

FLEXIBLE NOTICE-TO-PROCEED PROVISION ON THE PERFORMANCE OF
TRANSPORTATION INFRASTRUCTURE PROJECTS

A Thesis

by

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ABSTRACT

State departments of transportation (DOTs) are looking into alternative contracting techniques to shorten project delivery time, reduce total project cost, and/or improve project quality. One such technique is the use of flexible notice-to-proceed (NTP), which is a contract provision that allows a contractor some discretion, within some criteria, to establish a project's start date. Despite the benefits of flexible NTP provision have already been extensively described in various sources, no actual study has been conducted to validate the benefits of this alternative contracting technique and its impact on key project performance. This study intends to fill this literature gap by supporting or disproving the benefits of flexible NTP provision with empirical, quantitative evidence. North Carolina DOT (NCDOT) has been chosen to be the subject of this study. Fifteen projects with flexible NTP provisions were respectively paired with another project that was similar in terms of project length, type of work, and location but did not have the flexible NTP provision. Results showed that projects with flexible NTP provisions were able to attract a significantly higher number of bidders. Despite the findings showing that the mean values of award growth, award price, engineer's estimate, and contract time of projects with flexible NTP provision were lower than those without this provision, the difference was found to be not statistically significant at the 1% significance level. This study also investigated the effect of the length of the NTP window on project performance based on a sample of 25 bridge projects with flexible NTP provision. Findings indicated projects with longer NTP windows did not

necessarily attract a greater number of bidders. A positive correlation was also found between the length of the NTP window and the award growth. This study adds to the current body of knowledge by being the first study to prove that flexible NTP provision is effective in improving bidding competition. The findings of this study are expected to shed some light on the capabilities of flexible NTP provision, and thus providing more confidence to DOTs in adopting this alternative contracting technique for more efficient delivery of transportation infrastructure projects.

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NOMENCLATURE

A+B	Cost plus time (bidding)
AASHTO	American Association of State Highway and Transportation Officials
ACM	Alternative Contracting Method
CM/GC	Construction Manager/General Contractor
DB	Design-build
DOT	Department of Transportation
FHWA	Federal Highway Administration
I/D	Incentive/Disincentive
NCDOT	North Carolina Department of Transportation
NCHRP	National Cooperative Highway Research Program
NTP	Notice-to-Proceed

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1. INTRODUCTION

1.1. Background

For the past few decades, state departments of transportation (DOTs) in the United States have been using the standard, low bid contracting method to deliver countless transportation infrastructure projects that are vital in supporting the country's economy as well as improving the mobility of public. However, the increasing demand for public infrastructure, coupled with a shrinking budget for infrastructure development, have forced DOTs to look at alternative contracting methods (ACMs) to shorten the project delivery time, reduce the total project cost, and/or improve the quality of the project.

1.1.1. History of Alternative Contracting Methods in Highway Construction

In 1990, the Federal Highway Administration (FHWA) initiated the Special Experimental Project No. 14 (SEP-14) to evaluate the use of non-traditional contracting methods on federal-aid construction projects. The first four ACMs that were considered under this initiative were design-build (DB), cost plus time (A+B) bidding, lane rental, and warranty clauses. Based on the generally positive experiences from state DOTs, FHWA has successively declared that these four ACMs were no longer experimental (FHWA 2019). This is a turning point in the history of the highway construction industry in the United States as this essentially means that state DOTs now have the freedom to adopt these non-traditional contracting methods on federal-aid projects without seeking approval from the FHWA (FHWA 2019). Since then, FHWA has further approved the

usage of three additional ACMs under this initiative, which includes alternative pavement type bidding, construction manager/general contractor (CM/GC) project delivery, and alternative technical concepts (ATCs) on DB projects.

Since the inception of the SEP-14 initiative, ACMs have begun to gain interest among state DOTs across the nation. In 2006, the American Association of State Highway and Transportation Officials (AASHTO) released a report named “Primer on Contracting for the Twenty-First Century”. This document catalogs a total of 43 non-traditional contracting methods/techniques that are deemed suitable for state DOTs to implement. The adoption of ACMs was then further fueled by the introduction of the “Every Day Counts” (EDC) program by FHWA in 2010. EDC is “a state-based model that identifies and rapidly deploys proven, yet underutilized innovations to shorten project delivery process, enhance roadway safety, reduce traffic congestion, and integrate automation” (FHWA). One of those “innovations” include the use of ACMs. The EDC program has since promoted the use of previously proven ACMs such as CM/GC, DB, and ATCs (FHWA).

1.2. Current Status of Alternative Contracting Methods

While the adoption of ACMs in the highway construction sector has generally increased in recent years, the adoption has seemed to be only focused on a limited number of methods, out of the 43 identified in the AASHTO’s Primer on Contracting. Some of those ACMs have become so widely used in certain DOTs that it is deemed inappropriate to consider them as innovative practices anymore (FHWA 2019). DB and A+B bidding, for instance, are two “mainstream” ACMs that have received a

considerable amount of attention from both academia as well as the professional world. However, there has been little discussion on other less popular ACMs (or more precisely, alternative contracting techniques¹), such as lump-sum contracting, no-excuse incentive, flexible notice-to-proceed (NTP) provision, etc.

Although multiple studies have demonstrated that ACMs such as DB and A+B bidding seemingly offer more direct (usually positive) impacts on the performance of highway construction projects, implementation of these two contracting methods requires a significant change in the project procurement process of a state DOT. Besides, both contracting methods are typically only used in large, complex transportation projects in which significant road user impact is expected. Other alternative contracting techniques such as incentive/disincentive (I/D) and lane rental, on the other hand, require the accurate, meticulous calculation of road user cost to maximize their respective advantages without incurring excessive cost to a state DOT.

As a result, it is common to see state DOTs implement certain specific ACMs only in large projects as the scale of these projects (and subsequently the expected amount of benefits) made the additional effort and manpower needed in contract administration easier to justify. However, this should not be a reason to exclude any

¹ The current body of knowledge uses the word “ACMs” as an inclusive term that encompasses both alternative project delivery methods (APDMs) (e.g., design-build, CM/GC) and alternative contracting techniques (ACTs) (e.g., A+B bidding, I/D). APDMs introduce change in the “overall process by which a project, constructed and/or maintained”, whereas ACTs generally refers to all other procedures/contract provisions that were used (1) to alter the traditional practice by which a third party (designers, contractors, consultants) is evaluated and selected by an agency (e.g., A+B bidding, best-value procurement), and/or (2) to “ensure control of costs, timely completion and quality of construction” (e.g., flexible NTP, lane rental, I/D) (Trauner Consulting Services 2007).

small projects such as resurfacing projects or simple bridge replacement projects from reaping the benefits of alternative contracting. This is because small projects can constitute a significant portion of a DOT's construction program. For example, according to Florida DOT's (FDOT) construction office, out of 521 contracts that were awarded, 311 (60%) of them have a contract price of less than \$ 5 million (FDOT 2020). Any slight improvement in each of these small projects would quickly add up to a noticeable benefit for a state DOT. Hence, DOTs should look for other forms of alternative contracting that offer a balanced tradeoff between the anticipated benefits and the implementation effort, particularly those that can be practically and reasonably applied on small projects.

Considering this, the author proposes flexible NTP provision as a potential performance improvement tool that a state DOT could implement in small projects. This is because it seemingly offers a win-win situation for both the contractor and the department, without requiring much administrative change from the contracting agency (i.e., DOT).

2. LITERATURE REVIEW

2.1. Overview of Flexible NTP

Flexible Notice-to-Proceed (NTP) is a contract provision that “allows the contractor some discretion, within some criteria, to establish when a project’s working days are going to start” (WSDOT). The term “flexible NTP” is used by organizations such as the FHWA, AASHTO, and Wisconsin DOT (WisDOT). Alternatively, this alternative contracting technique may also be called under different names such as “flex-time” (Herbsman and Ellis 1995) or “flextime” (FDOT 2018), “flexible starting date” (MnDOT ; WSDOT), “variable start date” (Anderson and Ullman 2000), “flexible start window contract” (ODOT 2019), and “flex start” (Fick et al. 2010).

On a standard contract, a project’s start date is typically established using a specified number of days (e.g., 10 calendar days) after the execution of the contract (WSDOT). In a contract with a flexible NTP provision, the contractor is given some freedom, with limits, on deciding the start date of the project. This flexibility in scheduling the project start date is usually expressed in two different manners. A state DOT can specify either an “NTP window” in which the contractor can freely select any date within this window to commence work or a “latest start date” that the contractor must commence work by. In the latter case, the contractor should be informed earlier so that that the project site would be available soon after project letting. Once work commences (i.e., time charge begins), the project would need to be completed in a certain amount of time, or by a date specified in the contract (WisDOT 2019). While

flexible NTP provision is commonly used on the entire project, a DOT may also choose to only use this provision on portions of work within a project (ODOT 2019).

Several state DOTs have experience in using flexible NTP provision including Minnesota DOT (MnDOT) (Strong et al. 2007), North Carolina DOT (NCDOT) (AASHTO 2006), Maine DOT (Herbsman and Ellis 1995), FDOT (Herbsman and Ellis 1995), Washington State DOT (WSDOT) (Strong et al. 2007), and Missouri DOT (MoDOT) (Strong et al. 2007).

The primary purpose of using flexible NTP provision is to offer flexibility to the selected contractors in scheduling the start of a project. The contractor can use this additional time for utility coordination, shop drawing submission and approval, mobilization of subcontractors, and acquisition of material and equipment (FDOT 2018; Trauner Consulting Services 2007). This would, theoretically, give the contractor ample time to gather its resources and use them at the right place at the right time, thereby maximizing its productivity and efficiency.

2.1.1. Benefits of Flexible NTP Provision

The use of a flexible NTP provision offers a win-win situation for both the contractor and the contracting agency. For the contracting agency (i.e., DOT), the main benefits stem from the project's ability to start at the most appropriate time. One of the frequently mentioned benefits is that the additional scheduling flexibility may attract more contractors to bid, which increase the bidding competition. As a result, a lower bid price could be expected (Anderson and Damnjanovic 2008; Iowa DOT 2020; WisDOT 2019; WSDOT). Besides, when a large number of projects with specialized work are

being advertised and performed within a short period, the demand for inspectors increases significantly, which may subsequently drive up the inspection workload and costs. A flexible NTP provision may be able to spread the inspection workload for quality inspection as contractors are given more flexibility in scheduling inspectors for their respective projects (FHWA 2002). Besides, the use of flexible NTP provision is said to be able to reduce road user impact (FHWA 2002). Since a contractor can choose a date to start the project at a time where its productivity is the highest, the period in which road users are affected due to construction could potentially be minimized.

There is also consensus within some DOTs that reduction in contract time could be expected with the use of flexible NTP provision due to the anticipated improvement in contractor's efficiency in performing contract work (FDOT 2018; ODOT 2019; WisDOT 2019; WSDOT). Lastly, the likelihood of completing a project on time may also increase with the use of this provision. In fact, according to a study by Anderson and Ullman (2000), this reason, along with its ability to minimize road user impact, are the two primary reasons why FDOT uses flexible NTP provision.

2.1.2. Limitations of Flexible NTP Provision

The drawbacks of using flexible NTP provisions are primarily associated with the uncertainty in the project's start date. To ensure a contractor will have a sufficient amount of time to complete all work items, it is evident that a project with a flexible starting date should also have a flexible end date. This means that this provision cannot be used on projects with a critical completion date such as emergency projects, fast-track projects, or any project where its completion is critical to a DOT's work program (FDOT

2018). Besides, using this provision on a construction contract also requires that certain project parties such as the contracting agency (i.e., DOT), inspectors, and consultants have the flexibility as well in their work schedules. A study involving interviews with DOT personnel who have experience in projects with flexible NTP provision noted that flexible NTP provision “may strain local agency resources, particularly onsite inspectors” (Strong et al. 2007). Another disadvantage of using flexible NTP provision is that DOT loses control over the project schedule (WSDOT).

There are also several effects caused by the uncertainty in the project’s start date. Firstly, a DOT may find it more difficult to communicate the disruption period caused by construction work to the affected parties (e.g., communities, businesses, utility companies) (WisDOT 2019). Secondly, depending on fluctuation in prices, additional cost may incur for DOTs from fuel adjustments and asphalt binder adjustments (Anderson and Damnjanovic 2008).

Table 2.1 summarizes the benefits and limitations of flexible NTP provisions cited in the literature.

Table 2.1 Benefits and limitations of flexible NTP provisions based on literature

Benefits	Limitations
<ul style="list-style-type: none">• Increases bidding competition• Lower bid price• Avoids sudden spike in demand for inspectors• Reduces road user impact• Reduction in contract time	<ul style="list-style-type: none">• Cannot be used on projects with critical completion date• Strains local agency resources• DOT loses control over the project schedule• Difficult to communicate disruption period to affected parties• May incur additional costs from material price fluctuations and adjustments

2.1.3. Applicability of Flexible NTP Provision

As with any other alternative contracting techniques, the use of flexible NTP provision is only appropriate in certain kinds of projects. First and foremost, both the project start date and project end date must be flexible. Also, the estimated construction period of the project should be substantially less than the available construction window. Both WSDOT and ODOT (2019) caution against using this provision on projects with estimated completion near the end of the construction season. ODOT (2019) suggests only using this provision on projects with an estimated completion date around early fall.

Besides, flexible NTP provision may be more useful on projects where the limited number of bidders is anticipated to have participated. This may occur when multiple projects which consist of specialized work (e.g., seal coats, highway planting, pavement) are being advertised within a short period (FHWA 2002; ODOT 2019; WSDOT). For example, NCDOT had implemented flexible NTP provision in a large number of guardrail projects where the department was worried about getting good competition from a limited pool of guardrail contractors (AASHTO 2006). Besides, a DOT may consider using flexible NTP provision when there is a limited supply of construction materials (e.g., concrete, asphalt) or when the labor force is limited (Strong et al. 2007; WSDOT). Lastly, a project that involves significant offsite preparatory work that can be performed before the start of construction may also be a good candidate for this provision (Strong et al. 2007; Trauner Consulting Services 2008; WSDOT).

2.2. Literature Review

2.2.1. Comparison of Alternative Contracting Methods with Conventional Methods

The SEP-14 initiative introduced by the FHWA at the turn of the 21st century has sparked a significant amount of research interests on the four non-traditional contracting methods (e.g., DB, A+B bidding, lane rental, and warranty clauses) that were first evaluated by this initiative. As a result, numerous studies have attempted to evaluate the effectiveness of these non-traditional contracting methods in comparison to the conventional, low bid delivery method.

One notable study is the one performed by Strong (2006). In this exploratory study, a national survey was administered to investigate the preferences of state DOTs in

using different ACMs which include DB, A+B bidding, and lane rental. To further understand the performance effectiveness of these methods, Strong (2006) also conducted several in-depth case studies of projects with ACMs in the state of Minnesota. Findings from the national survey indicated that among the three methods under consideration, A+B bidding is the preferred contracting method for all project types, except for major corridor alignment. The study also revealed no cost premium but significant time savings from the use of A+B bidding. Besides, the DB delivery method is found to be highly effective for urban projects with high complexity. Nonetheless, Strong (2006) cautioned that the time savings from using DB method may be negated if issues such as environmental remediation, right-of-way acquisition and utility relocation are not addressed effectively.

A more recent study by Choi et al. (2012), however, presented conflicting findings that indicated that pure A+B contracting performed worse than conventionally contracted projects in terms of schedule performance. In this study, Choi et al. (2012) quantitatively analyzed 1,372 public transportation projects in the state of California to evaluate the schedule effectiveness of three different types of contracting techniques - pure A+B, A+B with I/D, and conventional. Results showed while A+B with I/D technique was effective in minimizing overall construction duration, but this was clearly not the case for pure A+B contracting (i.e., no I/D clause). Significant schedule overrun was found to be associated with pure A+B contracting. Choi et al. (2012) believed that under this strategy, contractors are more likely to unrealistically deflate the contract time

(i.e., “B” portion of the bid) to win the contract, thus significantly increase the possibility of schedule delay.

2.2.2. Past Studies on Flexible NTP Provision

Past research efforts have predominantly focused on “mainstream” alternative contracting methods such as DB, I/D, A+B bidding, and lane rental. There is a very limited amount of studies exclusively on flexible NTP provisions. Most of the prior literature only discussed flexible NTP provision alongside with other ACMs.

In the National Cooperative Highway Research Program (NCHRP) Synthesis 215, flexible NTP provision was one of the four alternative contracting methods discussed by Herbsman and Ellis (1995). The researchers concluded that all 4 ACMs (including flexible NTP provision) do not have a direct effect on the determination of contract time. However, they noted that practitioners generally agreed that those ACMs may indirectly influence the estimate of contract time. For instance, a few DOTs reported that their contract time estimation for a project with flexible NTP provision was “based on higher production rates and no time allowances for material acquisition and delivery, as compared to contract time of conventional contracts” (Herbsman and Ellis 1995).

As ACMs are increasingly being used to shorten project delivery, Anderson and Damnjanovic (2008) were tasked in NCHRP 379 to assess the effectiveness of different ACMs in accelerating the completion of transportation projects. Results from this national study showed that the relative potential for schedule reduction of flexible NTP provision is not as superior as other ACMs such as DB, I/D, A+B, interim completion

dates, and no-excuse incentives. The same survey also showed flexible NTP provision is not as well-received as other ACMs among state DOTs in the United States. This is proven when 15 state DOTs indicated that they have never used flexible NTP provision, and only between 6 to 15 state DOTs reported using this alternative contracting technique. Besides, flexible NTP provision was also featured in NCHRP Synthesis 293 as one of the ACMs that have the potential to minimize lane occupancy, though the impact of this practice in doing so is estimated to be medium to low (Anderson and Ullman 2000). A respondent in this study has even made it clear to the research team that his/her agency would not use flexible NTP provision as the primary strategy to reduce lane occupancy.

Despite its inferior performance highlighted in the previous paragraph, Fick et al. (2010) recommends flexible NTP provision, whenever possible, to maximize the effectiveness of time-related I/D provisions. A strong level of agreement between contractors from the survey has made the researchers believe that flexible NTP is an essential tool in helping contractors to alleviate some of their staffing and resource issues created by time-related I/D provisions. Besides, the cost-savings potential of flexible NTP provision is partially proven when a contractor commented that a project will cost less for the contracting agency when flexibility in scheduling projects start date is offered (Fick et al. 2010).

The study conducted by Strong et al. (2007) is the only study found in the literature that exclusively investigates the state-of-practice of state DOTs in implementing flexible NTP provision. The study first presents several legal cases

involving construction start dates to demonstrate the significance of the project start date in construction disputes. The review of these legal cases indicates that flexible NTP provision has the potential to mitigate some of the schedule risk and disputes related to project commencement. Then, Strong et al. (2007) went on to examine how three different state DOTs (e.g., WSDOT, MnDOT, and MoDOT) have been using this non-traditional contracting technique. The researchers conducted surveys and telephone interviews with resident engineers from MnDOT and MoDOT, respectively. For WSDOT, the researchers opted to perform a query search on WSDOT's website to gather relevant information. Based on the engineers' feedback, Strong et al. (2007) concluded that flexible NTP provision "appears to provide better risk allocation, increased competition among bidders, lower bid costs and shorter duration of work zone traffic disruption", which is in line with the consensus from the literature regarding flexible NTP provision.

Table 2.2 summarizes the findings of past studies regarding flexible NTP provision in chronological order.

Table 2.2 Summary of a literature review regarding flexible NTP provision

Sources	Findings/Conclusions
(Herbsman and Ellis 1995)	<ul style="list-style-type: none">• Flexible NTP does not have a direct influence on contract time determination.
(Anderson and Ullman 2000)	<ul style="list-style-type: none">• Flexible NTP has medium to low potential in minimizing lane occupancy
(Strong et al. 2007)	<ul style="list-style-type: none">• “Provide better risk allocation, increased competition among bidders, lower bid costs and shorter duration of work zone traffic disruption”
(Anderson and Damjanovic 2008)	<ul style="list-style-type: none">• The relative schedule reduction potential of flexible NTP is not as superior as DB, I/D, A+B, interim completion dates, and no-excuse incentives.• 15 DOTs reported never used flexible NTP provisions before.
(Fick et al. 2010)	<ul style="list-style-type: none">• Use flexible NTP to maximize the effectiveness of time-related I/D provisions

2.3. Need for Flexible NTP Provision

Competitive, low bid method has been, and will still likely be, the primary procurement method for a state DOT to deliver the majority of its projects. Under this

method, competition becomes the vital key in ensuring that each project is procured at the lowest price as deemed appropriate by the market to maximize the value of each dollar of taxpayer's money. With the limited number of general contractors who participate in the bidding and procurement phase, state DOTs are facing a critical challenge of receiving a final price that is significantly higher than the engineer's estimate. If this happens regularly, it will have a detrimental impact on a DOT's construction program, forcing the DOT to reevaluate the feasibility of some future projects given the limited annual budget. Thus, competition is a critical component in the successful implementation of the low-bid procurement strategy.

Nonetheless, a national survey jointly performed by FHWA and AASHTO (2012) on competition and bid price has found that lack of competition is still a prevalent issue in some state DOTs. This can be seen when, on average, 25% of the total number of construction contracts let in 2011 by a state DOT (80 out of 320) received 2 bids or less, with single-bid contracts (contracts that received only one bid) constitute approximately 8% of the total number (27 out of 320). The same survey also found that projects which received 2 bids or less to have positive average variance from the engineer's estimate (i.e., overrun), with contracts that received only one bid to have an average variance of +7.5% from the engineer's estimate. These findings concur with the common belief that there is a correlation between the level of competition and the difference between the lowest bid and engineer's estimate. Besides, the survey also discovered that, in 2011, out of 6 work types, on average, asphalt resurfacing has the highest percentage of single-bid contracts (19%), followed by specialty

projects/transportation enhancements (17%) and maintenance projects (10%). The main takeaway from this particular finding is that these three work types are ideal candidates for using flexible NTP provision, since projects of these work types are typically not complex, and the scale of these projects often do not justify the use of other ACMs such as A+B, I/D, or DB. FHWA (2002) has recognized flexible NTP provision as a potential means to improve the competitiveness of a bid let by a state DOT in its contract time determination guideline. Therefore, incorporating flexible NTP provision into highway contracts should be seriously considered as one of the promising initiatives that state DOTs can take to address the problem of lack of competition in their bid lettings.

3. PROBLEMS AND RESEARCH SETTINGS

3.1. Gaps in Knowledge

Compared with other alternative contracting methods (e.g., DB, A+B, I/D, etc.), there is a very limited amount of studies regarding flexible NTP provision. Although the advantages and disadvantages of flexible NTP provision are extensively described in various sources (e.g., DOT manuals, NCHRP reports, etc.), a thorough search of relevant literature has yielded no study that validated the benefits of this method. For example, the lower bid price is one of the frequently cited potential advantages of flexible NTP, but no study has been found that offer concrete evidence in supporting this claim.

To date, only one research study has been identified that attempted to evaluate the effectiveness of flexible NTP provision in an exclusive manner (Strong et al. 2007). However, the researchers of this study adopted a qualitative approach – utilizing tools such as email surveys, telephone interviews, and case studies. Hence, the results of the study were entirely based on the perceptions of several DOT engineers with no real quantitative evidence to support their claims. In addition, to reduce road user impact, the case study project employed a combination of different ACMs, which include flexible NTP provision, A+B bidding, and I/D. There is no clear indication in the research report that the observed improvements in the performance of the case study project can be attributed to a specific contracting method/technique. Hence, the actual implications of using flexible NTP provision in project performance remains unknown. Lastly, this study was conducted more than a decade ago, which does not take into consideration

learning curve biases and the various changes that have occurred in the landscape of ACMs in highway construction since the conclusion of the study.

The lack of research activities around the use of flexible NTP provision has caused this particular contracting technique to be effectively “drowned” by the tremendous amount of research effort on other ACMs such as DB and A+B bidding. This situation is further exacerbated by the lack of quantitative evidence that supports the benefits of flexible NTP provision, which may have led to some state DOTs to start questioning the actual effectiveness of this alternative contracting technique. State DOTs are typically conservative in implementing any changes in their existing work processes. Until a practice has been consistently proven to be effective and reliable, state DOTs usually take the “if it isn’t broke, don’t fix it” approach. This may be one of the reasons why flexible NTP provision has a low adoption rate among state DOTs in the United States, as indicated by the findings of a national survey (Anderson and Damnjanovic 2008).

Therefore, the current study attempts to fill this literature gap by supporting/disproving the benefits of flexible NTP provision with quantitative evidence obtained using sound research method, instead of subjective annotations that are both vague and susceptible to bias.

3.2. Research Objectives

The primary goal of this study is to provide empirical evidence on the effects of incorporating flexible NTP provision in the contract of transportation infrastructure projects in the United States. By conducting statistical analysis on actual project data, it

is to the author's belief that this will be the first research study that quantitatively verifies the benefits of flexible NTP provision.

Particularly, this study aims to investigate the implication of using flexible NTP provision on the performance of transportation infrastructure projects. This is because without understanding how much of the flexibility given to a contractor translates to actual time and/or cost savings, DOTs are most likely to be hesitant to take the initiative to incorporate this alternative contracting technique into their construction contracts. Therefore, the current study will focus on correlating the contractor's flexibility enabled by this provision to several performance aspects that state DOTs are mostly concerned about, such as time, cost and competition.

It is also the author's hope that the results of this study will help state DOTs to be better informed about the effectiveness of flexible NTP provision in the real world, and thus DOTs will be able to make a better decision on whether or not to use this alternative contracting technique for projects in the future.

3.3. Research Questions

With those research objectives in mind, this study intends to answer the following research questions:

- i. Does the use of flexible NTP provisions improve the bidding competition (i.e., number of bidders)?
- ii. Does the use of flexible NTP provisions reduce the award price of a project?
- iii. Does the use of flexible NTP provisions reduce the contract time of a project?

- iv. What is the relationship between the amount of flexibility given to a contractor (i.e., duration of NTP window) and the three aforementioned performance measures (e.g., competition, award price and contract time)?

3.4. Research Limitations

There are several limitations that the author would like to acknowledge from this study.

Firstly, this study was conducted under a limited sample size. To begin with, there were significantly fewer projects with flexible NTP provision than those without this provision – only 34 out of 607 projects were found to have this provision included in the contract. The sample size was then further shrunk down during the pairing process as additional projects were discarded from the sample to establish project pairs that are similar in size, work type and location.

Secondly, care should be taken in extending the findings of this study to other populations that do not share similar characteristics to the one analyzed in this study. The author of this study opted for data homogeneity at the cost of the generalizability of the result. All projects in this sample were let by NCDOT. As such, they were similar in terms of geographic locations, contracting community, etc. Besides, the author took the conservative approach to focus the analysis only on projects that involved “grading, drainage, paving and structure” work because a large majority of NCDOT’s flextime projects were of this work type.

Lastly, the results of this study were based on the assumption that the observed performance difference was caused by the sole inclusion of flexible NTP provision.

Because the sample did not include any projects that used any other ACMs aside from flexible NTP provision, the findings may not apply if this provision is used in parallel with other alternative contracting techniques such as A+B or incentives/disincentives. The complex relationships between each contracting method does not guarantee that the benefits of each method are additive. The use of one ACM may potentially negate the benefits of the other, or in some cases, creates unnecessary issues that are previously non-existent.

4. RESEARCH METHODOLOGY

4.1. Identifying Data Sources and Collecting Data

North Carolina Department of Transportation (NCDOT) has been chosen to be the subject of this study for two reasons: (1) easy access to NCDOT's project bidding data via its website named "Connect NCDOT"; and (2) the data crucial to this study can be obtained from each project's bid tabulation.

This study examined all lettings that occurred beginning January 2015 through December 2019. Bidding data were collected by downloading monthly bid tabulations from NCDOT's letting website (NCDOT). Relevant project data fields that can be obtained from the bid tabulation include (1) contract number, (2) proposal length, (3) type of work, (4) project location, (5) number of bidders, (6) engineer's estimate, (7) project start date, (8) expected completion date, and (9) lowest bid (i.e., award price). All these relevant data were extracted from each project's bid tabulation and recorded in a Microsoft Excel spreadsheet.

4.2. Data Cleaning and Classification

A total of 709 lettings were found from the NCDOT's letting website that occurred between 2015 and 2019, representing approximately \$ 11.16 billion worth of contract work. A data-cleaning step was performed in which lettings with any of the following characteristics were excluded from this study: (1) the project utilized any non-traditional contracting techniques or delivery methods other than flexible NTP provision (e.g., design-build, express design-build, cost plus time bidding), (2) the project has a

flexible start date but with a fixed completion date, (3) the project received zero bids, and/or (4) letting rejected by NCDOT.

In total, 102 lettings were eliminated. The resulting dataset was comprised of 607 lettings with a total contract value of \$ 6.07 billion. These 607 projects were then divided into two subsamples based upon whether a flexible NTP provision is used or not. A project is identified to have incorporated a flexible NTP provision when the project's start date is expressed as an interval (e.g., mm/dd/yyyy thru mm/dd/yyyy) instead of a specific calendar date (mm/dd/yyyy). Unless specifically noted on the bid tabulation, all contracts were assumed to be procured using the traditional low-bid method, regardless of whether a flexible NTP provision was utilized in the contract or not.

Out of 607 low-bid projects, there were 34 projects with a flexible NTP provision (called "flextime projects" hereafter) and 573 projects without this special provision (called "traditional projects" hereafter).

4.3. Performance Metrics

To align with previous research efforts, the following metrics have been chosen to quantitatively characterize the performance of a transportation infrastructure project.

4.3.1. Contract Time

Contract time is the maximum duration a contractor has to complete all work items specified in a contract (FHWA 2002). In this study, it is more precisely defined as the number of calendar days between the date project site becomes available to the contractor, and the completion date determined by the DOT. For a flextime project, in

which the available date is specified as a range, the contract time is the number of days that is readily specified in the estimated completion date field on the bid document.

$$\text{Contract time} = \text{Final completion date} - \text{Available date}$$

4.3.2. Engineer's Estimate

All DOTs require that their respective engineers to estimate the cost of a project before advertisement. This estimated project cost is aptly named “Engineer’s estimate”. The engineer’s estimate is essentially the estimator of award price and is often used as a benchmark for bids evaluation. A significant difference between the engineer’s estimate and the lowest bid received could indicate there may be some errors in the estimation procedure or there may be some misalignment in the understanding of the project’s requirements.

4.3.3. Award Price

Award price is the initial amount of money awarded to the contractor to perform all the works specified in the contract. Under the low-bid procurement process, award price is generally the price submitted by the lowest responsive bidder.

4.3.4. Award Growth

Award growth is calculated by subtracting the engineer’s estimate from the award price and dividing it by the engineer’s estimate. It measures the percentage difference between the contract price at the time of award and the total cost estimated by the DOT engineer. The equation used to calculate award growth is

$$\text{Award growth (\%)} = \frac{\text{Award price} - \text{Engineer's estimate}}{\text{Engineer's estimate}} \times 100$$

Award growth is an important metric for state DOTs during the letting stage as it is often used as the basis for DOTs to make the final go/no-go decision for a project. If the award growth of the lowest responsive bid falls within a DOT's predefined range (e.g., +/- 10%), then the DOT will proceed by awarding the contract to the corresponding bidder. However, if the award growth of the lowest responsive bid is above a DOT's threshold value (e.g., the bid amount is greater than engineer's estimate by more than 10%), then the DOT is mostly likely to reject all the bids received, reevaluate its estimate, and re-advertise the contract at a later time.

Besides, award growth may occasionally be treated as an indirect indicator of the amount of risk of a proposed contract perceived by the contractor. Assuming the engineer's estimate is accurate, then a higher award price (than engineer's estimate) could be due to the additional cost contingency embedded in the winning contractor's bid. This cost contingency is typically proportional to the amount of risk a contractor anticipates from a proposed contract. Alternatively, if the risks are not realized, then award growth could be viewed as the profit opportunity of the winning contractor. The lower the award growth, the lower the profit margin of the winning contractor.

4.3.5. Number of Bidders

The number of bidders is the number of contractors who submitted a responsive bid on a proposed contract. It represents the amount of competition a DOT received on a contract. A higher number of bidders is associated with better market competition, which is normally desirable by a contracting agency such as state DOT that uses the low-bid procurement method. AASHTO (2013) has advised that the effect of competition on bid

price should not be ignored when deciding the DOT's letting strategies. This advice was made on the basis that multiple studies have demonstrated a lower bid price was often correlated with a higher number of bidders (AASHTO 2013; Gaver and Zimmerman 1977; Holt 1979).

4.4. Project Comparability

The objective of this study is to examine whether there is any significant difference in project performance when a flexible NTP provision is used. This could be done by comparing projects with this provision included (i.e., flextime projects) and those without this provision (i.e., traditional projects). For this comparative analysis to be fair, each project with a flexible NTP provision should be paired with a similar low-bid project that does not have this provision in its contract.

The original intent of this study was to classify projects (both flextime and traditional) by work type for comparison. However, insufficient similar projects were found for all work types, except for “grading, drainage, paving and structure” (see section 5.1.2). Therefore, to further improve data homogeneity, the research scope has been narrowed down, focusing exclusively on projects with “grading, drainage, paving and structure” work.

This change in research scope necessitated another round of data screening, specifically on the flextime subsample. Firstly, based on the “type of work” data field, any flextime projects ($n = 6$) that were not coded as “grading, drainage, paving and structure” were removed. Next, based on the “location” data field, projects ($n = 3$) that did not involve constructing structure over moving water body (e.g., creek, river,

tributary) were also discarded from the subsample. These ineligible locations include structure over swamp and structure over road. The resultant subsample includes 25 flextime projects of the same work type (i.e., grading, drainage, paving and structure) and of similar location.

In this study, project comparability was achieved by evaluating the similarity in three project characteristics, which include project length, type of work and project location. These three parameters were selected as similarity criteria because they collectively provide a meaningful way of classifying projects, along with the fact that they are the only useful ones that could be extracted from the bid document. They enable the clustering algorithm (explained in the following paragraphs) to detect major differences between projects but not too detailed to that extent that no projects would be found similar to each other since each construction project is, in fact, unique.

The project length represents the physical size of the project. The contract amount (i.e., award price), which is also often used to indicate project size, was not chosen to be a primary similarity criterion because it is a dependent variable in this study. Type of work, on the other hand, provides decent information on the types of major work activity involved in a project. Lastly, project location is chosen as a similarity criterion because it serves as an indirect indicator of the complexity of a project. This parameter is particularly useful when comparing projects of the same work type. For example, the work requirements for replacing a bridge over a creek would most likely be different than replacing a bridge over an existing highway.

To lend objectivity to this study, a hierarchical clustering technique was used as the primary mechanism to complete the pairing process. Clustering, in general, is a technique that groups together observations that share similar values across several variables, into a cluster. Hierarchical clustering is a special method of clustering that combines clusters successively. This method begins by treating each observation as an individual cluster. Then, at each iteration, the clustering process calculates the distance between all pairs of clusters and combines the two clusters that are closest together. This process continues until all observations are contained in one large cluster (JMP 2020). This clustering approach is also called agglomerative clustering because of the combining approach that it uses. Using commercial statistical software JMP, the result of this clustering process can be illustratively presented using a dendrogram or a constellation plot.

In this study, proposal length and type of work were selected as the variables for the hierarchical clustering algorithm to calculate similarity distance between clusters. Project location would be an “after-the-fact” similarity criterion, instead of being directly considered by the clustering algorithm, due to the overly specific location description which would compromise the accuracy of the clustering algorithm.

The constellation plot (Figure 4-1) was used in this study as the main tool to identify project pairs. The identification process mostly focused on the clusters located on the outer edges of the “constellation” because these outer clusters are made up of observations that have the smallest similarity distance (i.e., most similar). The deeper

(i.e., towards the center of the constellation) one proceeds within each “branch”, the greater the similarity distance (i.e., less similar) between each cluster.

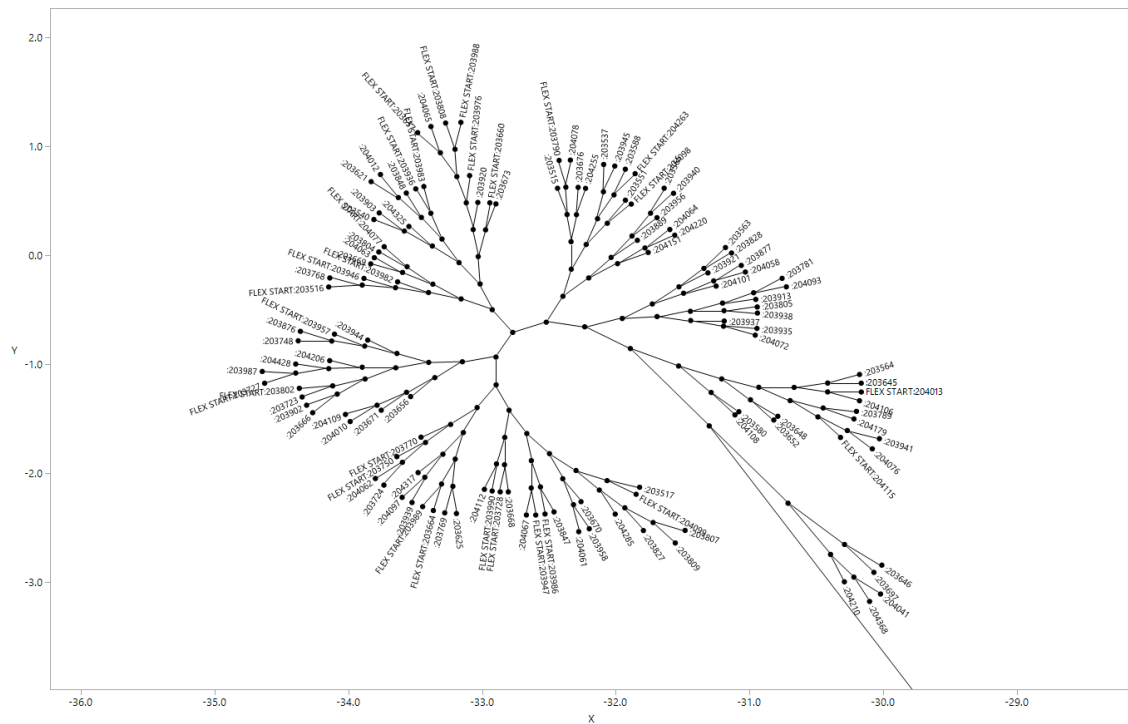


Figure 4-1 Constellation plot

The pairing procedure began by identifying outer clusters that contain at least one flextime project. If the outer cluster contains only one flextime project and one traditional project, the pairing process is complete. For any other situation (e.g., an outer cluster made up of two flextime projects, a cluster contains an unequal number of flextime and traditional projects, etc.), a systematic procedure was followed to manually complete the pairing process. First, a project pair that yielded the smallest similarity

distance was chosen. If more than one project pairs had an identical similarity distance, the project pair with the smallest absolute percentage difference in award price was selected.

Out of the 25 flextime projects, no similar traditional projects were found for 4 flextime projects. An additional screening procedure was conducted to ensure the remaining 21 project pairs were indeed similar. The percentage difference in award price between flextime and traditional project in each pair was calculated. As a conservative approach, any project pair with an absolute percentage difference greater than 50% in award price was removed from the dataset. The resulting paired sample included 30 projects (15 pairs), representing a combined award amount of \$ 27.8 million.

To assess the degree of similarity between flextime and traditional project in each pair, the percentage differences in proposal length and award price were calculated (Table 4.1). The mean percentage differences in proposal length and award price were – 0.36% and – 0.89%, respectively. Although truly identical projects are extremely rare in the construction industry, given that the mean percentage differences for both parameters were close to zero, this is a good indication there were no noticeable mismatched cases and the paired sample was ready for further analysis.

Table 4.1 Percentage difference in proposal length and award price

PERCENTAGE DIFFERENCE IN	STATISTICS	FLEXTIME (N=15)	TRADITIONAL (N=15)
Proposal length	Minimum		- 6.00 %
	Maximum		5.88 %
	Mean		- 0.36 %
Award price	Minimum		-39.35 %
	Maximum		41.89 %
	Mean		- 0.89 %

4.5. Statistical Analysis

To accomplish the goals of this study, the performance metrics were compared by testing the following 2 hypotheses.

- i. Null hypothesis (H_0): The average performance of flextime projects will be worse than or equal to the average performance of traditional projects.
- ii. Alternative hypothesis (H_A): The average performance of flextime projects will be better than of traditional projects.

Unless noted otherwise, the significance level for all hypothesis tests used in this study was set at 5%. Statistical significance is found when the p-value is smaller than 0.05, which indicates that the null hypothesis is implausible. The null hypothesis is hence rejected and there is sufficient statistical evidence in the sample data to suggest that the alternative hypothesis be true.

A paired t-test, instead of independent two-sample t-test, was used in this study to compare the means between flextime and traditional projects. This is because the

hierarchical clustering method used in this study inherently created paired data, whereby a flextime project would be paired (combined to form a cluster) with a traditional project that yields the highest similarity in terms of proposal length and type of work. As a result, an observation in one group may likely be indicative of the value of another observation in the other group. Figure 4-2 shows there was a linear correlation between award price of flextime projects and that of traditional projects, suggesting the observations between groups were most likely to be not independent of each other. Therefore, the paired t-test (or the Wilcoxon signed rank test for non-parametric scenarios) was determined to be a more appropriate method of analysis for the sample of this study.

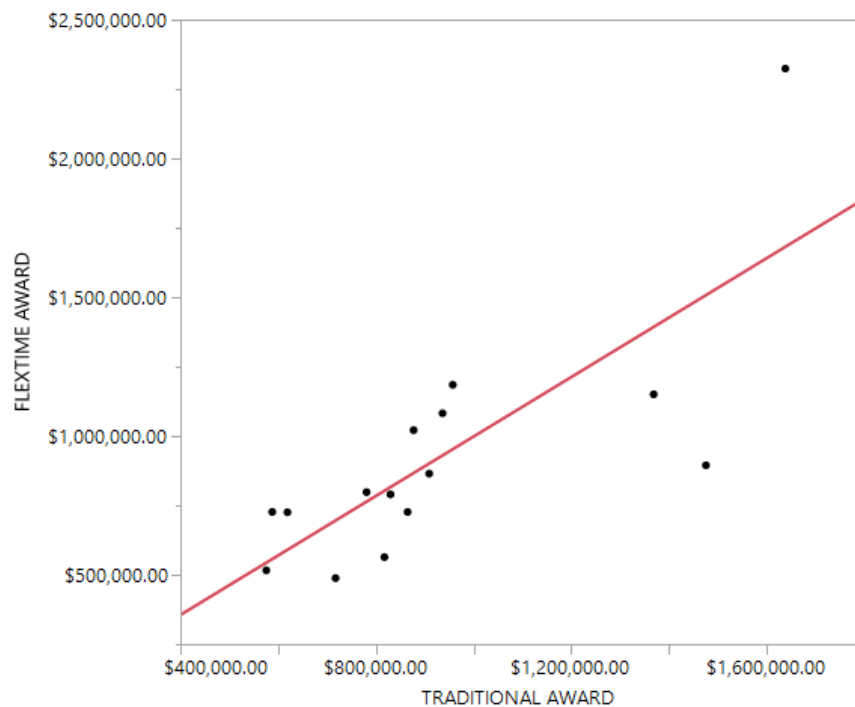


Figure 4-2 Flextime award price versus traditional award price (N = 15)

To select the most appropriate statistical test for the null hypothesis, the normality of the paired differences was checked using a graphical method (e.g., normal quantile plot), and supplemented with a formal normality test such as the Shapiro-Wilk test. If the paired differences turned out to be normally distributed, the paired t-test would be employed to determine whether the paired difference is statistically significant or not. If the paired differences were not normally distributed, a non-parametric version of the paired t-test, the Wilcoxon signed rank test would be used since this test does not require data normality.

Additional analysis steps would also be taken to ensure that the underlying assumptions of each test are satisfied.

5. ANALYSIS

This section discusses the various analysis performed for this study. Descriptive statistics are first reported, followed by results of inferential tests (e.g., hypothesis tests, regression analysis). The section concludes with a collective discussion and interpretation of findings.

5.1. Descriptive Statistics

5.1.1. Overall Sample (N = 607)

Table 5.1 shows the analysis results of the attributes of the flextime and traditional subsamples within the overall dataset (N = 607).

Table 5.1 Data attributes of the overall sample (N = 607)

	FLEXTIME	TRADITIONAL
No. of projects	34 (5.6%)	573 (94.4%)
Total contract value	\$ 57,020,977.30 (0.94%)	\$ 6,016,324,572.34 (99.06%)
<u>Median</u> award amount	\$ 998,786.76	\$ 5,334,770.46
<u>Median</u> contract time	360 calendar days	455 calendar days
<u>Mean</u> no. of bidders	6.65	3.60
<u>Mean</u> award growth	-5.27%	-2.07%

A few observations could be made in Table 5.1. Firstly, flextime projects constitute less than 1% of the total contract value, with a median award amount of

slightly less than \$ 1 million. Secondly, the average number of bidders on flextime projects is close to double than that of traditional projects. Lastly, while both flextime and traditional projects demonstrated a mean award growth of negative value, the average award growth of flextime projects is more than twice as lower than that of traditional projects. A negative award growth indicates that the winning bid is less than the engineer's estimate. From the perspective of a contracting agency (e.g., a DOT), lower (more negative value) award growth is generally better.

Table 5.2 summarizes the proportions of projects that received one, two, three and more than three bidders whereas Figure 5-1 offers a more detailed look at the distribution of the number of bidders. The histogram in Figure 5-1 shows that NCDOT received as low as one bidder to as many as 13 bidders on a project let between 2015 and 2019. The mode of the distribution is two bidders, constituting more than 30% of the total number of projects let in these 5 years period. Another important observation that can be made from Table 5.2 is that the majority (56.8%) of the projects received three or fewer bids, with single-bid projects made up close to 6% of the total number of projects.

Table 5.2 Number of bidders (N = 607)

NO. OF BIDDERS	FREQUENCY	PERCENTAGE (%)
1	36	5.9
2	194	32.0
3	115	18.9
4 and above	262	43.2
SUBTOTAL	607	100

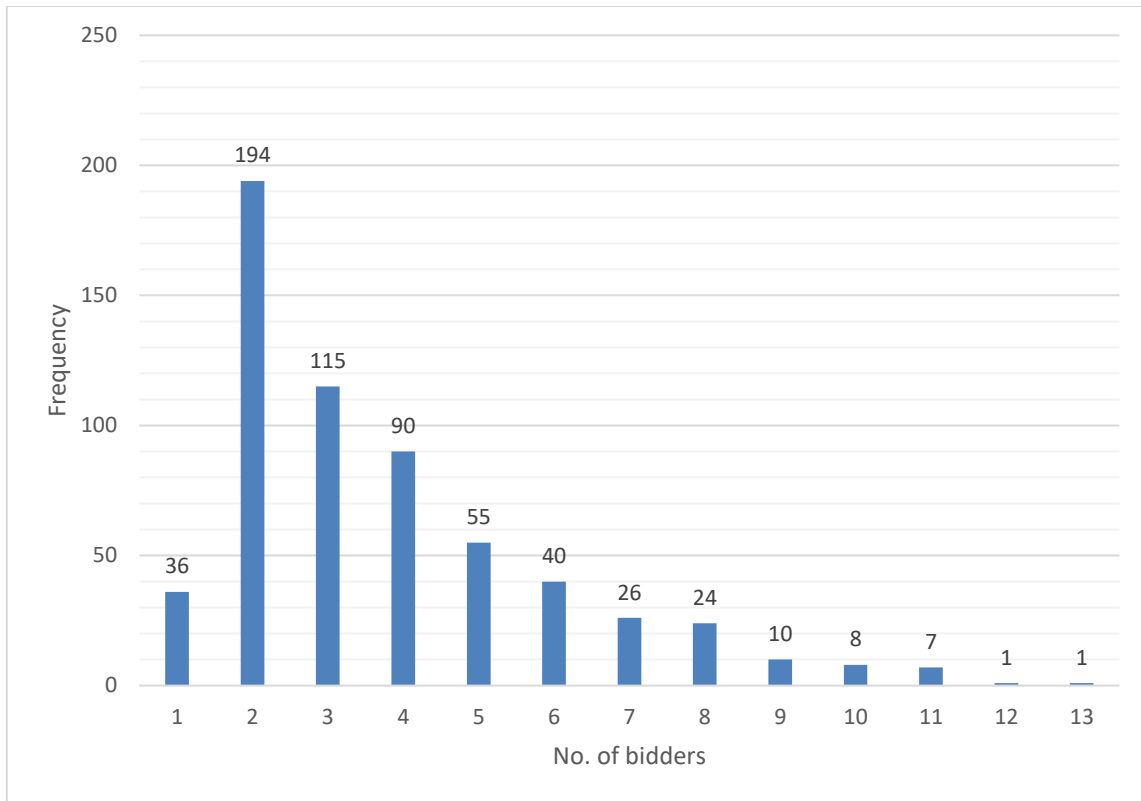


Figure 5-1 Distribution of the number of bidders (N = 607)

Figure 5-2 depicts the breakdown of the number of bidders by major work types. Approximately 43% of projects with 2 bidders involved “milling, resurfacing, shoulder reconstruction and other” works. Another work type that was deemed to be seriously impacted by lack of competition is “milling, resurfacing and shoulder reconstruction” – constituting more than 25% of all single-bid projects. Note that both project types were highly similar in which they both have major activities such as milling, resurfacing and shoulder reconstruction.

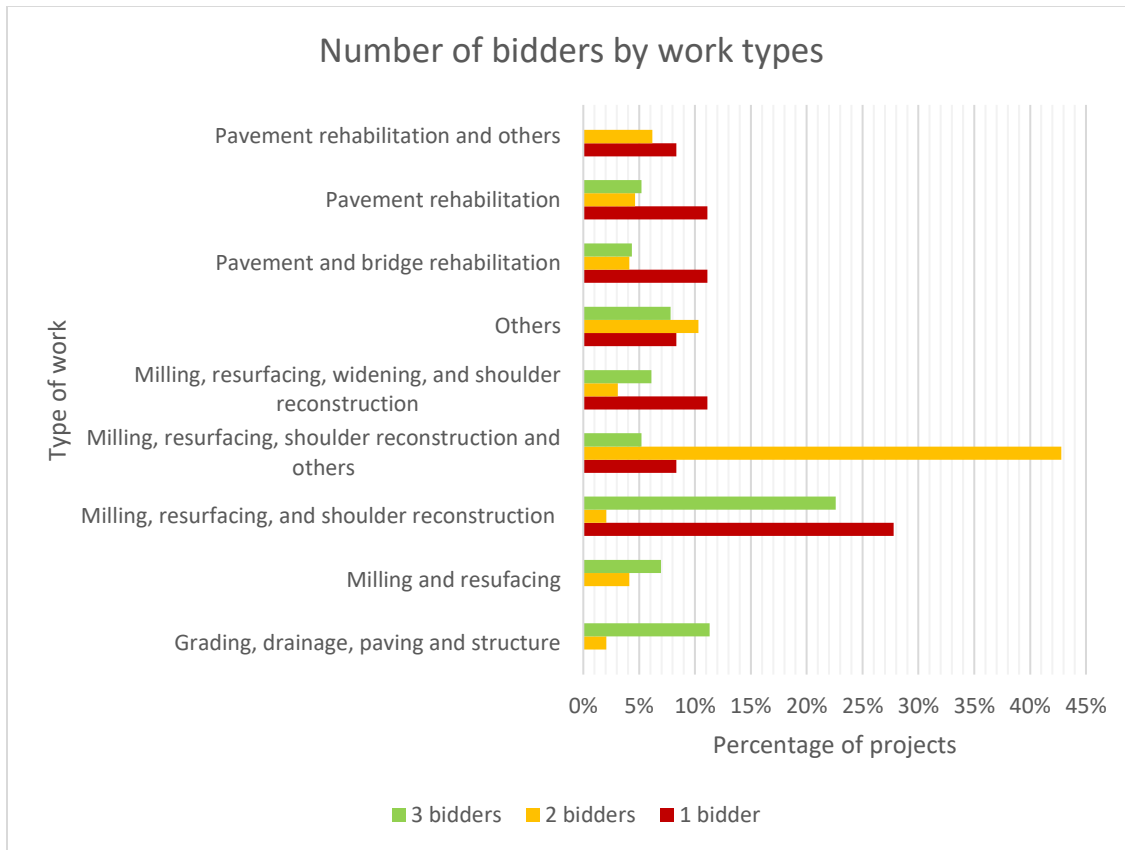


Figure 5-2 Types of work with the least number of bidders

5.1.2. Flextime Subsample (N = 34)

A total of 34 flextime projects were identified from the overall sample. Note that 3 flextime projects had been excluded from this study during the data cleaning stage. One flextime project was removed because the project was procured using the A+B technique. The usage of two alternative contracting techniques (A+B and flexible NTP provision) in a single project might yield inconclusive results for this study as it would be challenging to attribute any observed difference in project performance to a specific contracting technique. Besides, two projects with the flexible starting date were also

discarded from the sample because the completion date of these two projects was both fixed to a specific date (i.e., did not depend on the start date). Because there exists a theoretical minimum number of days required to complete all work items in a construction project, having a fixed completion date means that the winning contractor may potentially lose a certain amount of flexibility in scheduling the project's start date, which partially defeats the purpose of flexible NTP provision.

Table 5.3 presents the different types of work present in the flextime subsample. A large majority (82.4%) of flextime projects involved “grading, drainage, paving and structure” work. Although not specifically written anywhere on the bid documents, based on the description of project location, it was deduced that this “grading, drainage, paving and structure” work type is most likely referring to bridge replacement work.

Table 5.3 Flextime projects types of work

TYPE OF WORK	COUNT	PERCENTAGE (%)
Grading, Drainage, Paving and Structure	28	82.4
Grading, Drainage, Paving, Signing and Structure	1	2.9
Grading, Drainage, Paving and Culvert	2	5.9
Bridge Preservation	2	5.9
Pavement Rehabilitation	1	2.9
SUBTOTAL	34	100

Table 5.4 describes the award price distribution of the flextime subsample. The minimum award price was \$ 488,292.05 whereas the maximum award price was \$

9,699,053.68. Despite the huge range in award price (about \$ 9.2 million), the distribution is discovered to be heavily skewed as 75% of the flextime projects were priced at \$ 1,204,218.81 or lower.

Table 5.4 Award price distribution for flextime projects (N = 34)

STATISTICS	AWARD PRICE (\$)
Minimum	\$ 488,292.05
25% Percentile (1 st quartile)	\$ 726,499.10
Median	\$ 998,786.76
75% Percentile (3 rd quartile)	\$ 1,204,218.81
Maximum	\$ 9,699,053.68

5.1.3. Paired Sample (N = 15 pairs)

Table 5.5 shows the analysis of the attributes of the flextime and traditional subsamples within the paired sample set. For each data attribute in Table 5.5, the median, instead of the mean, was calculated and tabulated because the median is generally agreed to be more robust to outliers in measuring the central tendency of a dataset (Diez et al. 2019).

The proposal length of flextime projects varied between 0.047 miles and 0.237 miles, and the traditional projects' length varied between 0.050 miles and 0.232 miles. The noticeable short project length (less than 1 mile) is due to the fact that all 30 projects within this paired sample were minor bridge replacement project (grading, drainage, paving and structure). The minimum and maximum contract time for a flextime project

were 300 and 615 days, respectively. The minimum and maximum contract time for a traditional project were 304 and 625 days, respectively. The median award price in both flextime and traditional subsamples were \$ 798,288.00 and \$ 865,012.55, respectively.

Table 5.5 Data attributes of the paired sample (N = 15 pairs)

DATA ATTRIBUTES	STATISTICS	FLEXTIME (N=15)	TRADITIONAL (N=15)
Proposal length (miles)	Minimum	0.047	0.050
	Median	0.118	0.116
	Maximum	0.237	0.232
Contract time (calendar days)	Minimum	300	304
	Median	360	370
	Maximum	615	625
Award price (US dollars)	Minimum	\$ 488,292.05	\$ 575,682.56
	Median	\$ 798,288.00	\$ 865,012.55
	Maximum	\$ 2,324,232.00	\$ 1,638,000.00

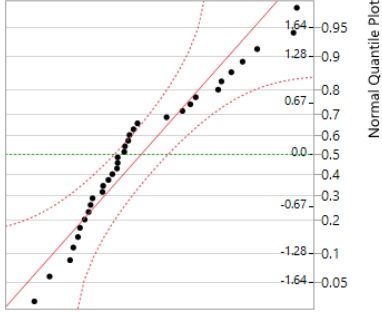
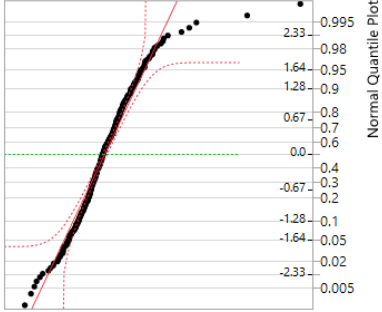
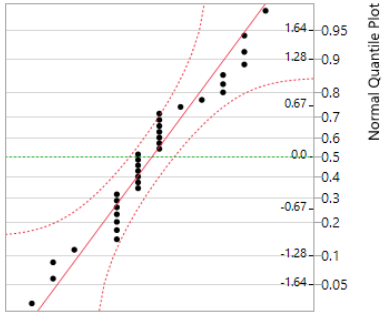
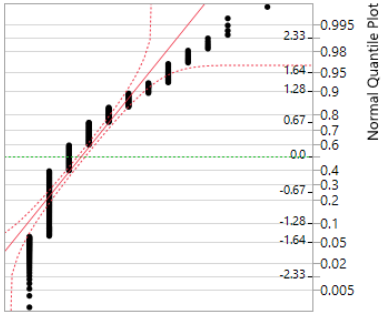
5.2. Inferential Statistics

5.2.1. Overall Sample (N = 607)

Table 5.1 shows on average, flextime projects received a higher number of bidders and lower (more negative) award growth. To assess the validity of these observations, hypothesis tests were conducted. However, before proceeding with statistical tests, the data for the award growth and number of bidders of flextime and traditional projects were checked for normality.

Table 5.6 tabulates the result of Shapiro-Wilk test, accompanied by the normal quantile plot for each sub-distribution. Except for the number of bidders from the flextime group, it was concluded that the other three sub-distributions were not normally distributed since their respective p-value for the Shapiro-Wilk test was calculated to be less than 0.05. Similarly, normal quantile plots show a noticeable deviation of data points from the 45° line in all sub-distributions, aside from traditional projects' award growth. Although the majority of the points closely follow the 45° line, huge deviations (i.e., outliers) were observed around the upper tail of the distribution of traditional project's award growth.

Table 5.6 Normality of award growth and number of bidders of flextime (N=34) and traditional project (N = 573)

PERFORMANCE METRIC	P-VALUE (SHAPIRO-WILK TEST)	
	Flextime (N = 34)	Traditional (N = 573)
Award growth	 <p>0.0153 ^a</p>	 <p>< 0.0001 ^a</p>
Number of bidders	 <p>0.0890</p>	 <p>< 0.0001 ^a</p>

^a Statistically significant ($p < 0.05$)

The normality analysis in Table 5.6 suggests the usage of Wilcoxon rank-sum test, a non-parametric version of the independent two-sample t-test, for both performance metrics. While the Wilcoxon rank-sum test does not require the normality assumption, it does assume that the two populations have roughly identical distribution shape. To verify the compliance with this assumption, histograms of these 4 sub-distributions were plotted and tabulated in Table 5.7.

Table 5.7 Histogram of award growth and number of bidders of flextime (N=34) and traditional project (N = 573)

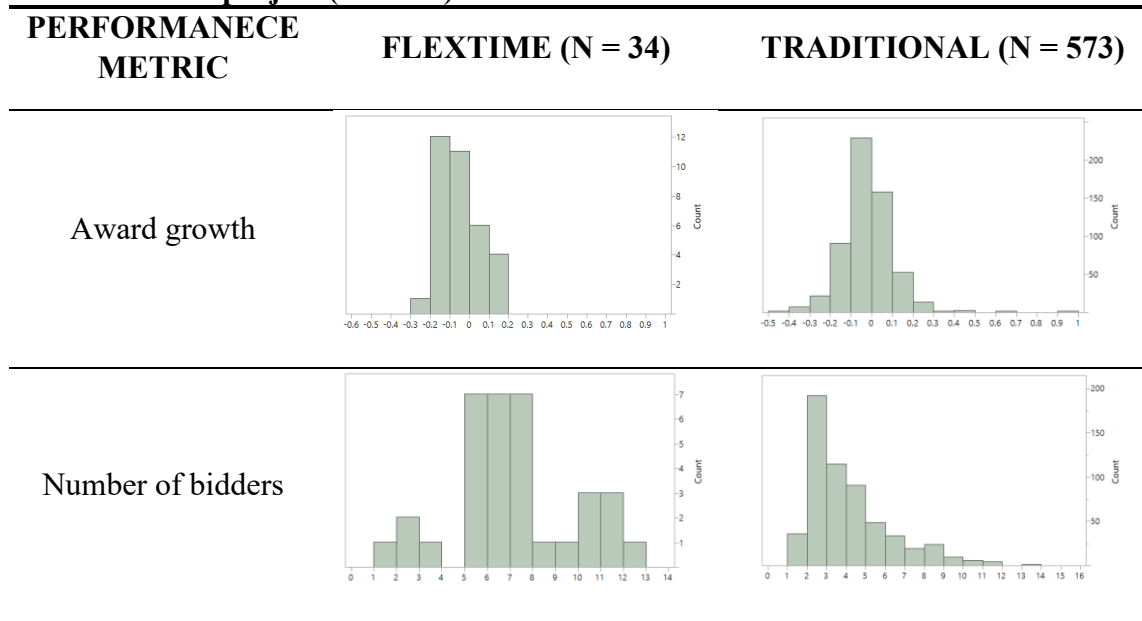


Table 5.7 shows that for award growth, both subsamples have roughly similar distribution shape, thus it is appropriate to use Wilcoxon rank-sum test to determine if the difference in award growth between traditional projects and flextime projects was statistically significant. For number of bidders, the distribution of flextime subsample is different from that of traditional subsample. There is no notable skewness in the distribution of flextime subsample (bottom left plot in Table 5.7), and the distribution looks fairly symmetrical. On the other hand, a long right tail is clearly visible in the traditional subsample (bottom right plot in Table 5.7), suggesting the distribution is right-skewed (not symmetric). Nonetheless, since the traditional subsample has large sample size ($n = 573$), the Central Limit Theorem will ensure that the distribution of sample mean is close to normal. Hence, independent two-sample t-test is thought to be

the more appropriate test to detect the difference in the number of bidders between flextime and traditional projects. Table 5.8 displays the test results.

Table 5.8 Mean performance results (N = 607)

PERFORMANCE METRIC	FLEXTIME MEAN (N =34)	TRADITIONAL MEAN (N = 573)	P-VALUE	TEST
Award growth	-5.27%	-2.07%	0.0344 * ^a	Wilcoxon rank-sum test* (two-sided)
Number of bidders	6.65	3.60	< 0.0001 ^a	Independent two-sample t-test (two-sided)

* with normal approximation

^a Statistically significant ($p < 0.05$)

The mean award growth for flextime projects was – 5.27%, compared to - 2.07% for traditional projects. The 3.2% difference between the two project groups was determined to be significant ($p = 0.03$). The mean number of bidders for flextime projects was 6.65, whereas the mean for traditional projects was 3.60. Since the p-value was calculated to be less than 0.0001, there is strong evidence in the data that suggests the mean number of bidders for flextime projects is significantly different from that of traditional projects.

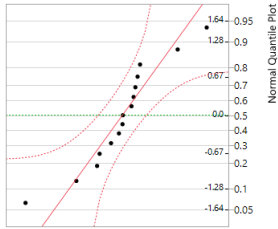
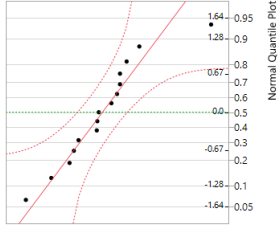
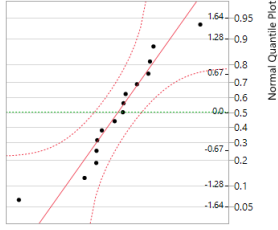
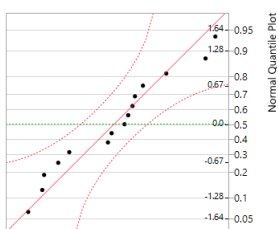
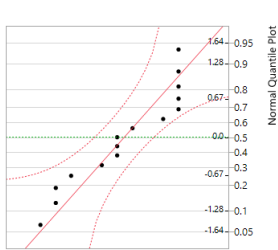
5.2.2. Paired Sample (N = 15 pairs)

The comparison analysis performed on the overall dataset (N = 607) (Table 5.8), while yielding seemingly promising findings, might suffered from a few flaws. Firstly,

the size of the flextime subsample ($n = 34$) is disproportionately smaller than that of traditional subsample ($n = 573$). Secondly, the type of work differs significantly within and between the two groups. The traditional group contained projects with miscellaneous types of work that do not exist in the flextime group. These miscellaneous work types include construction of ferry vessel, Intelligent Transportation System (ITS) works, pavement markings, etc. Furthermore, the proportion of work type within each group also differs significantly. For example, there was no flextime projects of work type “milling, resurfacing and shoulder reconstruction”, which constitutes close to 25% of traditional projects. Similarly, while “grading, drainage, paving and structure” work type accounted for more than 80% of flextime projects, only 16% of the traditional projects were of this work type. Hence, to increase the confidence that the results of the study were valid and accurate, the analysis was conducted on one specific work type by establishing project pairs (equal sample size) using a hierarchical clustering method.

To determine which statistical test is more appropriate, Shapiro-Wilk test was performed on the paired difference in contract time, engineer’s estimate, award price, award growth and number of bidders. The results and the normal quantile plots were tabulated in Table 5.9.

Table 5.9 Normality of paired difference in various performance metrics

PERFORMANCE METRIC	P-VALUE (SHAPIRO- WILK TEST)	NORMAL QUANTILE PLOT
Contract time (calendar days)	0.3507	
Engineer's estimate (\$)	0.3884	
Award price (\$)	0.3958	
Award growth (%)	0.4963	
Number of bidders	0.0354 ^a	

^a Statistically significant ($p < 0.05$)

Based on Table 5.9, it was deduced that all paired differences were normally distributed, except for number of bidders. Thus, paired t-tests would be used to test the difference in contract time, engineer's estimate, award price and award growth. For number of bidders, the histogram of the paired differences was plotted (Figure 5-3) to see whether the distribution is roughly symmetric prior to using the Wilcoxon signed rank test. A significant left skew (i.e., asymmetric) was observed in Figure 5-3, which violates the underlying assumption of Wilcoxon signed rank test. Since there exists certain assumption violation in both the paired t-test and the Wilcoxon signed rank test, both tests would be performed, and their results (i.e., p-values) would be interpreted with extra caution.

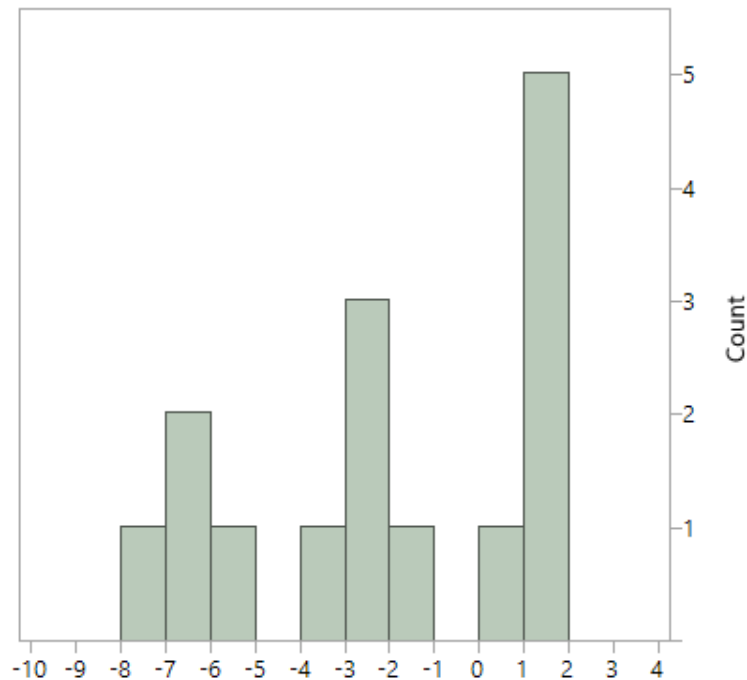


Figure 5-3 Histogram of the paired difference in number of bidders (N = 15)

Since multiple statistical tests would be performed on the same data set (i.e., the paired sample), a Bonferroni correction was adopted to reduce the chance of false-positives (i.e., detecting statistical significance when the null hypothesis is actually true) (McEwan 2018). This correction involved reducing the initial statistical significance level (5%) – by dividing it by the total number of tests. There were five performance metrics of interest in this study, which would correspond to 5 separate statistical tests. The new cutoff statistical significance level becomes 1%. Therefore, for this particular section of this study, statistical significance is only found when the p-value is less than 0.01.

Table 5.10 summarizes the results of the hypothesis testing conducted on all five-performance metrics. All p-values were obtained using paired t-test unless noted otherwise. Note that the significance level has been reduced to 1% as a result of Bonferroni correction.

Table 5.10 Mean performance results (paired sample)

PERFORMANCE METRIC	MEAN, μ			P-VALUE
	Flextime (N = 15)	Traditional (N = 15)	Difference (Trad – Flex)	
Contract time (calendar days)	377.00	391.73	14.73	0.3143
Engineer's estimate (\$)	\$ 976,123.88	\$ 980,632.34	\$ 4,508.47	0.4755
Award price (\$)	\$ 923,985.49	\$ 930,352.76	\$ 6,367.27	0.4659
Award growth (%)	- 6.79 %	- 4.79 %	2.01 %	0.2093
Number of bidders	7.67	5.13	-2.53	0.0076 ^a 0.0052 ^{*a}

^a Statistically significant ($p < 0.01$)

* Wilcoxon signed rank test

5.2.2.1. Contract Time

The average contract time for flextime projects was 377 days, compared to approximately 392 days for traditional projects, which amounted a mean difference of about 15 days. The p-value was calculated to be 0.31, which means there is 31% chance that the difference in contract time is purely coincidental. Since the p-value is greater than 0.01, the null hypothesis cannot be rejected. There is an insufficient amount of evidence in this sample to suggest the mean contract time of flextime projects is significantly shorter than that of traditional projects.

5.2.2.2. Engineer's Estimate

The mean engineer's estimate for flextime projects was \$ 976,123.88, whereas the mean for traditional projects was \$ 980,632.34. However, this mean difference (\$ 4,508.47) was discovered to be not significant ($p = 0.48$). The analysis failed to reject the null hypothesis. There is no ample evidence at the 1% significance level in this sample to suggest the mean engineer's estimate of flextime projects is lower than of traditional projects. This means that, based on this sample, the inclusion of flexible NTP provision does not seem to have any influence on the estimated cost of a project.

5.2.2.3. Award Price

The mean award price of flextime projects (\$ 923,985.49) is lower than that of traditional projects (\$ 930,352.76). Nonetheless, the mean difference of \$ 6,367.27 was determined to be not significant ($p = 0.47$). Since the p-value is greater than 0.01, the test failed to reject the null hypothesis. There is no evidence at the 1% significance level to support the alternate hypothesis that the mean award price of flextime projects is lower than that of traditional projects. In other words, data from this sample does not indicate that the inclusion of flexible NTP provision is able to reduce award price.

5.2.2.4. Award Growth

The mean award growth of flextime projects was -6.79% , whereas the mean for traditional projects was -4.79% . The mean difference of 2.01% was determined to be not significant ($p = 0.21$), indicating that there is 21% probability that this difference is a result of random occurrence under the assumption that there is no difference in award growth between the two project groups. Since the p-value is greater than 0.01, the null

hypothesis could not be rejected. There is insufficient evidence in the data at 1% significance level to demonstrate that the mean award growth of flextime projects is lower (more negative) than that of traditional projects.

5.2.2.5. Number of bidders

The average number of bidders for flextime projects was 7.67, compared to 5.13 for traditional projects. The p-value obtained from paired t-test and Wilcoxon signed rank test were 0.0052 and 0.0076, respectively. Notice that both p-values are lower than the adjusted significance level of 0.01, which means the null hypothesis for each of the two tests was rejected. Since both the normal and the robust tests indicated statistical significance ($p < 0.01$), even after the significance level has been adjusted (more conservative) to account for multiple testing, it is safe to say that on average, flextime projects attract more bidders than traditional projects. This finding aligns with the industry's perception that flexible NTP provision improves bidding competition.

5.2.3. Effect of NTP Window

The NTP window is a timeframe in which a contractor that is involved in a flextime project, can freely select any date within this timeframe to commence work. It is defined in this study as the number of calendar days between the earliest date that a contractor could start work and the latest date the contractor must begin work. The formula to calculate NTP window is presented below:

$$NTP \text{ window (in calendar days)} = Latest \text{ start date} - Earliest \text{ start date}$$

In addition to investigating the impact of the inclusion of flexible NTP provision, one of the goals of this study is to evaluate the effect of the length of NTP window on

project performance. Instead of solely analyzing the inclusion of flexible NTP provision as a binary input (i.e., yes or no), this section is more interested to see whether a project's performance could be further augmented (or diminished) by varying the amount of scheduling flexibility given to contractors, as measured by the length of NTP window.

To ensure data homogeneity, the subsample set which contained 25 flextime projects involving “grading, drainage, paving and structure” work over moving water body (called “flextime bridge project” hereafter) was analyzed. Table 5.11 presents the descriptive statistics of NTP window of this particular sample.

Table 5.11 Distribution attributes of NTP window (N =25)

STATISTICS	NTP WINDOW (N = 25)	
	No. of calendar days	No. of months*
Minimum	45	1.5
Median	108	3.6
Maximum	241	8.03
Mean	121.48	4.05

* Assume 1 month = 30 calendar days

Table 5.11 shows that, out of the 25 flextime bridge projects, the length of NTP window varied between 45 days (1.5 months) and 241 days (8.03 months), with a median of 108 days (3.6 months). The average length of NTP window was about 121 days (4.05 months). The vast range (196 days or 6.5 months) clearly indicates that NCDOT did not utilize a standard length for specifying the NTP window. This

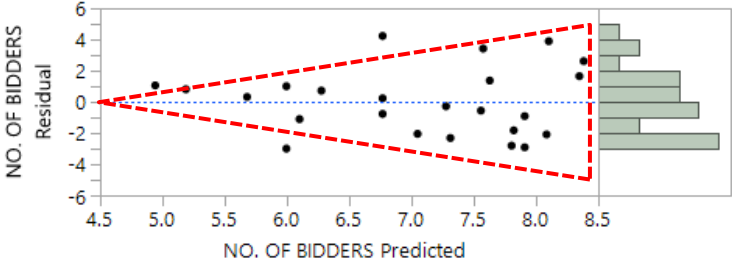
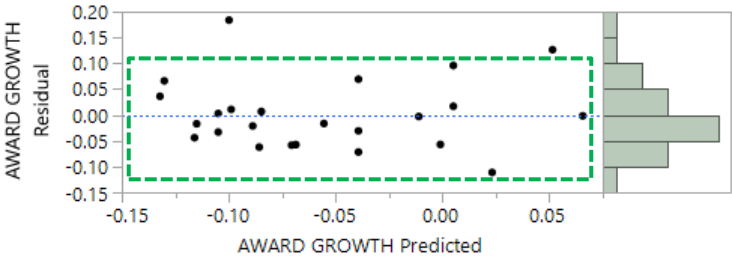
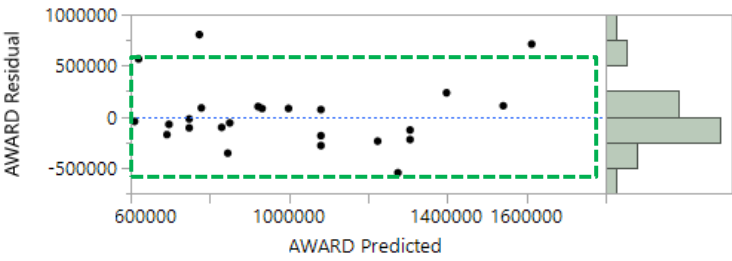
variability in administering the NTP window supports the worthiness to study whether there would be any correlation between the length of the NTP window and project performance.

For this research question, the performance metrics of interest were the number of bidders, award growth and award price. For each performance metric, assumptions on the linear regression model were checked, specifically on the normality and heteroscedasticity (i.e., non-constant variance) of errors. This was done by generating two different residuals (an estimate for the actual unknown true error) plots - residuals versus predicted values and normal quantile plot of residuals.

The former plot was used to visually identify the heteroscedasticity of residuals. If the model is correct, the residuals tend to randomly distribute about zero. If the plot shows an apparent pattern or structure of variation (e.g. fanning or funneling), this is an indication that the constant error variance assumption is violated.

Table 5.12 shows the residual versus predicted plots of all three performance metrics. For both award growth and award price, the residuals roughly form a “horizontal band” around the zero lines, suggesting that the variances of the residuals are equal. However, for the number of bidders, it is observed that the residuals “fan-out” from left to right, exhibiting a gradual widening as the predicted value increases. Thus, it can be deduced that the errors do not have a constant variance for the number of bidders.

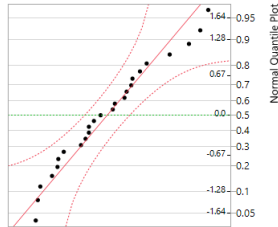
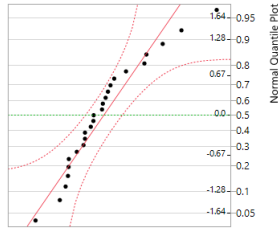
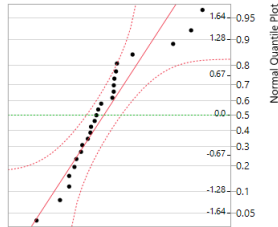
Table 5.12 Checking heteroscedasticity of errors (original variables)

PERFORMANCE	RESIDUALS VS. PREDICTED VALUES PLOT	
METRIC		
Number of bidders		
Award growth (%)		
Award price (\$)		

The normality of residuals was assessed a using normal quantile plot, supplemented with a formal normality test - the Shapiro-Wilk test. Table 5.13 presents the normality analysis of the residuals for the number of bidders, award growth, and award price. Results from the Shapiro-Wilk test indicated that except for award price,

the residuals of the other two performance metrics were determined to be normally distributed.

Table 5.13 Checking normality of errors (original variables)

PERFORMANCE METRIC	P-VALUE (SHAPIRO-WILK TEST)	NORMAL QUANTILE PLOT OF RESIDUALS
Number of bidders	0.3007	
Award growth (%)	0.0736	
Award price (\$)	0.0166 ^a	

^a Statistically significant ($p < 0.05$)

To rectify assumption violations, data transformations were performed on the number of bidders and award price. In the case of number of bidders, both X (NTP window) and Y variables (number of bidders) undergone log (natural logarithm)

transformations. In the case of award price, log transformation (i.e., natural logarithm) was performed only on the Y variable (award price).

Assumptions were evaluated once again after regressions were performed on the transformed variables. Table 5.14 shows that the constant error variance assumption was satisfied for both performance metrics since no distinct variation could be identified from their respective residuals versus predicted values plot. Table 5.15 shows that the residuals for the number of bidders are normally distributed whereas the residuals for award price are still determined to be not normally distributed. Despite undergoing data transformation, the condition that the error terms are normally distributed is still not met in the case of award price. Nonetheless, according to Penn State Department of Statistics (2018), the hypothesis test for slope parameters B_1 is “fairly robust against departures from normality”. Since this study is more concerned in investigating the existence of a linear correlation between length of NTP window and project performance, rather than predicting a future response (i.e., a performance value), the violation of this assumption was thought to be less profound (i.e., more forgiving) for this particular research question.

Table 5.14 Checking heteroscedasticity of errors (transformed variables)

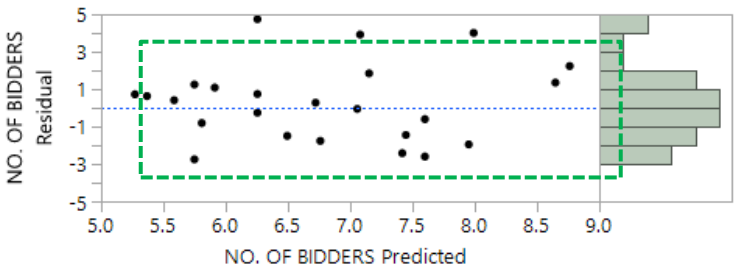
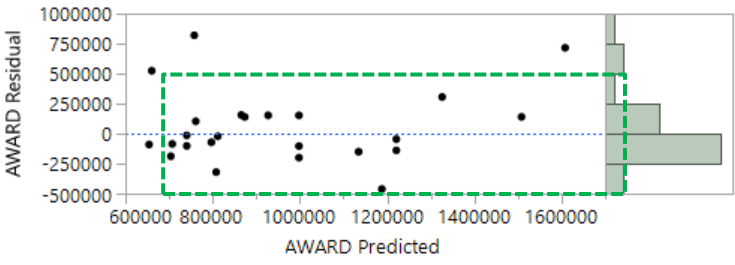
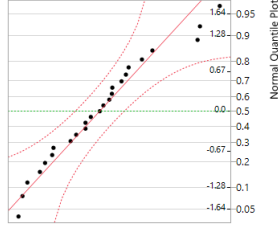
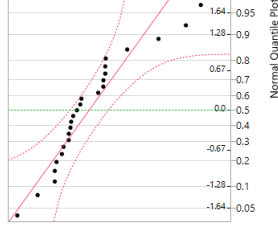
PERFORMANCE	
METRIC	RESIDUALS VS. PREDICTED VALUES PLOT
Number of bidders	
Award price (\$)	

Table 5.15 Checking normality of errors (transformed variables)

PERFORMANCE METRIC	P-VALUE (SHAPIRO-WILK TEST)	NORMAL QUANTILE PLOT OF RESIDUALS
Number of bidders	0.3168	
Award price (\$)	0.0166 ^a	

^a Statistically significant ($p < 0.05$)

In addition to checking the normality and heteroscedasticity of residuals, some diagnostic tests were also performed for each regression model to identify any unusual observations that would affect the model's accuracy. For each performance metric, the leverage value, Cook's distance and standardized residual of all 25 data points were evaluated. Based on these diagnostic measures, no data point was found to have undue influence on any of the three regression models. Hence, no data point was deemed necessary to be removed from the sample set.

Table 5.16 presents the results of linear regression analysis between length of NTP window and three performance metrics (number of bidders, award growth and award price), after data transformations were made. Note that no data transformation

was performed on award growth since both the normality and heteroscedasticity of errors assumptions were not violated.

Table 5.16 Linear regression analysis on length of NTP window

PERFORMANCE METRIC	LINEAR FIT		SLOPE PARAMETER, B_1		
	Coefficient of Determination (R^2)	Correlation coefficient (r)	Estimate	P-value	H_{alt}
Number of bidders *	0.202	- 0.449	-0.302807	0.0122 ^a	$\beta_1 < 0$
Award growth	0.416	0.645	0.0010091	0.0003 ^a	$\beta_1 > 0$
Award price * ^b	0.443	0.666	0.0045897	0.0002 ^a	$\beta_1 > 0$

H_{alt} : Alternate Hypothesis

^a Statistically significant ($p < 0.05$)

^b Errors are not normally distributed

* Undergone log transformation

Findings revealed that there is a weak linear correlation ($R^2 = 0.44$) between length of NTP window and the natural logarithm of award price. The right plot in Figure 5-4 depicts a trend in which projects with higher award price were often associated with longer NTP window. Note that the regression line in the right plot of Figure 5-4 is curved (i.e., not linear) because the vertical axis represents the original values of the variable (award price), not the log-transformed values. The p-value for the null hypothesis slope parameter ≤ 0 is calculated to be 0.0002. Since the p-value is less than 0.05, the null hypothesis is rejected and there is convincing evidence in the data to suggest that the natural logarithm of award price and length of NTP window are

positively correlated price (see the left plot of Figure 5-4). Using award price as a proxy for project complexity/scale, this means that NCDOT was offering wider NTP windows for larger, more complex projects.

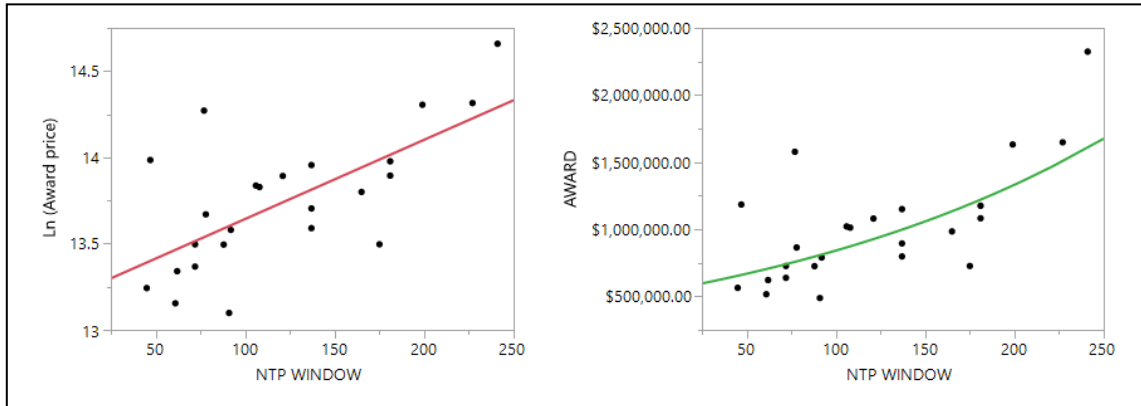


Figure 5-4 Award price versus NTP window (N = 25)

A weak linear correlation ($R^2 = 0.42$) is discovered between the length of the NTP window and the award growth. The p-value for the null hypothesis slope parameter ≤ 0 is calculated to be 0.0003. Since the p-value is less than 0.05, there is strong evidence suggesting that the true slope parameter (change in award growth per unit change in NTP window) is greater than zero – a positive linear relationship between the two variables. Figure 5-5 shows that the award growth increases (from negative values to positive values) as the length of the NTP window increases.

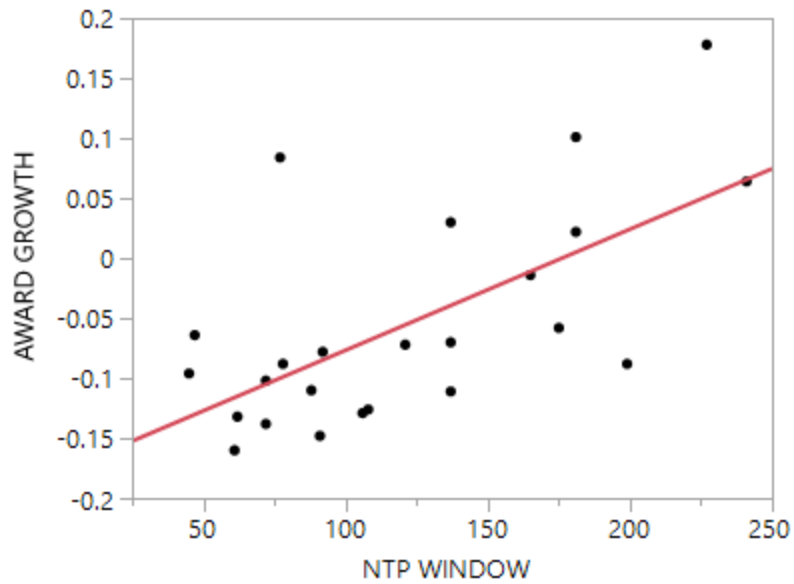


Figure 5-5 Award growth versus NTP window (N = 25)

Lastly, regression analysis showed an interesting finding in which a negative linear correlation is found between the natural logarithm of length of NTP window and the natural logarithm of the number of bidders (see the left plot of Figure 5-6). However, because the correlation is determined to be very weak ($R^2 = 0.20$), it is safe to say that there is no significant relationship between the length of an NTP window and the number of bidders.

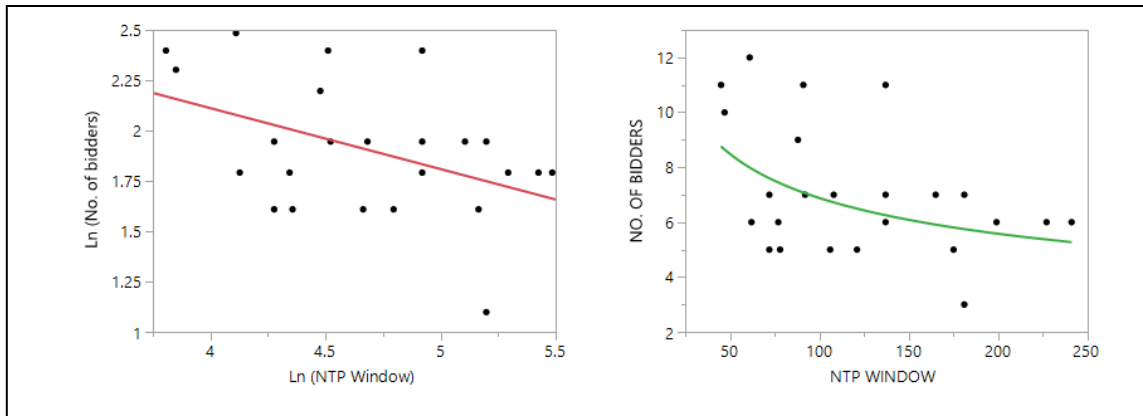


Figure 5-6 Number of bidders versus NTP window (N = 25)

5.3. Discussion

Figure 5-7 illustrates the research methodology used in this study whereas Figure 5-8 summarizes some of the important findings discovered by this study.

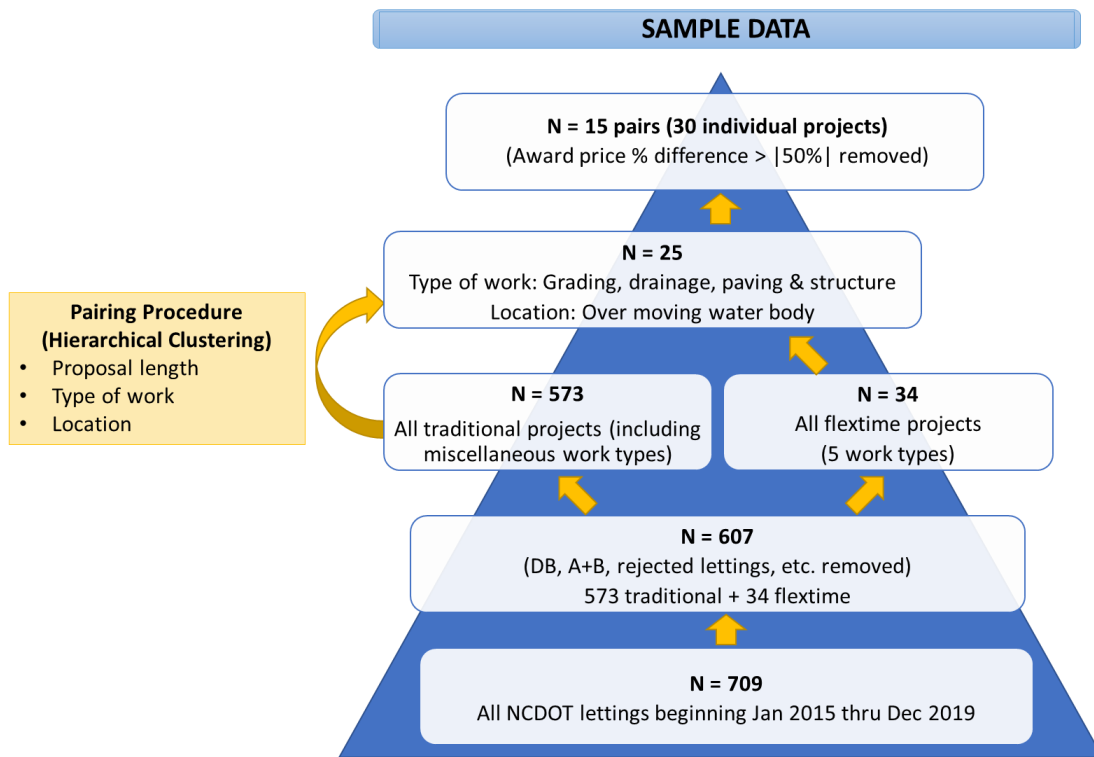


Figure 5-7 Methodology summary

SAMPLE SET	FINDINGS
N = 30 (15 Paired samples)	<ul style="list-style-type: none"> • Flextime has higher number of bidders ($p < 0.01$) • No significant difference is found between flextime and traditional with regards to engineer's estimate, award price, award growth and contract time.
N = 25 (Flextime bridge projects)	<ul style="list-style-type: none"> • Award growth increases with length of NTP window ($R^2 = 0.42$) . • No correlation between length of NTP window and no. of bidders ($R^2 = 0.20$). • Projects with higher award price are associated with longer NTP window ($R^2 = 0.44$).
N = 34 (Flextime projects)	<ul style="list-style-type: none"> • 82.4% of flextime projects are of "grading, drainage, paving and structure" work type.
N = 607 (All projects)	<ul style="list-style-type: none"> • 32.0 % (mode) received 2 bids. • Significant difference ($p < 0.0001$) in no. of bidders between flextime & traditional • Mean award growth is lower (more negative) in flextime ($p = 0.03$)

Figure 5-8 Results summary

Descriptive statistics on the overall dataset indicated that NCDOT might be facing challenges, to some extent, in attracting bidders for their projects. This was based on the findings that more than half (56.8%) of the projects let between 2015 and 2019 received three or fewer bids, with two bids being the most common number of bidders. This issue of lack of competition was found to be particularly pronounced on projects that involved milling, resurfacing and shoulder reconstruction work (Figure 5-2). These results were consistent with the market survey performed by FHWA and AASHTO (2012) in which asphalt resurfacing projects were reported to have the highest percentage of single-bid contracts.

In addition, this study investigated the state of practice of flexible NTP provision in NCDOT. Although NCDOT was regarded as one of the few state DOTs that have experience in administering the flexible NTP provision, the sample data seems to suggest that this alternative contracting technique is still in its experimental phase. Firstly, low implementation frequency was observed - only about 6% of the 607 low-bid projects were flextime projects. Secondly, flexible NTP provision was predominantly utilized on small projects, with 75% of flextime projects cost below \$ 1.2 million. Another interesting finding was that 82.4 % of NCDOT's flextime projects were of "grading, drainage, paving and structure" work type. This may suggest that this work type was thought, at least for NCDOT, to be a great candidate to implement the flexible NTP provision. It was an interesting finding that none of the 34 flextime projects involved "milling, resurfacing, and shoulder reconstruction" work, even though this

particular type of project was found to be plagued with the problem of lack of competition.

Results from performance analysis pointed out that the inclusion of the flexible NTP provision can improve bidding competition. The 95% confidence interval for the mean paired difference in number of bidders is $[-0.70, -4.37]$, which means flextime projects, on average, can attract approximately one to four more bidders than traditional projects. This confidence interval should be interpreted with extra caution since the sample size is small ($n = 15$) and the sample distribution is not normal. Nonetheless, statistical tests conducted on both the overall sample set ($N = 607$) and the paired data set ($N = 15$ pairs) have demonstrated that, compared to traditional projects, flextime projects were able to attract a significantly higher number of bidders.

Regarding award growth, mixed results were obtained. Negative average award growth was observed on both project groups, though flextime projects consistently showed lower (more negative) award growth. Comparison analysis performed on the larger, all-inclusive sample set ($N = 607$) revealed that the difference in award growth between flextime and traditional projects is statistically significant. However, statistical insignificance was found when a similar test was performed on the paired data set consisting of projects of a single work type. There was insufficient evidence at the 1% significance level ($p = 0.21$) to support the conjecture the award growth of flextime projects is lower (more negative) than that of traditional projects. Despite the lack of significance, the author would like to argue that an agency should not completely dismiss the ability of flexible NTP provision in reducing project cost. This is because

both sample sets have indicated flextime projects, on average, could secure an additional 2% to 3% of price savings than traditional projects could. It is believed that this extra savings are most likely caused by the increased bidding competition received in flextime projects.

On the other hand, the findings from the paired data showed that the mean values of award price and engineer's estimate of flextime projects were lower than those of traditional projects. However, none of these results were found to be statistically significant at the 1% significance level ($p \approx 47\%$). This indicates that, based on this sample, neither the initial cost estimated by NCDOT nor the award price is significantly influenced by the flexible NTP provision. As award growth is closely related to award price and engineer's estimate, these results were in accordance with the finding regarding award growth as the test also failed to detect any significant difference in terms of award growth among the two project groups at 1% significance level.

In terms of schedule performance, the mean contract time of flextime projects was shorter than that of traditional projects. However, the difference was determined to be not significant ($p = 0.31$). There was insufficient evidence at the 1% significance level to suggest that NCDOT was intentionally shortening the contract time of a project to account for the inclusion of flexible NTP provision. The added flexibility in scheduling a project start date is believed to have no direct influence on the duration required to complete the contract work. Stated in another way, if NCDOT initially estimates that a project would take 300 calendar days to complete, the time period given

to a contractor to finish the project will still be 300 calendar days regardless of whether the flexible NTP provision is incorporated into the contract or not.

Besides, the findings demonstrated that a longer NTP window does not attract more contractors to bid on a project, and it tends to negate the price-saving potential (i.e., award growth) of the flexible NTP provision. This was an interesting finding as it points to the possibility that offering the appropriate amount of scheduling flexibility is equally, if not, much critical than just giving utmost flexibility to contractors. One possible explanation for this phenomenon is that contractors may perceive the length of the NTP window to be proportional to the level of uncertainty associated with a project. It was also discovered that projects with higher award prices are more likely to be associated with longer NTP windows. This correlation is in line with the belief that large or complex projects may require contractors more time to complete off-site preparatory work such as finding the right subcontractor(s) or acquiring the right equipment/material. Hence, NCDOT might have established a longer NTP window to accommodate the potential increase in preparatory effort.

6. CONCLUSIONS

6.1. Conclusions

This research analyzed 15 pairs of flextime and traditional projects administered by the North Carolina Department of Transportation (NCDOT) to quantitatively evaluate whether a benefit is derived from the inclusion of flexible NTP provisions for these projects. Five performance metrics were chosen for investigation and they are the number of bidders, contract time, award price, engineer's estimate and award growth.

The findings from this study convincingly showed that flextime projects were able to attract a significantly higher number of bidders. Besides, an analysis of paired sample showed that the mean values of award growth, award price, engineer's estimate, and contract time of flextime projects were lower than that of traditional projects. However, the difference in these four performance measures was found to be not statistically significant at the 1% significance level.

This study also investigated the effect of the length of the NTP window on project performance. Based on a sample of 25 bridge projects, results indicated that projects with longer NTP windows did not necessarily receive a higher number of bidders. A positive correlation was also found between the length of the NTP window and the award growth.

The results of this study add to the current body of knowledge as it is the first study that empirically documents that flexible NTP provision is effective in attracting more contractors to bid on a project. This finding has significant implications for DOT

practitioners as it provides them with increased confidence in using this alternative contracting technique to improve bidding competition, which is a critical component in the successful implementation of the low-bid procurement strategy. Nonetheless, DOTs should be more cautious and thoughtful in determining the length of the NTP window as this study has alluded that a longer NTP window not only failed to increase the number of bidders, but it might also diminish the price-saving potential generated by this flexible NTP provision.

6.2. Recommendations

This study could be expanded to other state DOTs who utilize this alternative contracting technique to enhance the validation of statistical findings. Potential candidates include Washington State DOT, Florida DOT and Minnesota DOT. Alternatively, future research could examine the performance of flextime projects on other work types such as road resurfacing projects. In addition, future studies could assess the benefits of flexible NTP provision from the perspective of contractors who were involved in flextime projects. It would be worthwhile to evaluate the contractors' attitude towards this alternative contracting technique and to understand whether they actually take advantage of the NTP window. Finally, this study only compared 5 common performance measures (contract time, award price, engineer's estimate, award growth and number of bidders). Future studies may investigate different performance metrics such as change order-related metrics and traffic impact-related performance metrics to fully understand the implication of utilizing flexible NTP provision on transportation projects.

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