LHI Journal
of Land, Housing, and Urban Affairs

pISSN: 2093-8829, eISSN: 2234-1765
LHI Journal 2020;11(4):115-124 • http://doi.org/10.5804/LHIJ.2020.11.4.115

Factors That Affect Project Time and Cost Performance during Highway Construction Using Incentive/Disincentive Provisions*

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Abstract

Incentive/Disincentive (I/D) contract is designed for minimizing any disruption of traffic flow in road construction projects. I/D contracting projects have been evaluated with regard to time and cost performance in various states, more than 35 states. However, construction project managers and planners have little understanding of the project factors that affect the project time and cost performance of highway construction projects using I/D regulations. Therefore, the purpose of this research is to find factors that affect I/D project success or failure to improve the decision-making process for the implementation of I/D projects. In order to achieve the objectives of this research, the researchers collected I/D road construction project data from FDOT and performed evaluation for each collected project. Then, project data analysis to identify key factors that affect I/D project performance was performed. In conclusion, five significant factors for project time performance and six significant factors for project cost perfornace were identified and summarized.

Keywords: Project Performance, Performance Evaluation, Highway Construction, Incentive/Disincentive, Innovative Contracting

1. Introduction

1.1 Research Background

Highway construction projects often require lane closures and detour and it reduces road capacity. Therefore, road drivers and adjacent businesses have frequently faced inconveniences associated with transportation construction such as time delay and cost increase. Road construction has side effects that increase travel time, vehicle operation costs, road accidents and air pollution. The Federal Highway Administration (FHWA), which is well aware of the problems that can arise from road construction, has been constantly looking for ways to minimize the negative impact of road construction work on road traffic. Improving construction project performance and accelerating project completion whenever possible can be a good solution.

One of the well-known traffic construction contract method, I/D (Incentive/Disincentive) contract is designed for minimizing any disruption of traffic flow in road construction projects. I/D contracting projects have been evaluated with regard to time and cost performance in various states, more than 35 states (Ellis and Pyeon, 2005; MnDTO 2005; AASHTO 2006; Ellis et al., 2007; Choi et al., 2012; Hasan and Jha., 2016)

* The authors would like to express their gratitude to the Mineta Transportation Institute for the financial support that made this research possible as well as to the Florida Department of Transportation for providing valuable inputs.
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(**Received:** December 14, 2020 / **Revised:** December 22, 2020 / **Accepted:** December 22, 2020)

Although significant project time and cost savings have been reported from various projects, many project cases of inefficiency about I/D contracting implementation for numerous highway construction projects have been reported as well. For example, a lot of general contractors were able to earn maximum incentives without reducing the original contract time. It is because that incentive money was typically paid based on the extended contract time, which included various time extensions and bad weather days.

It is thought that the reason for this inefficiency is often a lack of understanding of the factors that influence the suitability of the use of I/D contracts. It is important to provide clear guidance for better use of incentive contracts. Therefore, a better understanding of the relationship between factors such as project type and size, location, contract type and amount of incentives and other similar factors must precede (Pyeon, 2005).

1.2 Research Objective and Scope

The purpose of this research is to find factors that affect I/D project success or failure to improve the decision-making process for the implementation of I/D projects. In order to achieve the objectives of this research, the researchers aim to accomplish the following tasks:

(1) I/D road construction project data collection;
(2) Project performance evaluation for each collected project;
(3) Project data analysis to identify key factors that affect I/D project performance.

1.3 Research Methodology

This research was first performed by collecting road construction project data. Then, collected construction project data were evaluated in terms of time and cost performance. Finally, various statistical data analysis was performed to identify important factors that affect construction project time and cost performance.

2. Literature Review

Various incentive plans such as time-based, cost-based, and performance-based incentives, have been used for highway construction projects. Christiansen (1987) argued that financial incentive plans are typically more effective than non-financial incentive plans. Abu-Hijileh and Ibbs (1989) reported that using bonus-only incentives is more effective than using penalties only incentive. The implementation of time-based incentive is relatively easy and economical. Therefore, time-based incentive contracting for early project completion has been most widely used in road construction. Therefore, only I/D contracting projects for early completion were studied in this study.

The FHWA technical advisory recommended that I/D provisions should not be used routinely and should be limited to the projects: 1) significantly disrupt highway services or highway traffic; 2) greatly increase road user costs; 3) have a heavy impact on adjacent businesses/neighborhoods; or 4) close a gap providing a significant improvement in the highway system (FHWA, 1989). The FHWA advisory report suggested the characteristics related to construction projects appropriate for the use of I/D contracting as follows (FHWA, 1989):

- Projects with high traffic volume in urban areas;
- Projects filling a gap in the highway system;
- Major rehabilitation/reconstruction projects severely disrupt traffic;
- Major bridge projects out of service;
- Projects with long detour time.

According to the survey results performed by Anderson and Damnjanovic (2008), I/D contacts helped enhance project time performance. However, overall construction project costs including incentives might be increased. The authors claimed that the project cost increase might be tolerable when the project early completion reduces the road user cost. Although the early or on-time project completion of I/D projects was advantageous, many respondents answered the following major disadvantages: 1) Construction cost increase because of incentives; 2) Potential quality reduction by expediting construction process, 3) Utility conflict problems; and 4) Potential increase in contractor disputes for change orders. The most frequently named key factors for selection of alternative contracting methods includes were found to be: 1) Project type, 2) Project complexity, 3) Project size, and 4) Important completion dates.

Sillars and Leray (2007) proposed a model including the different phases of the project life cycle and showing the step-wise procedures of I/D contracting implementation for State Transportation Agencies (STAs). Since the general I/D guidance for State Transportation Agencies provided by the FHWA in 1989, many states have developed their own guidelines and manuals for selecting I/D projects. Some of them have established their own contracting manuals and I/D selection criteria. Others developed their principles of I/D contracting guidance by expanding the original FHWA guidance.

3. Data Collection

The Florida Department of Transportation (FDOT) is one of the most active STAs in implementing I/D provisions in their highway construction projects. The required project data for this study was collected from several different FDOT project data management systems. In the following sections, the I/D project data collection process are explained and the construction procedure of I/D contracting project database is described.

3.1 I/D Project Data Collection

FDOT I/D contracting project data in highway construction were obtained from several sources. The FDOT main office and district offices provided highway construction project data for this study. The collected construction project data are as follows; project type, cost, location, duration, length, contract type, maximum I/D amount, daily I/D amount, etc. A total of 295 I/D projects from 1998 through 2008 were used for this study. There are three different I/D contracting types. The three combinations were identified as follows: 1) I/D; 2) A+B with I/D (A+B I/D); and 3) A+B Bonus with I/D (A+B B. I/D). An example of I/D project sample data obtained from FDOT is shown in Table 1.

3.2 I/D Project Database Construction

FDOT publishes construction time and cost quarterly reports and the research team obtained these reports electronically. Then, they were combined to create a single database. In addition, spreadsheets of Time and Cost Analysis of Passed Alternative Contracts Reports were collected from a district office and it was integrated into the time and cost report database. Finally, spreadsheets of highway project data and historical contract data obtained from the FDOT WebFocus project database were joined with the time and cost report database.

Table 1. Sample Project Data Collected from FDOT

Column Name	Data	Column Name	Data
Project ID	410678	Type of Contract	I/D
District Number	06	Roadway ID	87060000
County Location	Miami-Dade	Transportation system	Non-intrastate
Work mix	Bridge-painting	Location	SR A1A /Mcarthur CSWY
Let date	5/22/02	Project manager	Luis Amigo
Award date	6/19/02	Contractor	Mayo Contracting
Execution date	7/03/02	Project length	0.399 miles
Notice to proceed	8/2/02	Number of lanes	0
Work begin date	2/16/03	Number of lanes added	0
Final acceptance date	9/26/03	DOT original estimate	$1,501,000
DOT time estimate	240	Original contract amount	$1,976,732
Incentive days	239	Present contract amount	$2,083,065
Original contract days	240	Total amount paid	$1,979,886
Present contract days	267	Actual expenditure	$1,945,886
Contractor's Days used	222	Actual Incentive paid	$34,000
Days suspended	0	Daily incentive amount	$2,000
Weather days	27	Max. incentive proposed	$105,000
Total work order Time Extension	0	Total Supplemental Agreement (SA) amount	$106,333
Total SA days	0	Production rate	$8,100
Number of SAs	2	Incentive production rate	$10,400
Incentive time maximum	188	Historical production rate	$7,700

Summary tables for the project data collected are shown in Tables 2 and 3.

4. Data Analysis

The objective of the project data analysis was to identify key factors that affect I/D project cost and time performance. The obtained I/D project data were evaluated using time and cost performance indices. Four performance indices were developed and used for data analysis: 1) original contract duration based time performance index; 2) present contract duration

Table 2. Construction Project Summary by Contract Type

District	Contract Type	Number of Projects	Total Contract Amount
1	A+B I/D	11	$101,234,088
	I/D	22	$203,299,659
District 1 Total		33	$304,533,747
2	A+B I/D	23	$134,369,850
	I/D	2	$3,853,518
District 2 Total		25	$138,223,368
3	A+B I/D	19	$243,325,709
	I/D	8	$45,733,389
District 3 Total		27	$289,059,098
4	A+B I/D	9	$116,752,055
	A+B B. I/D	4	$199,693,064
	I/D	31	$226,169,502
District 4 Total		44	$542,614,621
5	A+B I/D	15	$237,207,911
	I/D	13	$102,124,145
District 5 Total		28	$339,332,056
6	A+B I/D	8	$35,029,381
	A+B B. I/D	26	$345,650,232
	I/D	62	$83,698,282
District 6 Total		96	$464,377,895
7	A+B I/D	9	$113,845,418
	A+B B. I/D	1	$7,861,142
	I/D	14	$92,001,259
District 7 Total		24	$213,707,819
8	A+B I/D	6	$119,281,020
	A+B B. I/D	1	$3,721,761
	I/D	11	$169,181,846
District 8 Total		18	$292,184,627
Grand Total		295	$2,584,033,231

Table 3. Construction Project Summary by Project Type

Project Work Type	Number of Projects	Total Construction Duration (Days)	Total Contract Amount
Access improvement	2	375	$4,750,119
Add lanes & reconstruction	66	38,610	$957,745,630
Add lanes & rehabilitate pavement	16	8,957	$252,154,000
Add right turn lane (s)	2	210	$436,396
Add thru lane (s)	1	130	$1,330,442
Add turn lane (s)	7	830	$4,234,520
Bridge-painting	2	440	$3,138,951
Bridge/culvert replacement	2	500	$4,741,346
Bridge rehab and add lanes	1	925	$32,859,777
Bridge repair/rehabilitation	14	2,612	$31,805,272
Construct bridge-low level	4	1,525	$17,509,373
Construct bridge-movable span	1	576	$23,445,002
Construct bridge-high level	1	500	$18,486,091
Construct/reconstruct median	1	120	$593,653
Federal aid resurface/repave	1	120	$2,944,870
Fender work	1	390	$2,284,662
Fixed guideway improvements	1	500	$3,494,000
Flexible pavement reconstruction	5	1,510	$24,633,355
Guardrail	5	1,156	$44,472,567
Highway enhancement	1	152	$3,607,477
Interchange (major)	6	4,885	$233,479,355
Intersection (major)	2	1,345	$36,624,974
Intersection (minor)	7	640	$3,017,766
Landscaping	1	150	$2,212,452
Mill and resurface	1	150	$4,229,690

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Project Work Type	Number of Projects	Total Construction Duration (Days)	Total Contract Amount
Miscellaneous construction	4	1,039	$10,730,812
Miscellaneous structure	1	525	$37,935,485
New road construction	6	3,185	$132,177,053
Replace low-level bridge	19	6,194	$103,284,848
Replace medium-level bridge	6	3,876	$74,358,292
Replace movable span bridge	4	3,485	$171,273,445
Resurfacing	79	18,034	$253,119,539
Rigid pavement reconstruction	2	1,082	$32,286,750
Rigid pavement rehabilitation	1	280	$6,630,067
Safety project	7	1,163	$9,759,660
Sidewalk	1	100	$420,608
Traffic signals	6	670	$1,978,393
Widen bridge	3	1,260	$18,062,628
Widen/resurface existing lanes	5	806	$17,783,911
Grand total	295	109,007	$2,584,033,231

based time performance index; 3) original contract duration based cost performance index; and 4) present contract duration based cost performance index. Then, statistical analyses were performed to identify any significant differences in project cost and time performance among variables. Finally, significant factors that affect project cost and time performance were identified.

4.1 Statistical Analysis Process

In this study, the construction project data used for analysis composed of qualitative and quantitative variables. Correlation analysis for the quantitative variables was performed to identify significant factors that might affect project performance.

Then, numerous statistical analyses were performed to test the potential differences on project cost and time performance among project factors. In this study, the two-sample t-test was used to decide if the means of the two groups were significantly different. The ANOVA (analysis of variance) test was also performed. When the ANOVA test was significant, the multiple comparison test was performed.

In this study, each project collected from FDOT was completed independently at a different project site. It was also assumed that all variables with a large sample size were normally distributed based on the central limit theorem.

If necessary, a reasonable categorization process was performed for qualitative variables before performing the ANOVA test. For example, a project major work type briefly describes project characteristics. Based on the major work type for each project, the collected projects were put into similar groups. Following this categorization process, we performed an ANOVA test on the null hypothesis that all major work type groups' population means are equal. Whenever the F-test results were significant, multiple comparison procedures were performed.

4.2 Evaluation of Project Time and Cost Performance

Project cost and time performance was measured. A project time performance index (TPI) was calculated using the following formula:

$$TPI = \frac{Final\ Duration - Contract\ Duration}{Contract\ Duration}, \quad (1)$$

In this formula, a negative TPI value means time savings and a positive TPI value means time overruns. For instance, TPI=-0.1 means a 10% project time savings. TPI=+0.1 means a 10% time overrun.

The TPI was further developed based on the contract duration. An original contract duration-based time performance index (OTPI) does not include any time extension. However, a present contract duration-based time performance index (PTPI) includes time extensions and SA (supplemental agreement) days. OTPI was determined as follows:

$$OTPI = \frac{Final\ Duration - Original\ Contract\ Duration}{Original\ Contract\ Duration}, \quad (2)$$

PTPI was determined as follows:

$$PTPI = \frac{Final\ Duration - Present\ Contract\ Duration}{Present\ Contract\ Duration}, \quad (3)$$

Similarly, a project cost performance index (CPI) was calculated using the following formula:

$$CPI = \frac{Final\ Cost - Contract\ Cost}{Contract\ Cost}, \quad (4)$$

A negative CPI value means cost savings and a positive CPI value means cost overruns. For instance, CPI=−0.1 means project cost savings of 10%. CPI=+0.1 means a 10% cost overrun.

The CPI was further developed based on the contract amount. An original contract amount-based cost performance index (OCPI) does not include any cost increase. However, a present contract amount-based cost performance index (PCPI) includes total work order amount, SA amount, paid incentive amount, and other contract cost adjustment amount. OCPI was determined as follows:

$$OCPI = \frac{Final\ Cost - Original\ Contract\ Cost}{Original\ Contract\ Cost}, \quad (5)$$

PCPI was determined as follows:

$$PCPI = \frac{Finaual\ Cost\ Paid - Present\ Contract\ Cost}{Present\ Contract\ Cost}, \quad (6)$$

4.3 Project Cost and Time Performance Influencing Factors

Based on the original contract and the current contract, many project elements to identify the important factors that influence construction project time and cost performance were studied. The tested variables are: Contracting type, Project type, Project location and length, Number of road lanes, Engineer's project time estimate, Original contract duration, Days suspended, Weather days, Engineer's original cost estimate, Original contract cost, and Daily and max. incentive amount.

Some of project date were modified and tested. The tested project data variables are: Weather Days / Original Contract Duration; Days between Let Date and Work Begin; Date / Original Contract Duration; Total Work Order Time Extension / Original Contract Duration; Supplemental Agreement Days / Original Contract Duration; Original Contract Cost / Original Contract Duration; Total Supplemental Agreement Amount / Original Contract Cost; Total Supplemental Agreement Amount / DOT's Actual Expenditure; Innovative Contract Adjustments Amount / Original Contract Cost; Innovative Contract Adjustments Amount / DOT's Actual Expenditure.

As a result of statistical analysis, the following factors were determined to be significant: Contracting type, project size, type, length, incentive proposed maximum amount, incentive proposed daily amount, and project location (district).

4.3.1 Contract Type Factor

The I/D contracting has been used in various ways. It was used alone as well as with a combination of other contracting methods. The contacting type factor was categorized into three groups: I/D alone, A+B with I/D (A+B I/D), and A+B with I/D and Bonus (A+B B. I/D). Among all project data, the number of I/D contract type was 163, the number fo A+B I/D was 100, and the number of A+B Bonus I/D was 32.

For the data analysis of contracting type variables, an ANOVA test was performed, and the results are shown in Table 4. In this study, when the probability value (p-value) is smaller than 0.05, it was considered that the test is statistically significant. We concluded that each variable's effect is significant.

For the further analysis to test which means are different from which others, the Tukey test was performed for multiple comparisons. The results of the Tukey test are shown in Table 4. All three possible cases were tested: I/D vs. A+B with I/D; I/D vs. A+B with I/D and Bonus; and A+B with I/D vs. A+B with I/D and Bonus. The results indicated that there are significant differences among contract type variables. For OTPI, PTPI, and PCPI parameters, this contract type variable was significantly influencing project time and cost performances.

Table 4. ANOVA and Tukey Test Results: Contract Type Variables

Contract Type Variables	F-value	p-value	Significant Tukey Tests (0.05 Level)
OTPI	9.623	<0.001	A+B I/D – A+B I/D Bonus I/D – A+B I/D
PTPI	5.644	0.0039	I/D – A+B I/D
OCPI	0.445	0.6412	N/A
PCPI	4.586	0.0109	A+B I/D – A+B I/D Bonus I/D – A+B I/D Bonus

4.3.2 Project Type Factor

The project types of highway construction projects are various based on their work types. Each project has its own major work type and other several minor work types. The major work type generally describes project key characteristics.

For the data analysis, projects were categorized based on their major work description. The following four levels of project type variables used: Bridge Rehabilitation or Reconstruction (BRR); Roadway Rehabilitation or Reconstruction (RRR); Roadway Resurfacing or Paving (RRP); and Others.

For the data analysis of project type variables, an ANOVA test was performed, and the results are shown in Table 5. For the further analysis, the Tukey test was performed. The results of the Tukey test are also shown in Table 5. All three possible cases were tested: BRR vs. RRR; BRR vs. RRP; BRR vs. Others; RRR vs. RRP; RRR vs. Others; and RRP vs. Others. After testing all possible cases, we found that the performance differences among project type variables are significant only for OTPI and PTPI. This indicates that project type variables are significant in terms of project time performance.

Table 5. ANOVA and Tukey Test Results: Project Type Variables

Project Type Variables	F-value	p-value	Significant Tukey Tests (0.05 Level)
OTPI	6.545	<0.001	BRR – Others RRR – Others RRP – Others
PTPI	6.212	<0.001	BRR – Others RRR – Others
OCPI	1.582	0.1938	N/A
PCPI	0.634	0.5936	N/A

4.3.3 District (Project Location) Factor

The number of transportation districts are eight in Florida. This number includes the turnpike district as well. Eight districts are allowed to manage their business with a certain flexibility. Each district has its own project management process and system. They are in general very similar. However, it is not the same. So, it may influence project cost and time performance in construction. The tested district variable was from District 1 to District 8.

For the data analysis of the district variable, an ANOVA test and the Tukey test were performed. The test results were summarized in Table 6. The district variable test results were significant: OTPI and PTPI for time performance as well as OCPI and PCPI for cost performance. This indicates that district variables influence project time performance.

4.3.4 Project Size Factor

There were various construction projects in terms of construction cost, small and large. The smallest construction cost was \$114,185 and the largest one was \$99,537,000. To make this variable more meaningful. the construction cost was divided by construction duration and the result was named as the daily project cost as follows:

$$Daily\ Project\ Cost = \frac{Original\ Contract\ Cost}{Original\ Contract\ Duration}, \quad (7)$$

Table 6. ANOVA and Tukey Test Results: District Variables

District Variables	F-value	p-value	Significant Tukey Tests (0.05 Level)
OTPI	7.579	<0.001	District 1 – District 6 District 3 – District 6 District 4 – District 6 District 5 – District 6
PTPI	2.487	0.0171	District 1 – District 6
OCPI	6.735	<0.001	District 4 – District 6 District 6 – District 8
PCPI	4.460	<0.001	District 1 – District 8 District 2 – District 8 District 3 – District 8 District 4 – District 8 District 5 – District 8 District 6 – District 8 District 7 – District 8

The smallest daily project cost was $1,014 and the largest one was $96,638. For correlation analysis, the relationship between daily project cost and performance indices was studied. There was a positive correlation analysis result. As a next step, the categorization process was performed. For this process, a box-and-whiskers plot distribution analysis was used. The daily project size data was divided into three groups based on the inter quartile range (IQR). The lower quartile (Q1) was $9,152 and the upper quartile (Q3) was $24,450 with IQR=$15,298. Three categorized variable are: Project size small (PSS; <$9,152); Project size medium (PSM; $9,152-$24,450); Project size large (PSL; >$24,450).

For the data analysis of the daily project size variable, an ANOVA test and the Tukey test were performed. The test results were summarized in Table 7. All three possible cases were tested and two cases were significant: PSS vs. PSM; PSS vs. PSL.

The results indicated that there are significant differences among daily project size variables. For OTPI, OCPI, and PCPI parameters, this daily project size variable was significantly influencing project performance.

4.3.5 Project Length Factor

Project length of each project varies, and 136 projects have available project length data. The shortest project length was 0.001 mile and the longest project length was 23.5 miles. The average of project length of resurfacing type projects was 4.23 miles.

For the data analysis of the project length variable, the correlation analysis was performed to test the relationship between project length and time and cost performance indices. There was a positive correlation analysis result.

Table 7. ANOVA and Tukey Test Results: Project Size Variables

Project Size Variables	F-value	p-value	Significant Tukey Tests (0.05 Level)
OTPI	7.186	<0.001	PSS – PSM PSS – PSL
PTPI	1.945	0.1448	N/A
OCPI	16.788	<0.001	PSS – PSM PSS – PSL
PCPI	15.877	<0.001	PSS – PSM PSS – PSL

For further analysis, the project length data was divided into two groups based on the mean value of total project length. The average project length of 136 projects was 2.8 miles. The two project length variables were: Project length below average (PLBA; <2.8 miles); Project length above average (PLAA; >2.8 miles).

As a next step analysis, a two-sample comparison t-test was performed. The test results were summarized in Table 8. As shown in the table, for PCPI, present contact-based project cost performance of PLBA and PLAA was significantly different and they are not the same with the 0.05 confidence level.

4.3.6 Maximum Incentive Amount Factor

FDOT proposed the maximum amount for each incentive project. The largest max. incentive proposed was $2,643,559 and the smallest max. incentive proposed was $3,000. The average max. incentive amount for I/D projects was $370,548.

For the data analysis, correlation analysis was performed to test any relationship between the max. amounts proposed and project time and cost performance indices. There was some positive correlation between them. Therefore, the project max. incentive data was categorized into three groups using the IQR: Q1=$45,000; Q3=$450,000; IQR=$405,000. The three categorized groups were names as follows: MIS (maxi. incentive proposed small); MIM (max. incentive proposed medium; MIL (max. incentive proposed large).

When categorization process was done, an ANOVA test and the Tukey test were performed. The test results were summarized in Table 9. All three possible cases were tested and all three cases were significant: MIS vs. MIM; MIS vs. MIL; MIM vs. MIL.

The results indicated that there are significant differences among max. incentive proposed amount variables. For OCPI

Table 8. Two Sample t–Test Results: Project Length Varibles

Project Length Variables	t-Test Statistics	p-value	Significant Tests (0.05 Level)
OTPI	0.358	0.7213	N/A
PTPI	0.516	0.6064	N/A
OCPI	-0.695	0.4888	N/A
PCPI	-2.743	0.0070	PLBA – PLAA

Table 9. ANOVA and Tukey Test Results: Maximum Incentive Amount Variables

Maximum Incentve Amount Variables	F-value	p-value	Significant Tukey Tests (0.05 Level)
OTPI	2.335	0.1016	N/A
PTPI	1.849	0.1622	N/A
OCPI	11.611	<0.001	MIS – MIM MIS – MIL
PCPI	18.065	<0.001	MIS – MIM MIS – MIL MIM – MIL

and PCPI parameters, this max. incentive proposed amount variable was significantly affecting project performance.

4.3.7 Daily I/D Amount Factor

FDOT paid various amount of incentives for each project. The largest daily incentive/disincentive amount was $10,000 and the smallest amount was $600 with an average amount of $3,390 per day.

For the data analysis, correlation analysis was perform to test any relationship between the daily incentive amounts proposed and project time and cost performance indices. There was some positive correlation between them. Therefore, the project daily incentive data was categorized into three groups using the IQR: Q1=$2,000; Q3=$4,000; IQR=$2,000. The three categorized groups were names as follows: DIS (daily incentive proposed small); DIM (daily incentive proposed medium; DIL (daily incentive proposed large).

When categorization process was done, an ANOVA test and the Tukey test were performed. The test results were summarized in Table 10. All three possible cases were tested, and two cases were significant: DIS vs. DIM; DIS vs. DIL.

Table 10. ANOVA and Tukey Test Results: Daily I/D Amount Variables

Daily I/D Amount Variables	F-value	p-value	Significant Tukey Tests (0.05 Level)
OTPI	4.699	0.0112	DIS – DIL
PTPI	2.989	0.0549	N/A
OCPI	13.298	<0.001	DIS – DIM DIS – DIL
PCPI	17.247	<0.001	DIS – DIM DIS – DIL

The results indicated that there are significant differences among daily incentive proposed amount variables. For OTPI, OCPI, and PCPI parameters, this daily incentive proposed amount variable was significantly affecting project performance.

4.4 Summary of Data Analysis

In summary, Table 11 shows a summary of significant factors and non-significant factors with the 95% confidence level. In addition, useful findings for project managers and planners considering incentive/disincentive contracting for their future projects are: 1) A+B with I/D and Bonus contract was statistically most effective to improve OTPI; 2) Among all eight districts, incentive/disincentive construction projects implemented in District 6 was significantly better than other seven districts in terms of project time performance; 3) Although project original contract amount did not have any influence in project cost or time performance, the modified variable such as daily project cost has an influence in project performance.

5. Conclusions and Recommendations

This study investigated FDOT's I/D construction projects, and based on them, found factors that influence project time and cost performance among highway construction projects using statistical techniques. The results of this study will provide construction project planners and project managers with valuable information on which construction projects to apply I/D.

While we cannot guarantee complete and accurate predictions using the study results, this research outcomes will pro-

Table 11. Summary of Significant (S) or Non-Significant (NS) Factors for Each Performance Index

Variables	OTPI	PTPI	OCPI	PCPI
Contract Type	S	S	NS	S
Project Type	S	S	NS	NS
District	S	S	S	S
Project Size	S	NS	S	S
Project Length	NS	NS	NS	S
Max. Incentive Amount	NS	NS	S	S
Daily I/D Amount	S	NS	S	S

vide a better understanding of the factors influencing project performance based on previous I/D project experience and results.

5.1 Conclusions

Each project time and cost performance can be influenced by many different project situations. In this study, many project variables considering different project situations were tested and seven project factors influencing project time/cost performance were found using various statistical analysis.

In terms of project time performance, five project variables such as construction contracting type, project work type, project location (district), project daily size (dollar amount), and daily I/D proposed dollar amount were found.

In terms of project cost performance, six project variables such as construction contracting type, project work type, project length, project daily size (dollar amount), max. incentive amount proposed and daily I/D proposed dollar amount were found.

5.2 Recommendations and Limitations

Because this study used FDOT-provided incentive/disincentive contract project data to identify only the critical factors affecting project time/cost performance, it may be overwhelming to apply the key factors universally to all other transportation agencies. Factors influencing construction project performance are diverse and many other factors, such as site conditions, location, weather, and local project management systems, can affect construction project performance differently than they do on Florida's construction performance.

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