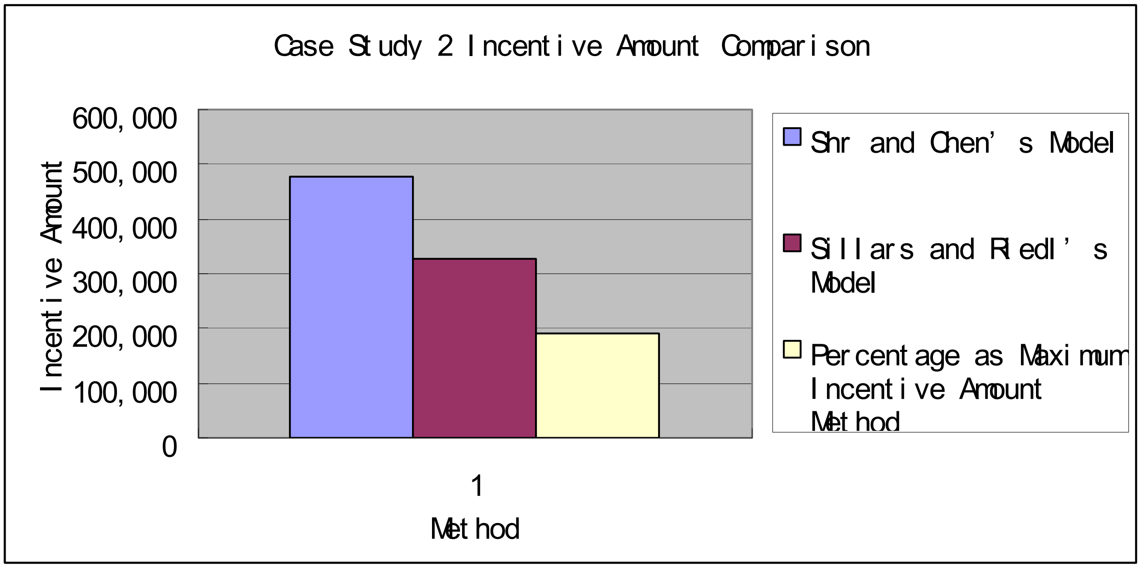

Figure 2. *Case Study 2 Incentive Amount Comparison*

Case Study 3: FDOT Project FM238320

Project FM238320's award bid and contract time estimated by FDOT are $7,534,000 and 485 days, respectively. The daily RUC for that portion is $3,500. The following steps are running each model with the data of Project FM238320.

Shr and Chen's model.

Using (485, 7534) as (D_0,C_0) and applying Equation 5 and Equation 6, the process of calculation is shown below:

$$
\begin{aligned}
D &= D_0 - 1.0736\times [(I\times D_0^2)/C_0]\\
&= 485- 1.0736\times (3.5\times 485^2/7534)\\
&= 485-117\\
&= 368 \text{ (days)}
\end{aligned}
$$

The maximum days for incentive= 485-368=117 (days)

The maximum incentive amount= $3,500 × 117 days=$409,500

Sillars and Riedl's model.

The same assumptions (project type, market condition, specific sub-element percentage breakdown, acceleration impact, and how many times I/D incentive profit value is more than the neutral profit value) are made when applying Sillars and Riedl's model to Project FM238320. The calculation results of Project FM238320's incentive amount using Sillars and Riedl's model is shown in Table 14 below.

The calculation of Sillars and Riedl's model shows that Project FM238320 has an acceleration cost of $532,503, and an incentive profit of $109,661. The total incentive amount of Project FM238320 is $642,164.

Percentage as maximum incentive amount (PMI) method.

When applying the PMI method to Project FM238320's data, the same assumptions (percentage value of incentive amount, normal schedule pace of work and accelerated schedule pace of work) are made as those applied to Project FM210623 when using the other two methods. So the incentive amount for Project FM238320 is $7,534,000 × 5% = $376,700. The calculation of incentive days using the percentage as maximum incentive amount method is as followed:

The total weeks of normal schedule = 485days/7days = 69 weeks

The total hours needed = 10hours per day × 5days per week ×69 weeks = 3464hours

The working hours per week of accelerated schedule = 16hours per day × 6days per week = 96 hours per week

The total weeks of accelerated schedule = 3464hours/96hours per week = 36 weeks

The total days of accelerated schedule = 36weeks × 7days per week = 253days

The maximum incentive days = 485days – 253days = 232 days

Summary of Case Study 3.

The results of calculating Project FM238320's incentive amount and incentive duration using the three models are shown in Table 15 below. According to the results obtained from the three models, there are still apparent differences. However, the differences among the results are not similar with the differences in the previous two case studies. The Sillars and Riedl's model has the largest value of incentive amount ($642,164) among the three. The percentage as maximum incentive amount method still has the smallest value of incentive amount ($376,700). The incentive amount calculated by the Shr and Chen's model ($409,500) falls in between the other two results. The comparison of the incentive amount calculated by each method is shown in Figure 3 below.

The two results of the incentive days are no longer close to one another. The larger result calculated by the PMI method (232 days) is nearly two times the amount calculated by the Shr and Chen's model (117 days).

Table 15

Comparison of Incentive Amount and Incentive Duration of Project FM238320 Calculated by Three Models

Model	Incentive Amount ($)	Incentive Duration (days)
Shr and Chen's Model	409,500	117
Sillars and Riedl's Model	642,164	-
PMI Method	376,700	232

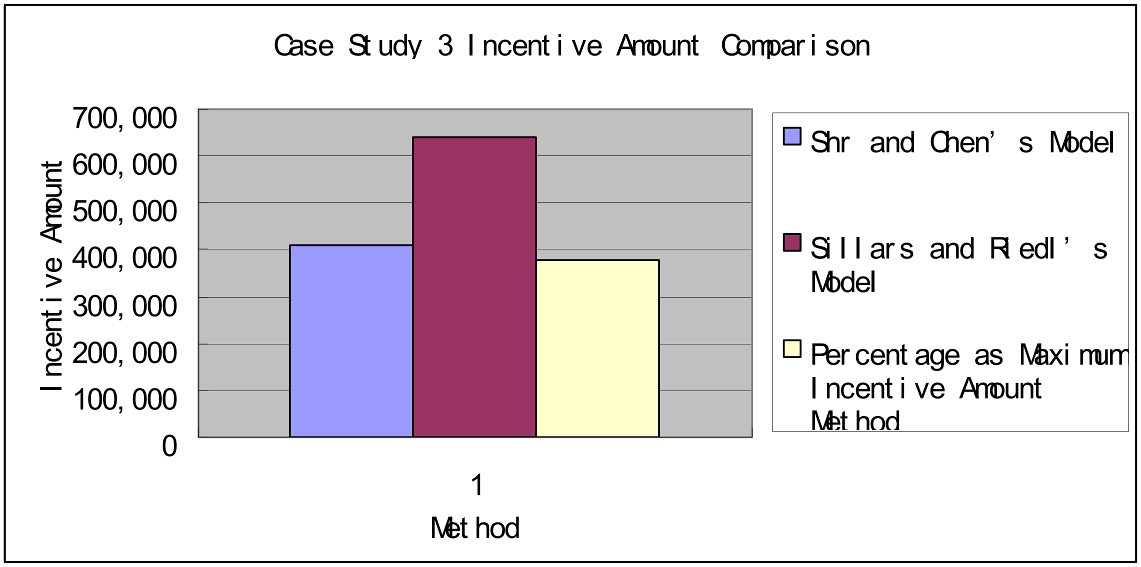

Figure 3. *Case Study 3 Incentive Amount Comparison*

Table 14

Sillars and Riedl's model Incentive Determination User Screen of Project FM238320

Project	FM238320
Type	Roadway
Market Condition	Normal
Total Project Estimate	7,534,000
Total Project Direct Cost Estimate	5,725,840
Reasonable Acceleration Days	117
Estimated RUC/Day	3,500

Element[a]	Sub-element[b]	Stage 1 Value (%)	Project Specific Value (%)	Portion Specific Value ($)	Acceleration Impact (+/-%)	Acceleration Cost (+/- $)
Direct cost		81%	76%	5,725,840	8%	**380,768**
	Labor	25%	25%	1,431,460	20%	286,292
	Materials	45%	45%	2,576,628	5%	128,831
	Equipment	30%	30%	1,717,752	-2%	(34,355)
	Subcontractor	0%	0%	0	0%	-
Indirect cost		6%	8%	629,842	1%	**8,589**
	Supervision	2%	2%	114,517	10%	11,452
	Time-related facilities	1%	1%	57,258	-5%	(2,863)
	Non-time-related facilities	1%	1%	57,258	0	-
	Mobilization/demo	3%	5%	286,292	0	-

	bilization					
	Insurance and taxes	1%	2%	114,517	0	-
Markup		12%	15%	1,408,557	12%	**143,146**
	Risk	3%	5%	286,292	50%	143,146
	Home office G&A	8%	10%	572,584	0%	-
	Profit	9.1%	9.60%	549,681		
Total			100%	7,764,239	8%	**532,503**

Acceleration Cost	532,503
I/D Incentive Profit	109,661
Total Incentive Amount	642,164

[a] Stated as a percentage of total project cost

[b] Stated as a percentage of total direct cost

Findings

During the course of this project, several findings were made with respect to estimate incentive amount and incentive duration using the three models in the case study. The general findings are as follows:

1. Compared with the Shr and Chen's model and the PMI method, the Sillars and Riedl's model takes more time and effort to use. The results of the Sillars and Riedl's model depend more on the situation of the particular project and display greater uncertainty than the other two models.
2. For most of the case, the PMI method has a lowest incentive amount among all the results of the three models. This incentive amount will probably not provide enough encouragement to the contractor for acceleration.
3. It is quite probable that the Shr and Chen's model has the largest result of incentive amount, which is more suitable to be used as the upper bound of incentive amount setting. Compared with the Shr and Chen's model and the PMI method, the Sillars and Riedl's model is likely to have a more reasonable incentive amount, which is neither too large nor too small. But calculation results of the Sillars and Riedl's model does not include the incentive duration, which needs to be provided by the other two models or other method.
4. When the Shr and Chen's model has the largest incentive amount among the results of the three models, the two results of incentive duration calculated by the Shr and Chen's model and the percentage as maximum incentive amount method are similar.

5. When in a particular project which has a relatively large contract amount, and a relatively small daily RUC and contract duration, the Sillars and Riedl's model is likely to have a larger result of incentive amount than the Shr and Chen's model.
6. When the Sillars and Riedl's model has the largest incentive amount, the incentive durations calculated by the Shr and Chen's model and the percentage as maximum incentive amount method are not close.
7. The equation, $CA \leq I / D \leq RUC$, is the basic factor used in I/D amount setting. All the models evaluated in this project have either included the equation in its basic philosophy, or applied the equation in its post-calculating verification.

Conclusions

Through data collection concerning I/D amount setting models, and case studies focusing on the outcomes of each model, it is apparent that there are marked differences among the usage and results of each model. This directed project finds that for one particular highway project using I/D contracting, there appears to be great differences in I/D amount by choosing different I/D amount setting method. It is also confirmed that the equation $CA \leq I / D \leq RUC$ is the basic theory of I/D. No matter what method is used when setting the incentive, the equation $CA \leq I / D \leq RUC$ can be applied to the process of setting for the purpose of calculation or verification.

Recommendations

The following recommendations are based on the knowledge gained from this research:

1. For a better result of incentive amount, the DOT can apply each of the models for a particular project. After comparing and adjusting the different results, a final result can be determined, which will satisfy the basic requirements and be fair and attractive to each party involved.
2. For projects that are in extreme need of acceleration, the percentage as maximum incentive amount method might not be a good choice for setting incentive amount for DOTs. In such a case, the DOT might need to consider the other two models.
3. When the portion of a project has a relatively high RUC and the incentive duration has been set relatively long, the Sillars and Riedl's model is a better choice for the DOT.

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