RESEARCH & DEVELOPMENT

Design of a Construction Expenditure Forecasting and Monitoring Tool for NCDOT Mega Projects

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16. Abstract

The research investigated how internal and external factors impact let date and construction start time change, and designed forecast model approaches to predict construction expenditures and monitor the performance for NCDOT projects of $50,000,000 or greater construction cost (Mega Projects). The research team developed an interview questionnaire and interviewed 23 NCDOT experts and contractors to identify the key problems and generate recommendations for improvement related to portfolio management, preconstruction phase, bidding phase, and construction phase. In addition, the research team has also identified checklists of major milestones to meet let dates and developed three model design concepts to better estimate construction payouts.

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EXECUTIVE SUMMARY

The project research goals were to investigate how internal and external factors impact let date and construction start time change, and study the design of a forecast model to predict construction expenditures and monitor the performance for NCDOT projects of $50,000,000 or greater construction cost (Mega Projects). Mega projects tend to make up nearly 50% of NCDOT's total construction expenditure although they are usually less than 10% of NCDOT's total project count. The estimated let dates and construction expenditures for these projects can vary significantly based on the type of project, work to be accomplished, and unpredicted events. When their let dates unexpectedly change, or when anything happens to impact their estimated schedule of payments, mega projects can have significant impact on the overall NCDOT financial management performance.

During the first quarter of this project the research team conducted a literature review of seven relevant studies to better understand causes for let date delays and research methodologies which have been developed to create payout prediction models for DOT projects. The seven studies are the Dye Management Report, the Performance Audit Report, the Roerden Study on Let Date Delay, PE Cost Trend Study by NC State, Mills and Tasaico Study on Construction Payments, the UNCC Study on the Impact of Funding Changes on Project Lettings, and the SAS Study on NCDOT Payout Curve Predictive Models.

The research team developed an interview questionnaire and interviewed 23 NCDOT experts and contractors. The key problems identified and the recommendations for improvement related to portfolio management, preconstruction phase, the bidding phase, and the construction phase are listed below.

In addition, the research team has also identified checklists of major milestones to meet let dates and investigated model design concepts to better estimate construction payout curves. The researchers focused on Design Bid Build (DBB) projects for the modeling studies because the data on Design Build (DB) projects were found to be limited and fragmented. Separate checklists of major milestones for DBB new location and widening projects were developed.

Based on the study of payout curve patterns of completed DBB Mega projects, the research team proposed three model designs covering both the preconstruction and construction phases.

1. Macro Approach during the preconstruction phase. This method is a "top down" approach that creates statistical models using cumulative construction payout data on past projects that have been normalized where the final cost and schedule basis is one hundred percent. Mathematical models were developed for two completed DBB projects showing a strong correlation to the actual values. In future work, standardized curves will be modeled for different project types, and they will be adjusted to the factors that apply to the forecasted projects based on location, seasonality, bid amount, duration, etc.

2. Micro Approach during the preconstruction phase. This method is a "bottom up" approach that builds the project payout curve based on the anticipated construction activities (e.g., mobilization, traffic control, excavation, etc.) and their associated unit costs. Data for this approach will come from detailed NCDOT project bid data from 2001 to 2014. Based on this database and on expert knowledge from NCDOT engineers, activity sequence,

characteristic, and quantities will be used to develop payout curves using construction cost, and schedule durations. Although more time consuming, this approach has the potential to create project payout curves that are more closely aligned to the actual project scope compared to the macro approach which uses data from projects with a similar scope. Additionally, as more data is acquired over time greater payout accuracy is obtained.

Summary of Key Findings from the Interviews

Phase	**No.**	**Problems Identified**	**Recommendations for Improvement**
Portfolio Management	1	Unbalanced lettings	Use "shelf projects" which are ready to go if money comes available. Good candidates are medium size projects.
Preconstruction Phase	2	Let date delay	Apply a "pencils down concept" when reaching the point for issuing permits: no scope change and no change in plans. Put someone in charge of coordinating all of the "pieces" (especially on DBB projects).
	3	Merger Process tends to hold up let dates	NCDOT should be more selective in use of the merger process.
	4	Scope Creep	NCDOT should develop better control of project cost in order to manage scope creep. Apply a "pencils down concept" when reaching the point for issuing permits. No scope change, and no change in plans before let date.
	5	ROW is done toward the end of preconstruction and sometimes gets squeezed on time	Get approval for ROW funds earlier to save time. Consider switching a DBB project to DB if there are problems with meeting ROW date.
	6	Railroads can cause delays related to plan approval	Initiate early railroad coordination.
	7	Permits are a major reason for project delays	Design can start in parallel with going forward with permits or ROW.
	8	Utility coordination and relocation issues	Plan and coordinate with various stakeholders a head of time to get utilities moved before construction begins.
Construction Phase	9	Delays caused by utilities, ROW, railroads, and permits	Minimize delays on permits, ROW, etc. Grant extensions on a yearly basis instead of at the end of the project. Provide quicker reviews and decisions on critical items.

3. Model design during the Construction Phase. This approach uses the contractor's estimated construction expenditure forecasts (both at the beginning of a project and quarterly during the project), which are based on the contractor's resource loaded schedule, to determine payout estimates. The NCDOT requests this forecasted payout information at the beginning of each mega project along with quarterly updates. The assumption is that the contractor has available to him all the material, labor, and equipment information needed to efficiently execute the project and anticipate its cash flow needs. However, it was discovered that many of the quarterly updates were not provided by the contractors to the NCDOT making it difficult to demonstrate the validity of this approach.

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1 INTRODUCTION

NCDOT Projects with a construction cost in excess of $50,000,000 comprise less than 10% of the centrally let projects awarded by NCDOT, but account for more than 50% of total construction expenditures. Current expenditure forecasting methods produce an aggregate forecast for all projects, using a limited set of available data to describe the projects: Scheduled Let Date, Estimated Construction Cost, and Project Type (Interstate, Rural, Urban and Bridge). Current models assume that the letting schedule will be met even though data demonstrates that there is significant variance in this schedule. Current models assume that construction will begin three months after the project is awarded regardless of the month of award and do not account for data that confirms there is a significant variation in this timeframe. It should be noted that an updated NCDOT model that addresses the letting variance and construction delay is being studied.

While gathering extensive data to predict expenditures for all active and future centrally let construction projects (usually in excess of one thousand projects) may not be practical, acquiring usable data on the approximately 100 projects of $50,000,000 or greater should be far more manageable. Extensive and detailed data exists that describes how these projects have performed in the past. There is a wealth of knowledge and experience within NCDOT and with highway contractors on how these projects behave. This knowledge and experience can identify data that predicts project performance.

The scope of this research project focuses on NCDOT mega projects (of $50,000,000 or greater in construction costs). The purpose of this research project was to identify factors, acquire and analyze data that predict project behavior, and design a forecast model that uses these data to accurately estimate future construction expenditures. Four main tasks to be completed in order to accomplish the goals of this study were:

1. Provide insights on the likelihood of meeting the let date. Identify internal and external factors that influence let date and determine their impact (e.g. funding, environmental permits, design, ROW, utilities, contract type, etc.) Identify possible corrective actions to meet letting schedule if problems arise.

2. Provide insights on the typical duration between let date and start of construction and the factors that impact this time period.

3. Investigate internal and external factors that affect the payout rate of mega construction projects (e.g., delayed entry due to utilities that have not yet been moved).

4. Design various model approaches that forecast construction expenditures based on individual project characteristics (project type, location, size, etc.) in the preconstruction and construction phases to improve the accuracy of current payout curve estimation.

2 LITERATURE REVIEW

2.1 Predicting Let Delay

A literature review was conducted to better understand causes for letting delays and learn more about considerations for creating a model for predicting mega project payout characteristics. In all, seven of the more relevant sources were reviewed these are summarized below.

2.1.1 Dye Management Report (Dye Management Group 2004)

This report indicated that a "large minority" of projects are not delivered within the planned 12 months of the letting schedule. Permitting delays were frequently cited as the reason, but this cause is more systemic. Other reasons cited include the complexity of NCDOT's program and the extent of new construction—NC DOT's program is heavily weighted towards complex, higher risk, and longer duration projects.

The uniqueness and extent of North Carolina's environmental requirements was also cited as a letting delay factor. There were several high profile examples of projects where the environmental process and permitting resulted in considerable delays (e.g., Monroe Bypass, Clayton Bypass, and New Bern Bypass). Within the NCDOT and among its partners and customers there is a general view that the length of time it takes to complete the environmental process is a major cause of project delays and the overall project delivery time. Other factors causing delays include staff shortages, employee retention, and human resource management. Utility clearance was also cited as a bottleneck in the process.

This report found that NCDOT staff performing the project manager (PM) role do not appear to focus on managing scope, schedule, or budget. The Dye Management report also suggested that preconstruction budgets were not particularly a concern since preconstruction cost is a relatively small percentage of the total cost of construction. Moreover, staff performing the PM role have little management authority over resources assigned to their projects. The NCDOT does not currently either require or actively encourage staff performing project management roles to be working towards the Project Management Professional (PMP) certification. In addition, PMP certification is neither a requirement nor a highly desirable skill in the recently developed job descriptions for the TIP Program Managers. NCDOT's current organization and culture was described as "fragmented across multiple organizational units," "informal project team structures," "communication within project teams is difficult and very siloed within functional organizations," and "does not have a can-do culture in terms of project management." In regard to project management processes and methods, the following characteristics regarding NCDOT were mentioned.

- Does not currently have an end-to end project development manual.
- There is little management information available for program and project delivery management.

- Does not have a set of metrics for measuring, managing, and monitoring project delivery performance.
- Lacks a project status reporting functionality, including the capability to manage projects on an exception basis against pre-defined criteria.

2.1.2 Performance Audit Report (Merritt 2008)

The audit was conducted to determine why highway projects are having schedule delays and cost increases. Key findings from this report suggest the following:

- The NCDOT was not meeting let dates, with 73% of the 390 projects missing their targeted construction start year. Additionally, 40% missed their start date by more than a year. The majority of these project delays were due to the permitting process, environmental reviews, and design changes.
- The audit concluded that the NCDOT was not meeting construction schedules and costs. Of the 390 projects audited the construction schedules were extended 21% beyond original completion date and payments exceeded original contract amounts by 7%. From a sample of 100 projects, the largest classification of schedule extensions was design changes and pro rata days. The largest cause of cost overruns were in construction materials pay items and design revisions.
- The audit was critical that preconstruction and construction sections manage projects separately and the DOT is deficient in performance management control activities.

2.1.3 Causes for Let Delay for Mega Projects (Roerden 2014)

Jeff Roerden conducted a study to rank reasons for project let date delay. One hundred and twenty projects were examined which generated a spreadsheet including 659 observations for letting status, either delayed or not impacted. According to the study, Planning, Undocumented Schedule changes, Design delays, and Funding issues were the most significant cause for let delay. Some of the more commonly cited planning comments related to additional study (design and environmental) and coordination time needed to identify alternatives, preferred site becoming unavailable late in the process, delays in obtaining technical data, and reviews by other agencies taking longer than expected. Based on the given data, the research team filtered the spreadsheet to account for only mega projects; yet planning was the most remarkable reason for shifting the let date. Figure 2.1 shows the ranking for letting delays for mega projects.

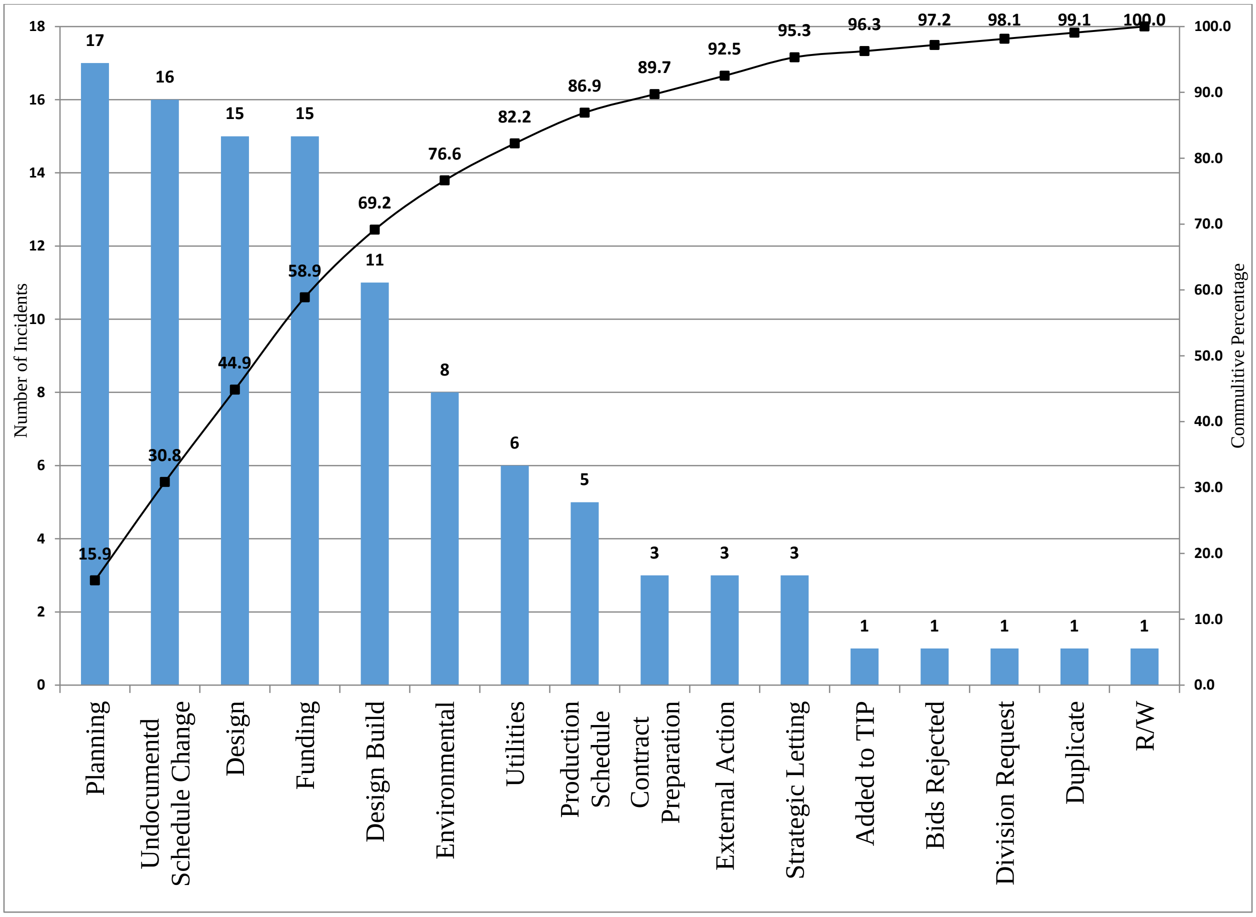

Figure 2.1 Causes for Letting Delays for Mega Projects (Data provide by Jeff Reardon)

2.1.4 <u>NC STATE PE Study (Liu et al. 2011)</u>

A study was conducted by North Carolina State University to estimate the Preliminary Engineering (PE) costs and time for NCDOT projects. Typically, preliminary engineering activities begin as soon as a project is approved for funding authorization for planning. NCDOT uses a fixed 10% of construction costs to account for PE costs. The research team studied 461 bridges and 188 roadway project lettings between 2001 through 2009. Factors were identified for each category to be utilized in the model. The mean PE cost ratio for the bridge projects was 27.8% of construction cost and the mean PE duration was 66.1 months. On the other hand, the mean PE cost ratio for roadway projects was 11.7% of construction cost and the mean PE duration was 55.1 months. The resulting predicative models accounted for independent variables such as the structure length, geographical region, and estimated costs for construction and ROW. The predictive models are anticipated to increase the accuracy of PE cost and duration estimates which will enhance the budgeting process.

2.1.5 Forecasting Construction Payments for NCDOT Projects (Mills and Tasaico 2005)

Mills and Tasaico studied 4,128 progress payments for 336 highway projects from August 2000 through June 2002 to develop a statistical model that forecasts the payout for NCDOT construction contracts. They developed two models that forecast the monthly progress payments. The first model predicts monthly payments for individual projects and is primarily used by project engineers and managers. The second model predicts monthly payments for a portfolio of projects; financial managers are the primary users of this forecasting tool. Each forecasting model relies on different independent factors to accurately predict the monthly progress payments. The independent variables for the first model include the contract's budget, age, duration, engineering type, month of payment, and region. For the aggregate model, the factors are the number of projects, total budget, the mean age and mean duration of all active contracts, and the month of payment. Both models rely on projects in the NCDOT 12 month let list. The second forecasting model has facilitated cash flow management at NCDOT.

2.1.6 UNCC Study on the Impact of Funding Changes on Project Lettings (Teng et al. 2013)

A research team from the University of North Carolina at Charlotte developed a risk-based project management tool *Register* for cash flow management. The UNCC team learned that projects are vulnerable for being delayed as a result of changing funding conditions because of a reschedule of the TIP. The first goal of the tool is to identify the probability of a project's funding being changed. The tool gives attention to projects that will likely be impacted by the funding change using a priority scoring method. The tool, *Register,* can forecast the payout curve for individual categories of projects such as bridges, rural, urban, and interstate projects. The second goal of the risk management tool was to optimize the project let schedule and produce a new let schedule based on the projected funding changes. The tool optimizes a revised let schedule with 15 built-in funding change scenarios along with a user-defined scenario. The revised let list reduces the effect of funding changes on project let delays and better accounts for such risks in budgeting, cash management, and project management.

2.1.7 SAS study (SAS 2014)

SAS was contracted by the NCDOT to develop models for predicting construction expenditures at the individual and aggregate project levels. The factors used in the expected models are the project cost, delivery method, predicted let date, project type, and location. The models are expected to have a better forecasting capability compared to the HiCAMS model and will be able to predict payout values one, two, and three years in the future. It was predicted that the SAS models will produce lower average yearly error rates compared to the HiCAMS model (4.2% versus 12.5%, respectively).

2.2 Predicting Construction Expenditure Payout Curves

The Building Research Board conducted a study to review and improve the current practices performed by federal agencies in developing their early cost estimates (Morris 1990). Inaccurate early cost estimates of project costs results in inaccurate budget requests, thus becoming the main cause of cost overruns. For most federal projects, A/E firms determine project cost and update it periodically as new information becomes available. The goal of federal agencies is to deliver projects within a fixed negotiated budget.

In the context of this report, different terminologies are used to describe cost estimation depending on the chronological order of their preparation as well as the available information. The typical key estimates during planning and design are as follows:

- Identification of User Needs (Pre-programming Estimates)
- Preliminary Screening of User Requests (Program Estimates)
- Development of a Program of Requirements (Concept Estimates)
- Development of a Preliminary Design (Design Development Estimates)
- Development of Contract Documents (Construction Document and Pre-bid Estimates)

The report finds that there are numerous different factors including (inaccurate budget estimation) that cause budget issues. Figure 2.2 summarizes one such set of factors that affect cost overruns in federal project with their ranges and overall averages.

Most federal agencies' estimates are prepared by private A/E consulting firms. Building preprogramming estimates are generally expressed in units of dollars per square feet, or dollars per hospital bed. In general, the unit depends on the primary use of the facility. When user needs are clearly defined, the A/E firm is able to make a better estimate than they originally made in the programming phase. Next, a concept or schematic design is created in elemental format. The Construction Specifications Institute's (CSI) format is the prevalent method in the elemental breakdown of the project. The funding request is based on completing the design development estimate which occurs at 35% of the overall detailed design effort.

The Building Research Board recommended that federal agencies should have the ability to review estimates prepared by others. In order to achieve that, it is recommended to improve agencies' personnel estimating skills by sponsoring conceptual estimating training. It is also suggested that terminologies as well as estimating formats be standardized among different agencies. While each federal agency has its own cost data history, it would be beneficial for all parties if the data is shared among agencies. In regards to estimation techniques, the report by Morris (1990) emphasizes the implementation of parametric estimates in adjusting the costs and the utilization probabilistic estimates for projects with great uncertainties and risk.

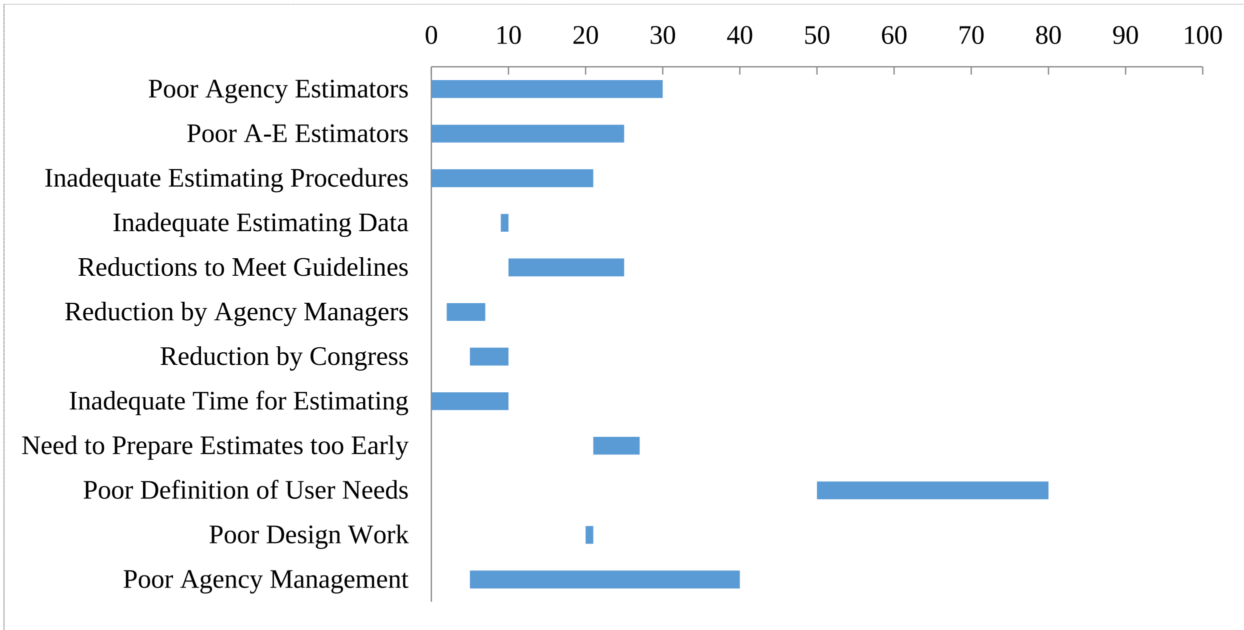

Figure 2.2 Factors of Budget Related Problems in Ranges and Overall Averages (Morris 1990)

A model of time and cost is dependent on contract sum and duration and it is necessary to investigate and estimate them beforehand. An industrial project consumes more time than do residential and commercial projects. Negotiated tender and DB contracts consume more time than do traditional and lump sum contracts (Ng et al. 2001).

No model is perfectly accurate. Studies to create a model with the least inaccuracy were begun in the 1990s. Hardy (1965) put forth the importance of plotting time vs. cost and value vs. cost. In the 1970's came the advent of financial management and mathematical models could be used if the total value and duration of the projects to be constructed were known (Banki and Esmaeili 2009). The majority of the models concentrated on developing S-curves that were standard and represented the cost of different projects. Data was collected regarding monthly valuations and segregated and standard S-curves were drawn for groups of particular types of projects. This gross estimation was barely useful because construction projects are unique by nature and often do not necessarily conform to the performance of other past projects.

"The underlying principle of the idiographic approach is that the value curves are generally unique and that they should be modelled separately; hence, a curve should be fitted for each project" (Kenley and Wilson 1986). Rather than relying on standard S-curves as has been done in the past. The uniqueness aspect of a project is a hurdle in modelling because if the type of modelling varies, the results may be well off the charts for different types of projects. To analyze, one would need data on all types of projects and yet there would be a need for constant updating for the sake of keeping up with new techniques in construction. Modelling is independent of the time period and one could do it for preconstruction or preliminary project stages as well as for the entire project.

Despite many claims stating that mathematical models would fail, numerous stochastic and regression models were experimented using past data. A model developed by Ostojić-Škomrlj and Radujković (2012) concluded that sixth degree polynomial regression was the best such modeling approach. This approach correlated with the actual values obtained using data from real time projects. The resulting curve's top and bottom limits showed a 95% reliability with respect to cost and time.

"It is obvious that breakdowns or stoppages, influences of considerable risks, poor organization of work, frequent changes, etc., will greatly modify the form of a prognostic curve, in which case each project has a specific dynamic represented by an irregularly shaped S-curve" (Ostojić-Škomrlj and Radujković 2012). A regression model based on a standardized work program framework was proven to be accurate but it is subject to reservation of model sample sizes in the development of S-curve models (Blyth and Kaka 2006).

Various models which used mathematical functions were then used to fit the S-curves including the alpha-beta cubic equation, the Weibull function, and a Dasgupta-Heal-Solow-Stiglitz (DHSS) model. When the total value and duration of the projects to be constructed are known, the above models could be used to forecast the periodic value/cost of that project (Blyth and Kaka 2006). Kaka (1999) sought to find the differences in the S-curves based on the planning strategy. He collected data from a project with four different managers and plotted S-curves for the different managers and found that they were significantly different. More accurate S-curves are to be developed using more criteria and factors else the future attempts to model would fail due to the nature of the construction industry, Kaka indicated that a stochastic model using data from past projects had the highest probability of achieving accuracy (Kaka 1999).

Grouping projects based on their characteristics is one of the best approaches to forecasting S-curves. Cost curves for projects are different because of differences in the projects' characteristics. Although the research was done on a small sample set of projects, the conclusions given by Banki and Esmaeili (2009) in this regard are noteworthy.

Since the greatest hindrance to modelling was contingency, models that take contingency into account were explored. Neural Networking models (NN) give more accurate estimation results than do case based reasoning (CBR) or multiple regression analysis models, but neural network modelling is a slow process because it is based on trial and error. With respect to tradeoffs, case based reasoning models were far more effective. There has not been enough research done in hybrid CBR-NN methods (Kim et al. 2004) to repeat results.

Smith and Mason (2010) studied the applicability of Monte Carlo simulation and regression methods by using inputs such as estimations of quantity of labor, materials, utilities, floor space, overhead, time, and other costs for a set of series of times. This estimation is also typically used as inputs for deterministic analysis methods, such as net present value or internal rate of return calculations.

Zayed et al. (2009) selected and used 43 factors which affect cash flow and studied variability and uncertainty in them using a questionnaire and interviews with practitioners. Monte Carlo stimulation was used to forecast cash flow and over draft. This model was determined by Zayed to have benefits when forecasting cash flow progress before and during construction.

Table 2.1 summarizes available research findings for predicting construction expenditure payout curves.

Table 2.1 Comparisons of Findings on Modelling Project Payout Expenditures

Year	Authors	Type of Model	Result	Conclusion
1999	Kaka, A.	Stochastic model using data from past projects	Future attempts to model would fail due to the nature of the construction industry	More accurate S-curves are to be developed using more criteria
2004	Smith, A. and Mason, A.	Monte Carlo simulation and regression methods	Used different characteristics	This estimation is also typically used as inputs for deterministic analysis methods, such as net present value or internal rate of return calculations
2004	Kim, G., An, S., and Kang, K.	CBR and NN models	CBR and NN models were apt for construction cost estimation	Not enough research done in these hybrid CBR-NN methods
2006	Blyth, K. and Kaka, A.	Regression model	Model on standardized work program framework is accurate	Individual S-curves were created from standardized activities applying multiple linear regression
2009	Banki, T. and Esmaeili, B.	Monthly valuations for segregated projects	Standard S-curves	Gross estimation was barely useful
2009	Liu, Y., Zayed, T., and Li, S.	Monte Carlo stimulation	Identified and ranked factors that affect cash flow forecasting	This model has vast benefits to forecast cash flow progress before and during construction.
2012	Ostojić-Škomrlj, N. and Radujković, M.	Sixth degree polynomial regression	95% reliability on the model	Standardized S-curves forecasts payout for building, tunnel, and highway projects during design phase
2015	Salah, A. and Moselhi, O.	Fuzzy set theory	Quantitatively used acquired knowledge and subjective feelings of project managers and stimulate the models	Research addresses the shortcomings of existing contingency estimation

3 METHODOLOGY

The study methodology involved:

- Reviewing relevant literature,
- Gathering insights from experts through structured interviews,
- Collecting and analyzing data provided to the research team,
- Designing a preliminary construction payout model for mega projects.

The literature included several reports produced by consultants. Seven previous and related studies were reviewed for their relevance to this project. A survey instrument was created to gather appropriate information from each of the selected interviewees (refer to Appendix 11.1 for a copy of the survey guide). In addition to collecting qualitative information from each respondent, the survey afforded the opportunity to rate each delay factor on its level of importance of impacting the let date. A total of 23 experts were interviewed, mostly face-to-face. Due to the travel distance, it was necessary to interview one of the contractor respondents by telephone (see Appendix 11.2 for a complete list of interviewees). Both qualitative and quantitative responses to these interviews are summarized in the next section. In addition, one of the NCDOT respondents was interested in finding out from the contractors how to accelerate project schedules and thus, this information was obtained as well.

The research team was provided with construction payout data for 48 Mega projects in the form of several data files that related to the causes for let date delays. The team also received supporting data files providing more details on the supplemental agreements and approved schedule changes to the project duration (see Appendix 11.3 for a list of the projects). Insights provided from these data, as well as from the interviews, helped the research team better understand factors for creating a payout curve for individual mega projects.

A preliminary study of a model for predicting payout expenditures for mega projects was undertaken and included three parts. It is important to note that a payout curve is an evolving entity and is adaptable to the normal changes that occur on a project (e.g., supplemental changes and their associated schedule increases).

The first portion of the study pertains to the preconstruction phase and provides insights into the likelihood of meeting a particular let date based on completion dates for strategic milestones (e.g., Location and Design Approval, ROW authorization, and Final Plan to Design). For example, for new location DBB projects, ROW authorization was completed as early as 98 months prior to letting and was as late as 25 months prior to letting. If a current new location DBB project has not achieved ROW authorization at least 25 months before letting, then the probability of let date delay is high. Corrective actions can be taken by the NCDOT to ensure that this key activity is completed in a timely manner so as not to jeopardize the current let date.

The second portion of the study relates to the bidding phase and estimates the duration between the let date and start of construction. An average duration and standard deviation were calculated for both DBB and DB mega projects.

The third part of the study relates to the actual shape of the payout curve for individual mega projects. The research team developed standardized payout curves for both DB and DBB using data from past projects. However, in the future we propose a new payout scenario that considers changes (such as supplemental agreements and increases in project duration) as they occur. A preliminary study of payout curve termination points was performed and shows that even though projects are planned to terminate at a cost and schedule factor of 1.0, they typically end up higher. This is important to note as the new model should have the flexibility to be recalibrated whenever there is a change in either the cost or the schedule.

After considering preliminary modeling concepts, the research team focused its efforts on the development of payout curve patterns of completed DBB Mega projects. Three model designs covering both the preconstruction and construction phases are proposed.

1. Macro Approach during the preconstruction phase. This method in a “top down” approach that creates statistical models using cumulative construction payout data on past projects that have been normalized where the final cost and schedule basis is one hundred percent. Mathematical models were developed for two completed DBB projects showing a strong correlation to the actual values. In future work, standardized curves will be modeled for different project types, and they will be adjusted to the factors that apply to the forecasted projects based on location, seasonality, bid amount, duration, etc.

2. Micro Approach during the preconstruction phase. This method is a “bottom up” approach that builds the project payout curve based on the anticipated construction activities (e.g., mobilization, traffic control, excavation, etc.) and their associated unit costs. Data for this approach will come from detailed NCDOT project bid data from 2001-2014. Based on this database, activity sequence, characteristic, and quantities will be used to develop payout curves using construction costs and schedule durations. Although more time consuming, this approach has the potential to create project payout curves that are more closely aligned to the actual project scope compared to the macro approach which uses data from projects with a similar scope. Additionally, as more data is acquired over time greater payout accuracy is obtained.

3. Model design during the Construction Phase. This approach uses the contractor’s estimated construction expenditure forecasts (both at the beginning of a project and quarterly during the project), which are based on the contractor’s resource loaded schedule, to determine payout estimates. The NCDOT requests this forecasted payout information at the beginning of each mega project along with quarterly updates. The assumption is that the contractor has available to him all the material, labor, and equipment information needed to efficiently execute the project and anticipate its cash flow needs. However, it was discovered that many of the quarterly

updates were not provided by the contractors to the NCDOT making it difficult to demonstrate the validity of this approach

4 FINDINGS– INTERVIEW INSIGHTS

This section includes a summary of comments from the respondents related to portfolio management, predicting let date, start of construction, and predicting the payout curve. Suggestions for meeting the let date are provided by NCDOT respondents as well. Additional comments were gathered from the contactors on how to accelerate project schedules. In the interviews, we obtained a variety of information from different sources. Participants in the interview process were drawn from a wide range of NCDOT units. These participants have different information sources and different perspectives on the difficult problem addressed herein. As a result, some of the findings appear to be anecdotal and some comments may be contradictory. Because of the broad scope of this study this result is not entirely unexpected or unusual and does not detract from the overall outcome.

Figures 4.1 through 4.3 provide a snapshot of the key planning, design, and external factors that impact let dates. Figure 4.1 shows that incomplete documents, scope change, document change, merger/agency coordination, public involvement, scope changes caused by the public, awaiting traffic analysis, railroad coordination, and sufficient resources were the highest rated planning factors impacting the let date. Figure 4.2 shows that the most significant delay let factors are late input, design revision, merger and agency coordination, and threatened and endangered species. Municipal agreements, redesign and rework caused by utilities, and utilities are shown in Figure 4.3 as the most significant external delay factors. Interview comments follow providing insights related to many of these factors.

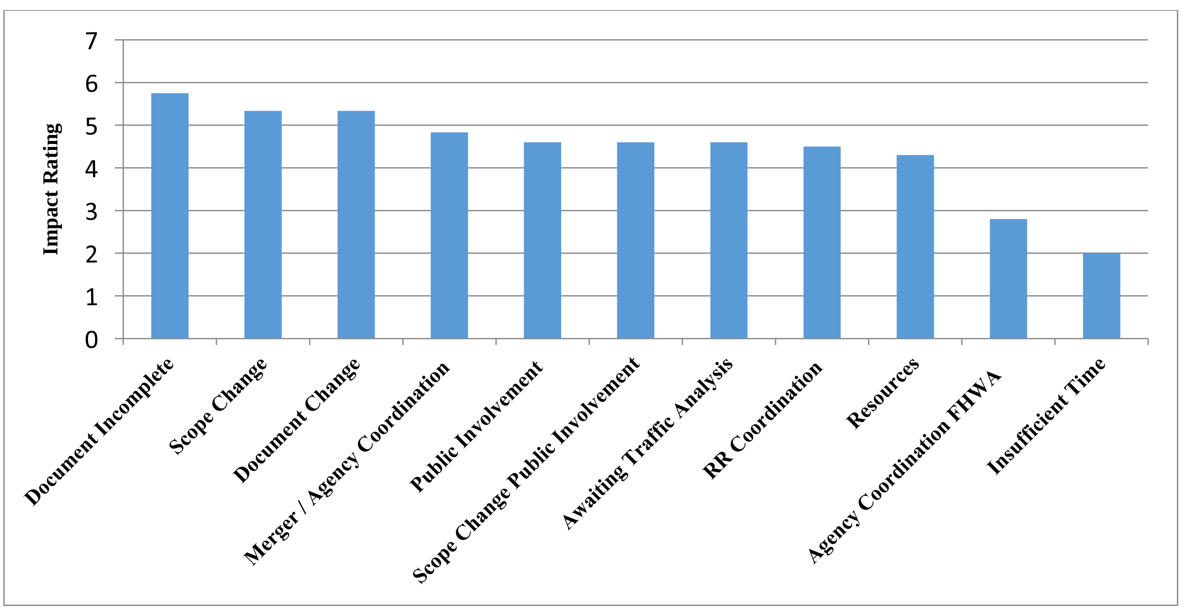

Figure 4.1 Planning Let Delay Factors (1=Low Impact, 7=High Impact)

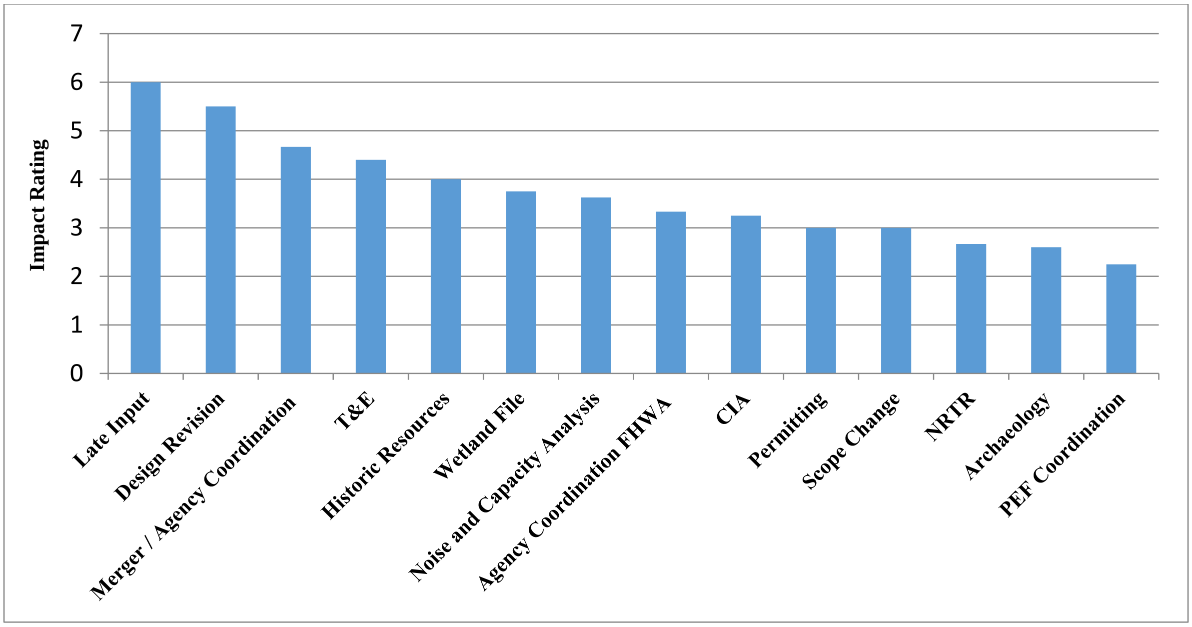

Figure 4.2 Design Let Delay Factors (1=Low Impact, 7=High Impact)

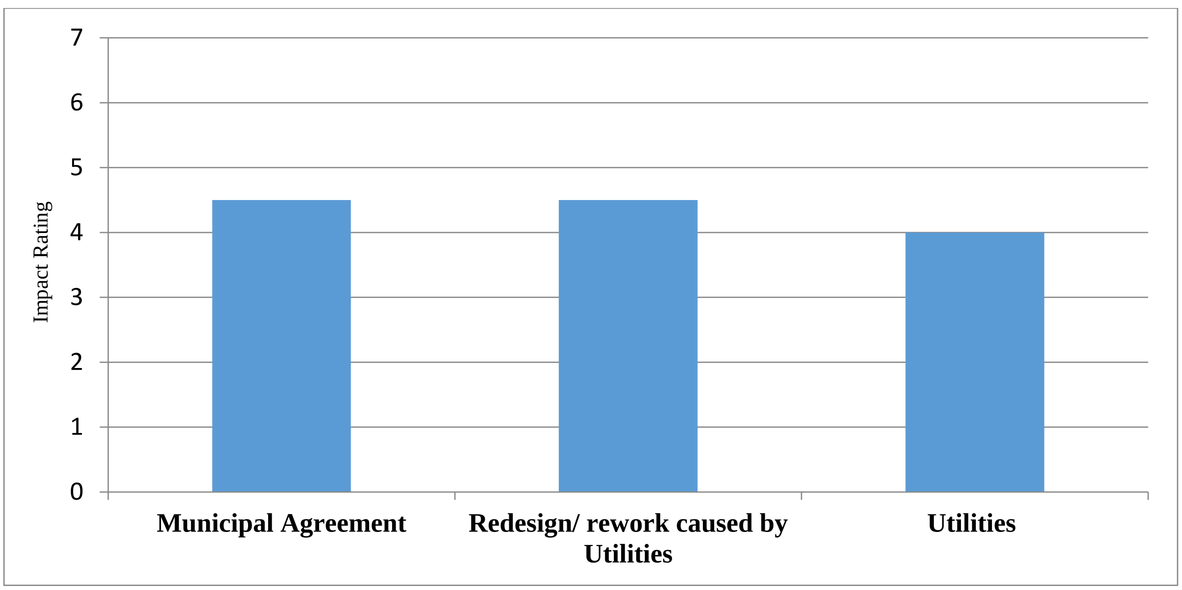

Figure 4.3 External Letting Delay Factors (1=Low Impact, 7=High Impact)

4.1 Portfolio Management

- Use "shelf projects" that are ready to go if money becomes available. Good candidates to be used as shelf projects are medium size projects.
- Move money from one project to another. The Bonner Bridge is a good example. One solution is to move some money to get other projects going while keeping an amount to pay for only the 1st year of the bridge when it gets approved.

- NCDOT needs to do a better job of balancing project let dates. One NCDOT source said "tried, but need to do a better job."

4.2 Preconstruction Phase (Predicting Let Date)

4.2.1 <u>General Comments</u>

- Let dates are set up more accurately now since projects are now regionalized. This change was made about 8 years ago.
- Contractor's impressions are that the NCDOT is doing a better job of meeting let dates once projects get into the 12 month let window.
- The interviewees held different opinions on the percentage of projects delivered on time. One suggested 60% while another thought it was 70%. Most delays are on small local projects using SPDA and transportation alternative funds. This affects the project delivery percentage and adds up to higher cost due to inflation. In some cases, it might mean having to go to the board for more money. Another interviewee thought that 60-65% of the projects will meet let date 36 months out. When a project is within the 12 month window, there is an 85-88% chance of meeting the let date. Another person felt that there was a 95% chance of making the let date when within the 12 month window. At 24 months out, there was an 85% change of making let date. At 36 months out, there was a 24-36% chance of making the let date. Figure 4.4 graphically portrays these predictions.

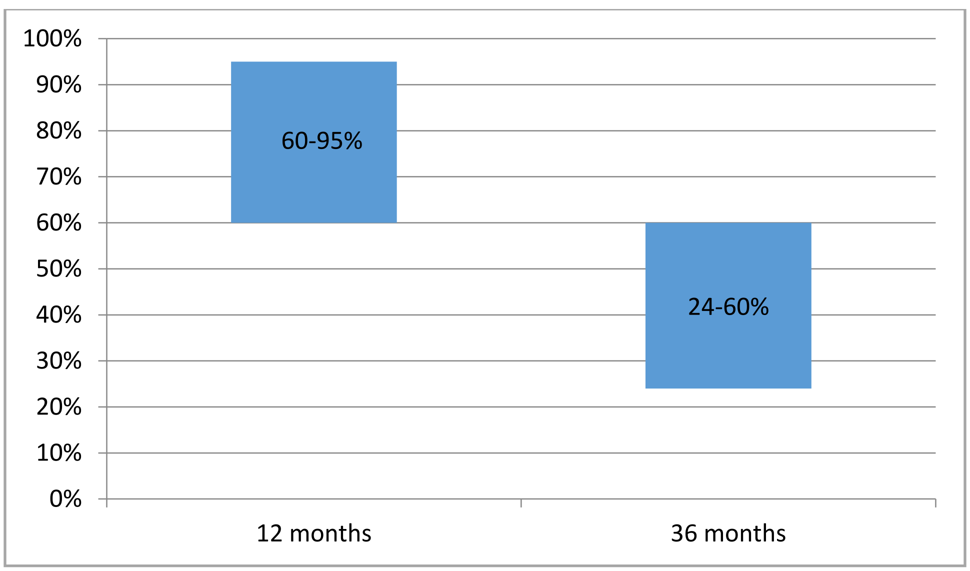

Figure 4.4 Chance of Meeting Let Date 12 and 36 months Prior to Let Date

4.2.2 <u>Planning</u>

4.2.2.1 General Comments

- Delays can happen during the planning stage. This is when project knowledge is both evolving and changing (e.g., other alternatives, public dissention, etc.)

4.2.2.2 Merger Process

- The merger process includes projects that should not need to be going through the merger process. Overall, merger is a good process, but determining which projects go through it should be more selective. There should be a better screening process.
- One interviewee said, "How we tackle the NEPA/Merger process is the most significant factor affecting project let dates." It is easier to obtain consensus with a smaller group than a large group that at times includes 25-35 stakeholders. As a result, it can take a lot of time to get to a concurrence point (causing much delay to get so many people in agreement). It took 6-7 years for an EA on one project.
- The merger process is a problem for the NCDOT. Staff meet once a month and spend a lot of time managing the process. It appears that the staff is process oriented rather than project oriented. Process dictates what the committee decides. This person also said: "we can't have merger the way it is today."
  - A Federal guidance provides that an Environmental Assessment (EA)s should be a maximum of 35 pages. Every EA this individual sees is 60-100 pages.
  - Environmental Impact Statement (EIS)s seem to have too much information as well. Is NCDOT asking for excessive public involvement?
- "Can get conflicting advice from different agencies within the Department of Interior." Primary agencies include the U.S. Army Corps of Engineers, Department of Water Quality, Environmental Protection Agency, U.S. Fish and Wildlife, and Marine Fisheries. Many of these organizations reside under the Department of Interior (DOI).
- The DOI attempts to regulate infrastructure construction for the entire U.S. The Southern long eared bat is a species example that covers several states. This can become part of the merger process, which can then impact the let date. If FHWA took a stronger role in dealing with other agencies, environmental issues could be handled more quickly. One interviewee agrees that NCDOT needs to lead this change.
- There are typically four merger meetings and they are "scattered." Consider combining concurrence point 1 and 2 meetings for improving efficiency. Ask agencies to concur at that time. In reality, most agencies say they need more information and move to meet again prior to establishing an agreement. Agency concurrence is critical to moving the project forward. Thus, if you don't have efficient meetings then this can lead to delay.
- There are projects that take time in the merger process. As soon as a project alternative is selected (LEDPA), it is possible to gain a better control on the project let date. In some cases there might be several alternatives which will lead to multiple designs which results

in an unnecessary waste of time and money. It was suggested that the NCDOT should study fewer alternatives and incorporate more technology such as GIS to reach a well-founded alternative selection.

- Merger is important but there needs to be a better screening process. Too often the process is conducted on projects that do not need it.
- The merger process lends itself to lack of leadership in delivering the project. With a merger team there are 10 leaders who all have equal footing in making decisions on moving a project forward. This requires for too much consensus. "Why is EPA making comments on wetlands or Fish and Wildlife worrying about sun flowers?" There is a lack of common effort to get to a conclusion. It is important to study alternatives but it is essential to quickly eliminate those that are less viable. There are meetings every month but sometimes little gets accomplished. Large projects often raise more issues.
- If a project requires an EIS (full merger process, meeting all concurrence points through 4B, significant amount of coordination with other agencies, NCDOT performed field work and data gathering), any slip in the data gathering can delay the let date. Establishing the purpose and need can take time. The more project alternatives that are considered, the more time it will take to reach a consensus on the selected alternative.
  - GIS has been used to streamline this process and make it more efficient. In one case, GIS helped reduce the number of alternatives to the 2-3 range.
  - Reducing the number of projects requiring an EIS is a recommendation from the NCDOTs six sigma efforts.
- There are numerous widening projects in the merger process. For these projects the NCDOT should consider using a Categorical Exclusion (CE) instead of an EA or EIS. It appears that planning and roadway defaults to the use of an EIS or EA "just to be safe". It was suggested to start with a CE then go to an EA, but only if necessary. NCDOT could gain a lot more (in terms of time and resources) on the projects that begin with a CE.
- NCDOT has been doing a lot more EIS's than others in this part of the country. There is an absolute need to do fewer EIS's and more CEs and EAs.
- NCDOT hired and pays agency positions to help with coordination among the various merger agencies. However, those individuals view their job as to enforce regulations rather than to support them and solve problems, and meet needs. One way to address this issue is to modify the job descriptions for these positions to be more performance based.
- NCDOT should try to achieve the alternative selection concurrence point as quickly and efficiently as possible. Once achieved, there is no need to go back and re-review decisions.
- Once the decision document is complete then should go for a permit.
- Presently, many new NCDOT projects are fixed in that there is only one alternative to be studied but yet, many of those projects go through the merger process.

- Entering widening projects into the merger process is a choice made by NCDOT, as they are the organization that makes the determination (CE, EA, or EIS). The NCDOT currently "questions" but does not "challenge" the other stakeholders.
- It was noted that FHWA would like to see more Categorical Exclusions.
- NCDOT should study how other states do the environmental process
  - On one project in South Carolina (SC), it took 10 months to obtain an EA. SC engaged the U.S. Army Corps of Engineers and kept them involved in decisions. SC thought that this seemed like a lot of time. But it really is not compared to the amount of time it might take in North Carolina.
  - Florida does a NEPA process that is transparent and is conducted on line. The Dye Management Report showed that Florida was processing their documents faster than North Carolina.
- In the past, Environmental was a consistent reason for schedule changes. However NCDOT has since made improvements in the environmental components of the project.
- It has been suggested to start with a CE (like on a bridge project) or an EA. After all, there are few alternatives for some projects. For a widening project, the choices are limited.
- Minimize the number of EISs without project funding or you waste money or run out of time as the preliminary engineering study gets out of date (note that it is valid for only three years).
- Adequate project screening is a key in the merger process.

4.2.2.3 Environmental

- Why does environmental process take so long—SC takes the shortest approach.
- Threatened and Endangered Species (T&E) is seen as a risk factor for delaying projects.
- Do environmental work and permitting first. Perform let scheduling only after all environmental work and permitting have already been completed.
- NCDOT needs to take a strong leadership role with respect to environmental activities ("our project, our mission")
- Need a new process to involve agencies during planning and preliminary engineering.
- Environmental legal actions occur more and more often.

4.2.2.4 Archeology

- It's something that pops up out of nowhere—unpredictable. It might affect construction when NCDOT puts a contractor on hold.

4.2.3 Design

4.2.3.1 Public Involvement

- Now that we are into the project, there are so many things that could go wrong. What the community feels about the project (community could be split), civil rights act, environmental justice, etc., all could cause problems.

- Scope changes due to public involvement could have a significant impact on the let date especially if the public does not like the selected alternative.

4.2.3.2 Cities

- Cities will sometimes want to make changes and these may occur late in the process.

4.2.3.3 Document Change

- Re-evaluation may be an issue which could mean the loss of a year in the letting date. As an example, this would occur if you started out with a CE then had to change to an EA Finding of No Significant Impact (FONSI).

4.2.3.4 Changes

- One reason for undocumented changes might be that the changes did not have a change form.

4.2.3.5 Scope Creep

- Keep the budget in the back of your mind and be open to different alternatives. Need to hold a hard line—to do this do a lot of preliminary work (preliminary studies) to figure out what the solution should be. Campo (Raleigh MPO) has already done this.

4.2.4 <u>Right of Way (ROW) and Easements</u>

- Another common delay is due to it taking longer to obtain ROW.
- ROW is usually done toward the end of preconstruction and sometimes gets squeezed on time.
- If you do not get ROW authorization early, then that will affect ROW acquisition. Early resolution of Right of Way considerations is only possible if the negotiators have previously received a good set of plans to work with.
- Getting approval for ROW funds through advanced acquisition could save time.
- One NCDOT interviewee said that planning and how it affects the ROW date is the number one cause for delaying the let date—not the fault of ROW. Sometimes there is a coordination problem that design needs to deal with. Sometimes there is a need for a risk assessment.
- It is rare that design changes will affect the easement plan, and as a result change the let date. The problem is it is expensive. We treat owners fairly in terms of the price.
- NCDOT has a condemnation authority, and as a result, ROW does not affect the let date.
- ROW issues usually do not affect let date but can delay construction.

4.2.5 <u>Utilities</u>

- Utilities are out of NCDOT control and cause let date slippages.
- Utility coordination has become more troublesome now compared to where it was in the past. Utilities do not usually hold up the project letting but can delay construction.
- Some divisions may let the projects before the utilities are moved. Other divisions will move the let date—it highly depends on which division and the importance of the project.
- Delaying let date hurts the NCDOT's credibility with utility companies—they will not move utilities unless they are absolutely certain that the project will be let by a certain

date. If the utility companies were more certain that a project will let, then they would be more willing to act sooner.

- From the contractor's perspective, utilities are always a factor for both DBB and DB projects. Most of the time, utility firms do not meet the established schedules. It has been said that the lettings move so much that utilities are reluctant to allocate dollars and resources unless they are certain that the project will be let. More reliability on the let date would help so utilities do not hold up construction.
- Greensboro project: AT&T (biggest offender) and Time Warner. Time Warner is out of money for the remainder of the year plus they are not allowed to splice this time of year due to the football schedule—effectively they can work 10 months out of the year.
- Two types of utilities: 1) prior rights—utilities are in their ROW and state needs to pay for relocation (e.g., gas and power) and 2) state owned ROW in which case the utility needs to pay for relocations costs. Water and sewer can fall into both categories. If there is catastrophic weather, utilities will typically pull workers from the project and go where their assistance is needed. Contractors can hire independent contractors to do the utility's work. It was noted that smaller utilities typically do not have their own forces to perform relocation services.
- One of the problems with utilities is that Duke Energy, for example, will not accept the Permit of Entry and refuse to move their utilities with this type of permit.

4.2.6 <u>Railroads (RR)</u>

- The railroads have delayed several projects in the past. Delays are typically caused by coordination issues and difficulty in reaching an agreement with the railroads. Plan for a minimum of two years to obtain an agreement.
- SHRP 2 R16 was referred to as a document that contains information on delays and identifies strategies between the RR and NCDOT to make projects go faster. One strategy in dealing with the railroads is to get them involved early in the design process and not go through a complete design cycle and have the railroad reject it. The scoping phase is a good time to get involved with the railroads.
- NCDOT attends the scoping meetings and continues to stay engaged during the preconstruction phase.
- Railroad at grade crossings with highways typically do not hold up lettings.
- Railroads feel that they own the air space above the tracks and are asking local governments to provide concessions in this regard. For example, CSX and Norfolk Southern now want the NCDOT to maintain a RR bridge over a highway. Administrative codes will need to be tightened up to deal with these demands.

4.2.7 <u>Municipal Agreement</u>

- Usually, it is not a problem; however, conflicts can occur when municipalities want last minute changes.

4.2.8 <u>Legal</u>

- About 95% of our projects don't have legal issues, but once it does, it stays for years. Bonner Bridge is a good example of a project that "we can't control".
- In regards to lawsuits, there appears to be a lack of legal sufficiency. An increase in legal sufficiency would make lawsuits less likely and result in fewer challenges. Currently, there are no negative consequences to Southern Environmental Law Center (SELC).

4.2.9 Permits

- Eco Systems Enhancement Program (EEP) says there are no delays due to wetland mitigation. Environmental permits, however, can still be an issue in meeting let dates.
- NCDOT needs authority to make the decision about what permits should be acquired (e.g., individual versus nation-wide). Currently, U.S. Corps of Engineers makes that decision.
- NCDOT has a permit with the U.S. Corps of Engineers for streams and acreage--similar to a nation-wide that was specific for North Carolina. Overall, the NCDOT permitting group is doing a lot better job with determining what type of permit to obtain and then getting it.

4.2.10 Funding

- Funding is not specifically a reason for a let delay; it is related to a change in the prioritization.
    - One interviewee challenged his fellow engineering colleagues that a project is delayed because of the department's lack of money (except the period from 2005-2008).
    - If there is a let date change showing funding as a reason, it is because of the TIP changing or change in priorities.
- Under the old Equity Formula project funding was an issue. Now under STI the funding is fairly well set.

4.2.11 Traffic Analysis

- Less of an issue today. In the past it might take up to one year.
- It can be a slow process.

4.2.12 Consultants (Private Engineering Firms—PEFs)

- Culture change from in-house work to consultants, i.e., transform to a new NCDOT model. Idea is to generate competition among groups to get employees working hard to release projects to consultants.
- NCDOT spends too much time reviewing consultant's work. Is this detailed review necessary since the consulting engineer has already stamped the work? Consider having NCDOT perform a higher level quality check.
- One interviewee said that 90% of the private sector work submittals came in one to two days late (for the final plans)—despite the tardy submittals, NCDOT was still able to meet the let dates.
- Do we over review the consultant's work? Seems like we spend twice as much time when consultants are involved.

- Mandated to use more consultants. NCDOT needs a faster process. Small changes can be disruptive, especially at the end where we need to go back to the firm. Cumbersome using the man-day estimate.

4.2.13 <u>NCDOT Staff</u>

4.2.13.1 Size

- There was concern about being thin in terms of manpower because of all the new projects at once.
- NCDOT has been cut 500-600 positions. Let's figure out how to get more done out there in the DB world.
- Staffing problems are a small issue. There are adequate numbers to perform the in-house design. The consulting industry exists to easily provide the services that the NCDOT groups can provide—general sense, that the NCDOT is moving in the direction of using more consultants. The NCDOT pays a little more for the service but the turnaround time is quicker. It was noted that there are contractual requirements on the PEFs (Private Engineering Firms) and that it is more difficult to enforce deadlines on employees than outside contractors.

4.2.13.2 Workload

- The high workload has an impact for project managers making it difficult for them to keep things moving forward. Will see this change with privatization—subcontracting to more consultants. Focus might be the need for more project management and administrative services in-house as opposed to design services. This is happening in PDEA during the preconstruction phase—project engineers are managing contracts. PDEA has seen a shift from ~60% planning work performed in-house and 40% subcontracted to the current 40% in-house planning and balance out-of-house.
- The regional approach to managing preconstruction projects has its efficiencies.

4.2.13.3 Skill Level

- Project managers need the necessary skills to deliver projects on schedule—some are better than others. Most do not have formal training in project management. One of the interviewees would like to have certification as a Project Management Professional. Currently, there is no reward for this.

4.2.13.4 Accountability

- NCDOT culture is missing sense of urgency to push projects forward. There are no consequences (no penalties) for not meeting expectations. Conversely, there are no incentives for meeting key milestones. Put something in place to have an impact—firm up internal work deadlines and have more performance accountability.
- In the past, there was no sense of urgency to meet let dates—"just change the schedule and let the let date slip." There were no consequences for missing the schedule. Now NCDOT is changing the culture to there being more urgency to meeting let dates. It's all about accountability. If planners and designers are not held accountable, then there is no incentive for them to do it. Legislature is the stick—if you don't change you could lose your job.
- One interviewee commented, "why don't we attack delivering projects that same way we deal with hurricanes and snow events?"

4.2.14 <u>Suggestions to make let date</u>

- Try to eliminate alternatives early and do fewer designs. Keep in mind that there is a risk that the design might be abandoned and this could increase the design cost. It was mentioned that the NCDOT is currently trying to move more design into the planning phase.
- Apply a "pencils down concept" when reaching the point for issuing permits, no scope change, and no change in plans. Three years before let date, stop design. There are many sources for design change such as municipalities. Do not make any major change that would affect obtaining permits.
- Put projects on a production schedule and lock down intermediate delivery dates for every project such as initial and final environmental documents, ROW plans complete, and roadway plans to contracts and proposals. Any let date changes should not change these intermediate milestone dates unless the let date change is so far out that it does not make sense to keep the original intermediate milestone dates. Try to make schedule changes an exception rather than the rule.
- If possible, get utilities moved before construction starts.
- Consider switching a DBB project to DB if there are problems with meeting ROW date.
- NCDOT pays a premium on DB projects because it is transferring risk to their design team. There is, however, a greater sense of urgency in completing the design, getting permits, and starting construction. DBs can usually start construction with 75% of the plans finished.
- For DBB projects, assign someone to be in charge of coordinating all of the "pieces" and keeping everything on track (as what is currently done by NCDOT on DB projects). It was noted that many states already do this as it leads to greater schedule predictability.
- Consider using more express design build contracts which leads to a shorter procurement process.
- NCDOT had about 400 bridges that were contracted as express design build projects. Bridges typically have no opportunities for innovation—will bundle 12-15 in one package. Contractor is told that they have 4 years to build these bridges. Other stipulation is that when the contractor begins construction, it has 60 days to close the road for each bridge.

4.3 Bidding Phase (Time from Let Date to Start of Construction)

Most of the comments in this section are from the perspective of the contractor and provide insights on factors that can delay or slow down construction activities. Figure 4.5 reveals the average number of days that it takes from the bid letting to the date the contractor can begin work. Note that the process is about 1 week faster on Design Build projects compared to the Design Bid Build approach [37.6 (Standard Deviation = 5.1) versus 43.6 days (Standard Deviation = 3.6)]. Comments from the interviews follow.

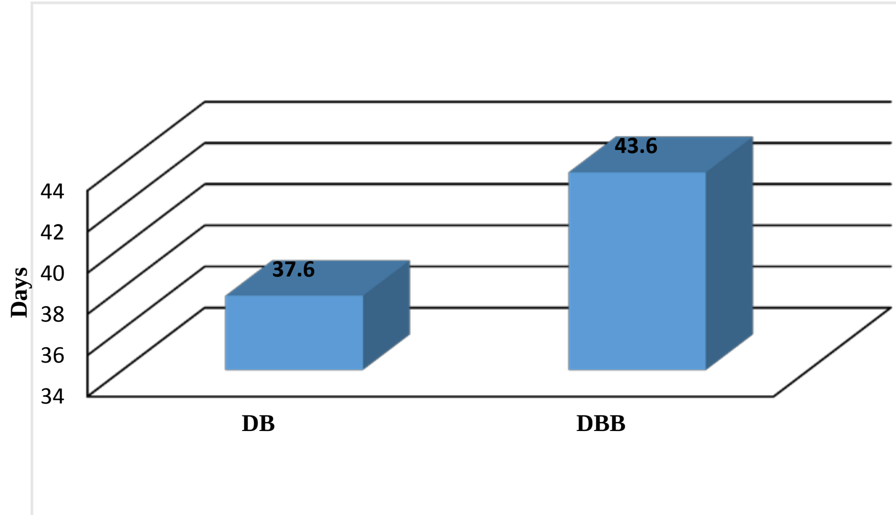

Figure 4.5 Let Date to Date Contractor can Begin Work (Average # Days)

4.3.1 General Comments

- Contractors perform a risk analysis on every project. Utilities are the major risk item followed by geotechnical conditions. Dealing with railroads and property owners are also risks.

4.3.2 Utilities

- Utilities are always on the critical path in project delivery.
- Relocating utilities might take one year to 18 months. Therefore, NCDOT negotiates with the contractor to work in other locations until the problem is resolved.
- Delays the contractor from starting construction. Several projects were delayed because Duke Energy was not able to move its power lines during the peak winter and summer months.
- Utility relocation is not as bad on new location projects.
- One contractor estimated that 25% of the major projects will not have problems with utilities in urban areas. Green field projects sites can still have utilities (e.g., gas lines and high voltage power lines).

4.3.3 Permits

- From a contractor's perspective, permits are always a big deal and the method the NCDOT uses is not efficient—majority of the reason projects get delayed is not having the permit. For DB projects, permits happen between let date and start of construction. Obtaining permits is particularly an issue on projects with "major permits." Contractor is rarely held up with a nation-wide permit. The likelihood of delay increases if there is a need for a project specific CAMA, 401 or 404 permit.
- Can begin moving utilities in non-permit areas.
- On DBB projects, property is usually purchased, permits are in hand (most of the time) and utilities are far enough along by the bid date. For DB projects, the permit process in in the contractor's hand. They need to have final design completed before obtaining the permits. Design can start in parallel with going forward with permits or ROW.

- Projects that involve FEMA could cause delays.
- It was noted that permits are easier to obtain for DB contractors—the agencies trust the hands-on experience demonstrated by the contractors.

4.3.4 Railroads (RR)

- From a contractor's perspective, railroads can also cause problems. Contractors see that the NCDOT is trying to work with the railroad but it seems like, "it's their way or no way".
- Biggest problem with the railroads is coming through a bottleneck related to getting the plans approved and scheduling a flagman.
- Track time and flagging can impact construction performance—this has gotten better since the railroad began contracting out the flagging.

4.3.5 Right of Way (ROW)

- NCDOT delays the entry if contractor does not have permission to use the ROW.
- For DBB projects, by and large, 95% of the time, NCDOT has all utilities moved and ROW done before contractor signs contract.

4.4 Construction Phase (Predicting the Construction Payout Curve)

4.4.1 Cash Flow Prediction

- The most significant variable for predicting the payout curve is when the letting will take place.
- The accuracy of the contractor's payout curves for DB projects is "hit or miss". It was noted that HiCAMS uses the contractor's projected payout curve for predicting future cash flows.

4.4.2 Payout Schedule Development

- Contractors typically develop their anticipated expenditure curves based on a detailed CPM schedule and assign dollars from the bid to each item. They are fairly confident with their expenditure curve when they turn it in. Events can occur beyond their control such as obtaining permits in a timely manner and weather issues. For example, the past two to three years have been wet and this makes it difficult to get the work done. They assume "normal" conditions in their bid but actual conditions can turn out to be wetter than "normal"—which affects work especially in borrow and waste pits.

4.4.3 Contractor Payments

- Contractor invoices can be paid in the following four ways: end of month, 7th, 15th, or 22nd. This method allows for balancing the bills and cash flows.
- When asked if contractors are required to submit monthly progress and performance reports to the NCDOT it was discovered that the NCDOT does not require contractors to submit them. The NCDOT, however, does ask for a payout schedule at the beginning of construction for DB or DBB projects $50 million or greater in size. Payout schedules are then updated on a quarterly basis.

4.4.4 DBB Projects

- For DBB projects, the schedule of payments should be fairly accurate as long as the contractor does not front load the bid.

4.4.5 DB Projects

- The first payment can be as much as 5% of the total cost—if full mobilization and start of construction activities are allowed to begin. If the contractor needs to obtain permits—there is usually a 9-10 month delay. In this case the contractor will generally receive 2.5% of the total contract amount for the first payment and the other 2.5% will be provided later (after all permits are approved). It was noted that the contractors need to arrange for all of the permits and ROW—the NCDOT pays for the ROW cost. This takes some of the burden off of the contractor and places it on the owner.
- For DB projects, the first year is primarily design.
- To determine the actual "construction" cost in a DB project, use the DBE cost as a basis since it is calculated based on the actual construction dollars (excluding the design cost).
- It is very difficult to separate out the PE and ROW costs in a DB project. All of the PE costs may be under one of the projects which includes multiple projects.

4.4.6 Overruns

- DB cost overruns are typically higher than DBB overruns.

4.4.7 Contractor Suggestions for Accelerating the Project Schedule

- All contractors are trying to do the work as quickly as possible. There needs to be incentives for contractors to accelerate the schedule. It was noted that a bonus was used on the I-40 Olympics Project.
- NCDOT needs to make sure there are no delays because of issues related to permits, ROW, etc.
- Get decisions made quicker—contractor doesn't want to be in limbo.
- Anything you can do to allow for quicker reviews and decisions on some critical items would help. Ten days is the required turnaround—and it always seems to take 10 days even though a contractor asks for an expedited review and decision.
- Eliminate conflicts with the utilities.
- Eliminate uncertainty on what the contractor needs to do.
- Grant extensions on a yearly basis instead of at the end of the project. NCDOT keeps up with weather delays but does not grant extensions until the end of the project.
- Contractors need help in fighting local ordinances. For example, working at night in an urban area with truck back-up alarms is a problem if there is a noise ordinance—contractor will need help. Public will probably not be happy.
- On major complex projects there is a need to have early contractor involvement. Contractors will be able to identify direct issues or those that can cause potential problems. It appears that after providing input, the jobs still have some of the same issues. The NCDOT needs to be a better listener of contractor suggestions early in the process. The appropriate time for contractor involvement is when there are enough plans or concepts of plans—need to be involved early enough to be able to make a change in the design. Sometimes the NCDOT brings the contractors in too late in the review process. It was noted that NCDOT is far more accepting when they have not developed their project very far. If the NCDOT has already studied all of the alternatives then there will most likely not be any changes allowed by the contractor.

- Allow for innovations to be used in the field such as the use of alternate soil stabilization methods (e.g., geofabrics and stone). This could allow the contactor to begin paving earlier—possibly before winter and not have to slip the schedule by several months.
- For DB projects, NCDOT could be more receptive to designs that are approved and used in other states. Not accepting such designs hurts out-of-state contractors.
- Maryland is using some innovative contracting techniques. Allow for contractor to work with the design team for a DBB and DB project and then provide the contractor with the first chance at negotiating the construction portion. If negotiations fail after a few days, then the project can be open for bid.
- Related to payments, some NCDOT divisions require detailed quantities in place (e.g., CY concrete, rebar paid by weight, LF of silt fence, etc.) to determine the estimated monthly pay amounts. In a sense, the NCDOT is treating the project as a DBB causing extra work by the contractor to provide the units needed for determining the pay amounts. In a DB project, the contractor might not use the same units as the NCDOT—as is prescribed in a DBB project. It was noted that each Division determines pay amounts differently—some use a DBB approach to establish pay amounts and others not. Methods for assessing progress for payment is different in each division—some convert work to unit prices and others accept the contractor's percent complete estimate.
- It was noted that HiCAMS is not set up for DB projects. On the Carolina Bay's project, four months would go by after the work was done before the contractor got paid—shaft testing (representing 1% of the work) was holding up payment on the other 19%. Contractor ends up paying the subcontractors on time using its own working capital. For design payments, this is not an issue since there is a well-defined schedule of values.
- Use more DB and let the private sector design the project.
- Use the Project Executive's Priority Office if there is a project that needs shepherding (as was done on I-77 and Yadkin River). Same group got us an EA FONSI quickly (~2 years)—did not need to go through the merger process. This can become administratively a burden on small projects – on larger projects this process works well.
- NCDOT is too prescriptive—consider being more performance-based. In the example cited, the NCDOT required the contractor to use a box spreader—whereas, another approach might have been just as effective, if not more so..
- Contractors need the opportunity to innovate. This is possible on the DB projects but not for DBB projects.

5 CHECKLIST FOR MEETING LETTING DATE

5.1 Checklist Development

Strategic activity milestones were identified prior to bid letting, in order to provide the necessary insights into meeting a project let date. These milestones were then used to develop a checklist to assist NCDOT in improving its chance of meeting project let dates. The research team first divided projects into DBB and DB groups because the two types of projects have different payout characteristics. The data on DB projects were found to be limited and fragmented. Therefore, the researchers focused on DBB projects only for this analysis. Because the project data recorded activity history at different levels of detail, a set of standardized strategic milestones were implemented. The milestones for DBB new location projects are as follows:

- Concurrence Point 3
- ROD or FONSI
- Location and Design Approval
- ROW Authorization
- Final Plans to Design
- Roadway Plans to Contract and Proposal
- Utility Agreement
- Permit

The research team identified the completion date of each activity and used each project's actual let date as a comparison point to calculate at how many months before the actual let date those activities were completed. Figure 5.1 combines the completion dates for all the DBB new location projects. The number on the left end of each horizontal bar represents the earliest completion month from the let date. The number on the right side of each bar represents the latest completion month. The aforementioned strategic milestones should be checked before the latest completion month of the milestone to increase the likelihood of meeting the let date for the project.

Figure 5.2 combines the completion dates for all the DBB widening projects. The milestones for DBB widening projects are as follows:

- Concurrence Point 3
- FONSI or CE OR EIS
- Location and Design Approval
- ROW Authorization
- Final Plans to Design
- Roadway Plans to Contract and Proposal
- Utility Agreement
- Permit

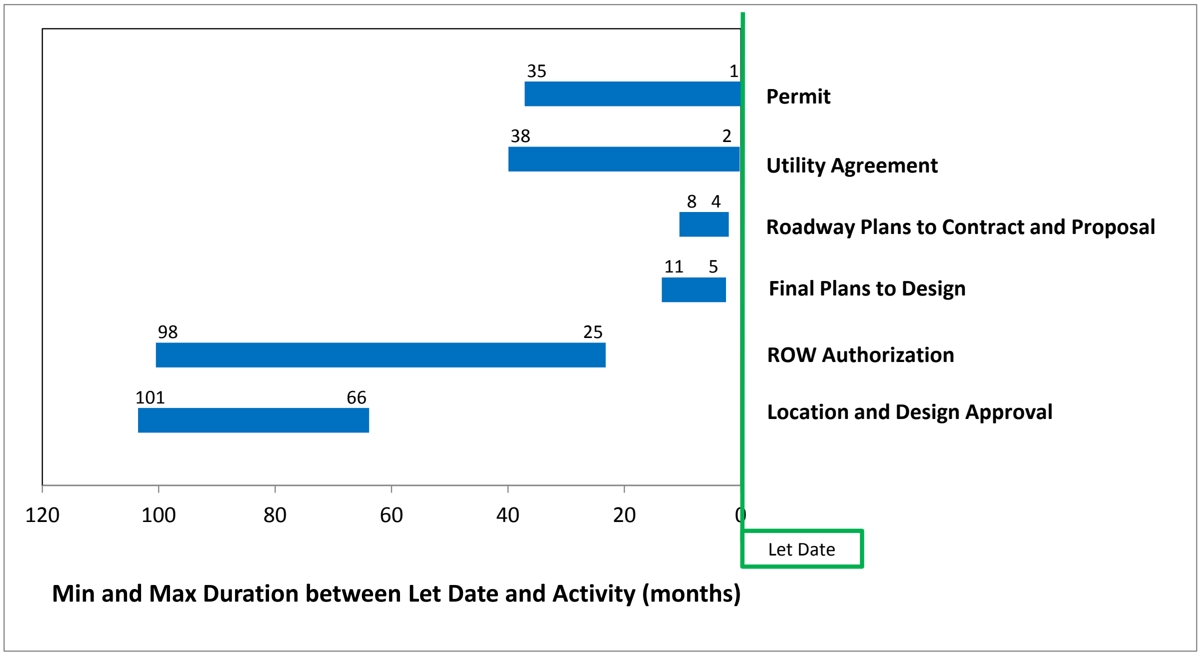

Figure 5.1 Strategic Milestones Analyses for DBB New Location Projects

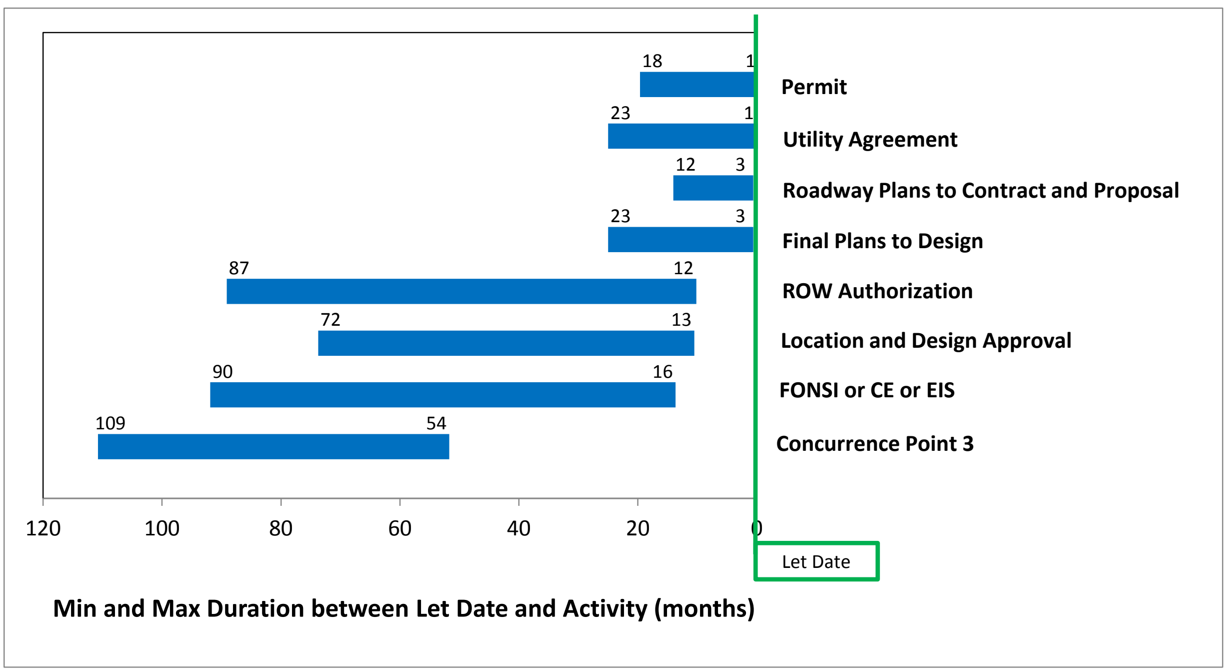

Figure 5.2 Strategic Milestones Analyses for DBB Widening Projects

5.2 Checklist for DBB New Location and Widening Projects

Table 5.1 demonstrates the checklist for DBB new location projects. Table 5.2 shows the checklist for DBB widening projects. As strategic milestones are accomplished before the minimum latter date for each milestone, the probability of meeting the let date increases.

Table 5.1 Checklist for DBB New Location Projects

Design-Bid-Build New Location Checklist*			
no.	**Description**	**Yes**	**No**
1	Does the NCDOT have **Location and Design** Approval at least 66 months before the let late?		
2	Does the NCDOT have **ROW Authorization** at least 25 months before the let date?		
3	Does the NCDOT have **Final Plans to Design** at least 5 months before the let date?		
4	Does the NCDOT have **Roadway Plans to Contract and Proposal** at least 4 months before the let date?		
5	Does the NCDOT have the **Utility Agreement** at least 2 months prior to the let date?		
6	Does the NCDOT have the **Permit** at least 1 month before the let date?		

*Due to the lack of data, Concurrent Point 3 and ROD or FONSI are not included

Table 5.2 Checklist for DBB Widening Projects

Design-Bid-Build Widening Checklist			
no.	**Description**	**Yes**	**No**
1	Has the NCDOT established **Concurrence Point 3** at least 54 months prior to the let date?		
2	Does the NCDOT have a **FONSI or CE OR EIS** at least 16 months prior the let date?		
3	Does the NCDOT have **Location and Design Approval** at least l3 months before the let date?		
4	Does the NCDOT have **ROW Authorization** at least 12 months before the let date?		
5	Does the NCDOT have **Final Plans to Design** at least 3 months before let date?		
6	Does the NCDOT have **Roadway Plans to Contract and Proposal** at least 3 months before let date?		
7	Does the NCDOT have the **Utility Agreement** at least 1 month before the let date?		
8	Does the NCDOT have the **Permit** at least 1 month before the let date?		

6 CONSIDERATIONS FOR DESIGNING A NEW CONSTRUCTION PAYOUT MODEL

This section presents preliminary considerations for predicting the construction payout curve for individual mega projects. In order to predict the payout curve, it is important to first predict the bid letting date, and subsequently, start of construction. As was explained in the previous section, achieving a let date depends, in a large part, on achieving key strategic milestones (e.g., ROD FONSI, Location and Design Approval, and ROW Authorization). These milestones differ depending the project delivery approach (DB versus DBB) and the type of project (widening versus new location). Missing any of these key milestone dates could increase the chance of missing the let date. Also as noted earlier, there is greater certainty in determining the duration between the let date and start of construction than there is in establishing the let date. Additionally, project data for mega projects revealed that DBB projects take approximately 44 days from the let date to when construction can begin compared to 38 days for DB projects. This information provides insights into the date construction begins and the potential start of the payout curve.

Predicting the shape of the payout curve itself is more challenging due to the fact that its shape changes because of supplementals, time extensions, and for other reasons. Furthermore, DBB contractor costs are solely related to construction as the DOT's PE cost will include design costs. For DB projects, PE costs will most likely not include design costs; thus, DB payout costs will include both design and construction costs, at least initially. Appendix 11.4 shows that typical PE costs for DBB projects are approximately 10% of construction cost. The research team was not able to calculate the design cost for DB projects since this portion is not itemized in the contractor invoices. Permits, ROW, and utility issues are addressed prior to the let date for DBB projects allowing them to begin construction immediately. For DB projects, since the design is not completed, the contractor will need to obtain permits which could delay construction activities on some parts of the site. The DB contractor may also need to deal with utility relocations and the railroad prior to construction start. For these and other reasons, it is anticipated that the payout curve will be unique for every project.

6.1 Performance of Completed Mega Projects

It is unrealistic to assume that both cost and schedule factors will be equal to 1.0 throughout the life of the project. These factors are calculated by dividing the estimates at completion by the original bid price and duration. A cost and schedule factor of 1.0 means that the project was completed based on no changes to the original bid amount and duration. Tables 6.1 and 6.2 show cost and schedule factors for completed DBB and DB mega projects, respectively. For DBB projects, the average cost increase was 3% (cost factor = 1.03) while the highest cost increase was 14% (cost factor = 1.14) over the bid amount. It is interesting to note that 71% of the DBB projects met or exceeded their cost expectations while none of these projects finished within the original bid duration.

Instead, they finished on average 14% (schedule factor = 1.14) longer than predicted with one project taking 41% (schedule factor = 1.41) longer than predicted. For DB mega projects, the cost increased by 6% and schedule increased by 14% on average. Still, on average, DB projects exceeded their bid cost by on average 6% and their estimated project duration by 14%. For DBB projects, the averages were 3% and 14%, respectively. Thus, both contract types are performing at similar levels. Only 9% of these projects met or exceeded the bid amount and 36% were completed on time.

Table 6.1 Cost and Schedule Factors for Completed DBB Projects (n=7)

At Completion	Cost Factor*	Schedule Factor*
Low	0.92	1.01
High	1.14	1.41
Average	1.03	1.14
Met or Exceeded Bid (%)	71%	0%

*Cost Factor = Final Estimated Cost/Bid Amount
**Schedule Factor = Final Estimated Duration/Bid Duration

Table 6.2 Cost and Schedule Factors for Completed DB Projects (n=11)

At Completion	Cost Factor	Schedule Factor
Low	1.0	1.0
High	1.18	1.50
Average	1.06	1.14
Met or Exceeded Bid (%)	9%	36%

6.2 Construction Payout Curves for Completed Mega Projects

Standardized payout curves for completed DBB and DB projects are provided in this section. The research team analyzed data on actual construction expenditures from let date to project completion for completed projects (>99% complete). Some projects had multiple payments in the same month that had to be combined. In order to normalize the data, researchers calculated % time (the actual project duration at a given point in time divided by the duration established in the initial contract) and % cost (actual monthly expenditure divided total project contract budget established in the initial contract). The payout curves for DBB projects and DB projects are illustrated in Figures 6.1 and 6.2, respectively. It is interesting to note that the payout slope is steeper initially for DBB projects compared to DB projects as the initial payments for DB projects include mostly design and fewer construction-related costs.

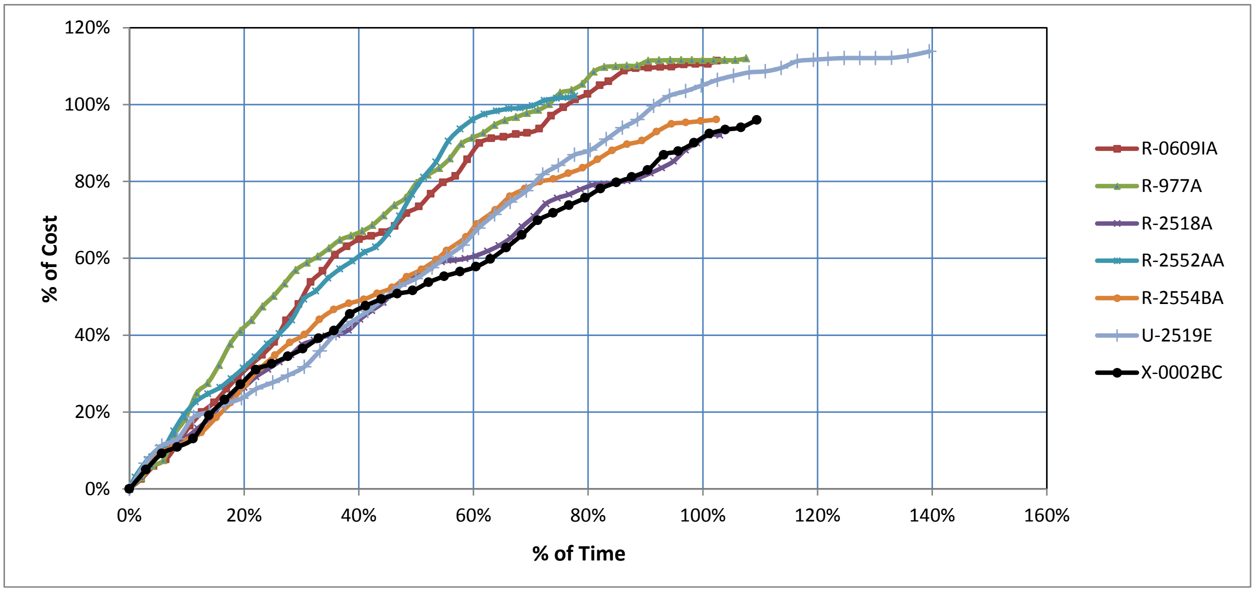

Figure 6.1 Payout Curves for DBB Mega Projects

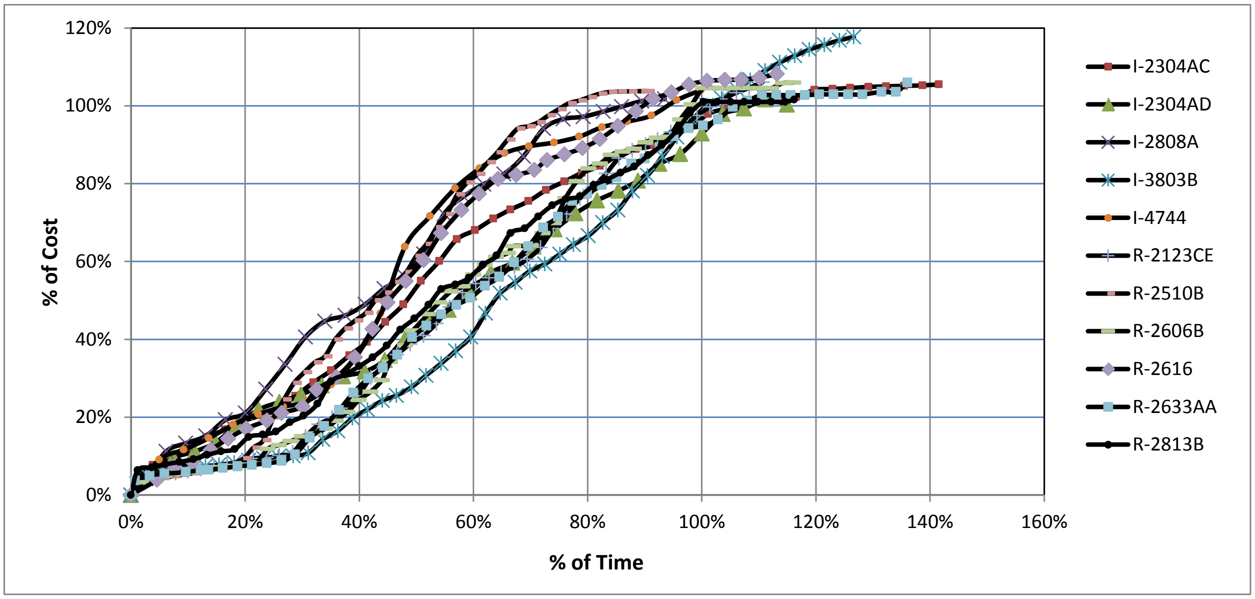

Figure 6.2 Payout Curves for DB Mega Projects

6.3 Timeframe of Payout Curve Development

Figure 6.3 shows a timeframe for predicting the payout for DBB "new location" projects reflecting the life cycle of the project from inception to substantial completion. This figure shows the strategic milestones during the preconstruction phase that, if met, improve the likelihood of meeting the scheduled let date. Missing any of these milestones will likely impact the let date. Still, if a milestone is not met, corrective actions can be taken in a timely fashion to meet the scheduled milestones. However, the exact recovery plan will depend on which milestone activity is delayed. The probability of meeting a let date can then be assessed using this model.

The bidding phase duration covers the bid let date to the start of construction when the contractor can officially begin work. For DBB contractors, this means the actual start of construction. For DB contractors, there is a period of time initially when the design is completed, permits are obtained, ROW is obtained, utilities are relocated, and any issues with the railroads are addressed (if necessary). Thus, the contractor is engaged in the project much earlier for DB projects. DB contractors are allocated up to 5% of the total bid amount for the first payment if all of the necessary permits are acquired by the let date. Otherwise, they are granted 2.5% of the total to cover design costs and to mobilize on the site. Construction activities can begin in earnest for a DB contractor typically 9-10 months after the letting. For these reasons, it is important to consider all of these differences in designing a payout curve model.

Figure 6.3 also shows payout curves for five different DBB "new location" projects. They all start assuming a schedule and cost factor of 1.0 (i.e., final cost and schedule equal the original plan at time of bid letting). As can be seen, two of the projects finished with cost factors below 1.0 (projects 3 and 4) and two of the projects exceeded 1.0 (projects 1 and 5) and in fact both were greater than 10% of the original bid amount. These payout curves reflect the shape after project completion. To better illustrate this concept, termination points are located in different zones (e.g., project 5 started in quadrant A-3 and finished in D-1). One can clearly see that the payout curve shape changes throughout the construction phase.

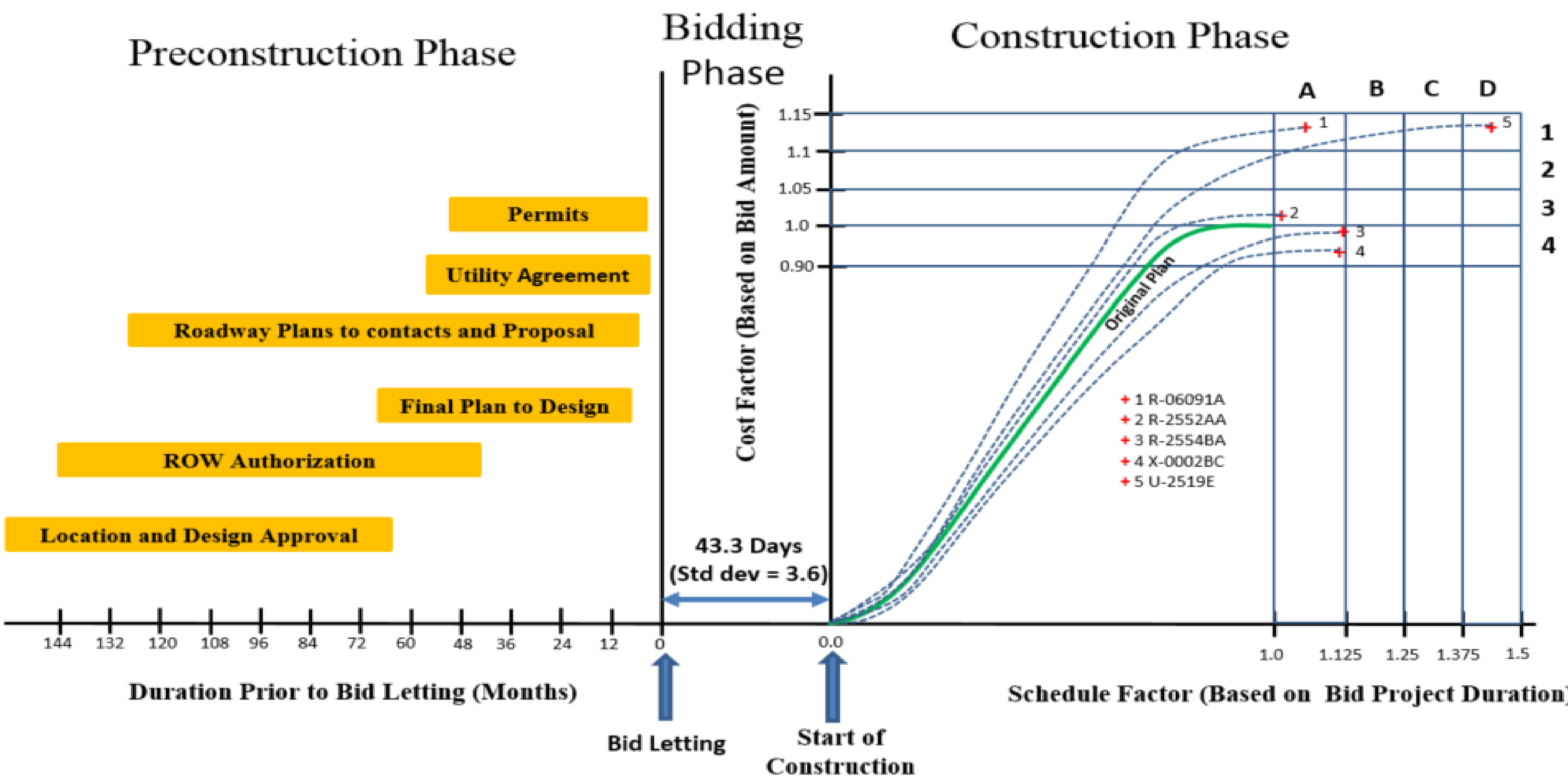

Figure 6.3 Timeframe of Payout Curve Development for Design Bid Build "New Location" Projects*

*For illustration purposes only

Figure 6.4 shows how the payout curve changed for project #5 (U-2519E) as shown in Figure 6.3. Initially, the project began on July 7, 2009 with a cost and schedule factor of 1.0 (as shown in quadrant A-3). The bid amount was $52,553,157.52 with a 1,099 day duration. Within the first month of the project, the estimated cost was reduced compared to the bid amount, and thus, the cost factor went below 1.0 (see quadrant A-4 on August 8, 2009). An approximate $7.8 million supplemental was approved on February 8, 2011 which increased the schedule by 183 days causing another payout curve change (from quadrant A-4 to B-1). Finally, at the end of the project, a claim was filed granting the contractor an additional 270 days to complete the project, again changing the shape of the payout curve (refer to quadrant D-1). From this example, it is important to note that the model design needs to be flexible enough to adapt to changes that most likely will occur during the construction phase. Sufficient data is provided in HiCAMS to identify these costs and schedule changes and thus provide the ability to reconfigure the payout curve in real time throughout the construction phase.

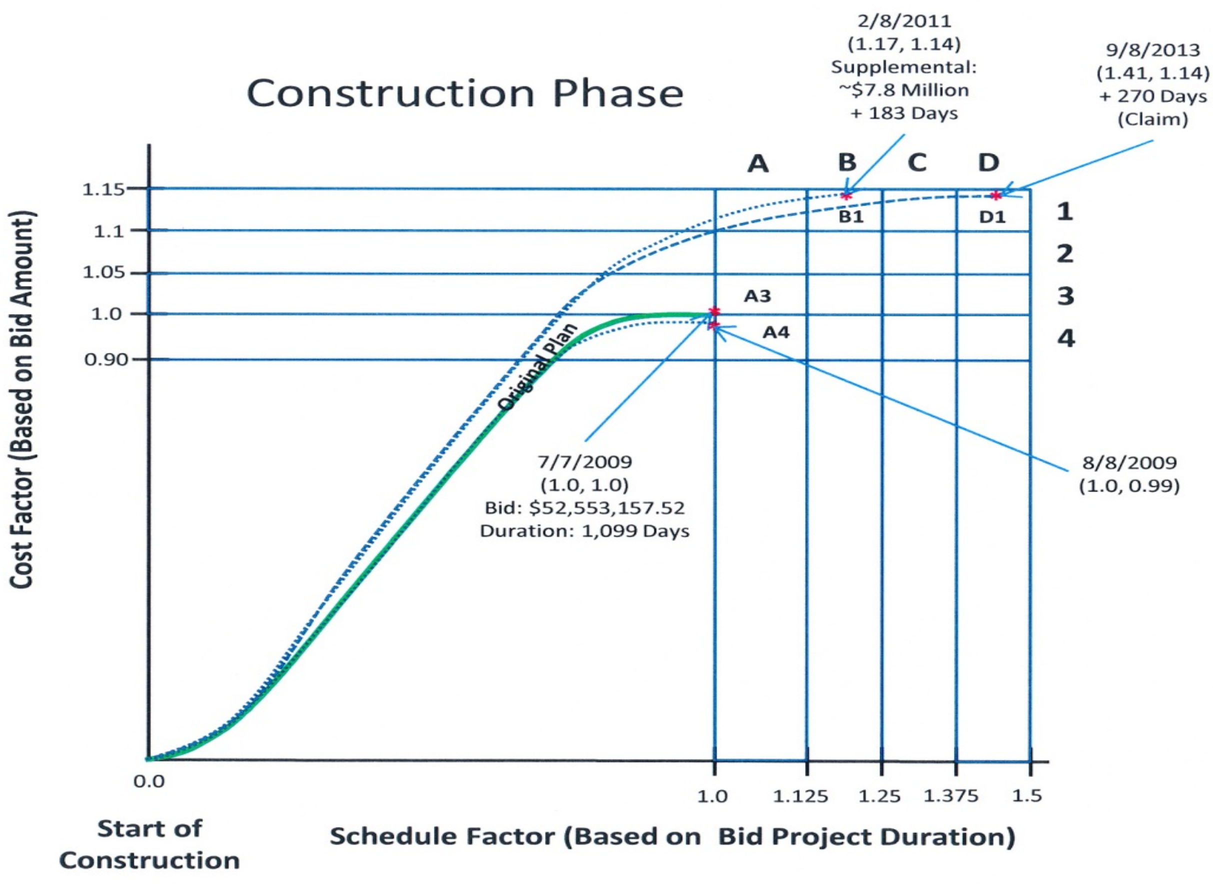

Figure 6.4 Change in Payout for C201977 (U-2519E) (DBB "New Location")

As illustrated above and in Figure 6.4, the shape of the payout curve changes when the project schedule changes--the termination point is moved to a new quadrant location e.g., from A-4 to B1. When the project cost changes at any point in time, a mathematical model of the new forward looking payout curve can be determined from the date of the last contractor payment to the new estimated project completion date. By following this approach, a more accurate projection of future payouts can be attained. These considerations are taken into account in the next section that provides a more detailed description of payout models that can be used during the preconstruction and construction phase.

7 CONSTRUCTION PAYOUT MODEL DESIGN

7.1 Current Approach

NCDOT's current approach for payout curve estimation is called Composite Construction Model (CCM), which estimates monthly payout values using an average (dividing total estimated cost by total project duration). Because mega project payout estimation can affect NCDOT cash balance significantly, it is critical to develop a tool to accurately estimate individual mega project payouts. In this chapter, we focus on DBB mega projects per NCDOT's preference. Section 7.1 reviews NCDOT's current cost estimation methods during the preconstruction and construction phases. Section 7.2 proposes three model designs—two for the preconstruction phase and one for the construction phase.

7.1.1 Preconstruction Phase

NCDOT project cost estimation includes six stages of estimates. They are Conceptual Estimate, Feasibility Estimate, Functional Design Estimate, Preliminary Estimate, Right of Way Estimate, and Final Estimate (see Figure 7.1). The accuracy of the estimate increases over each phase as more design details are developed and more information becomes known to the engineers.

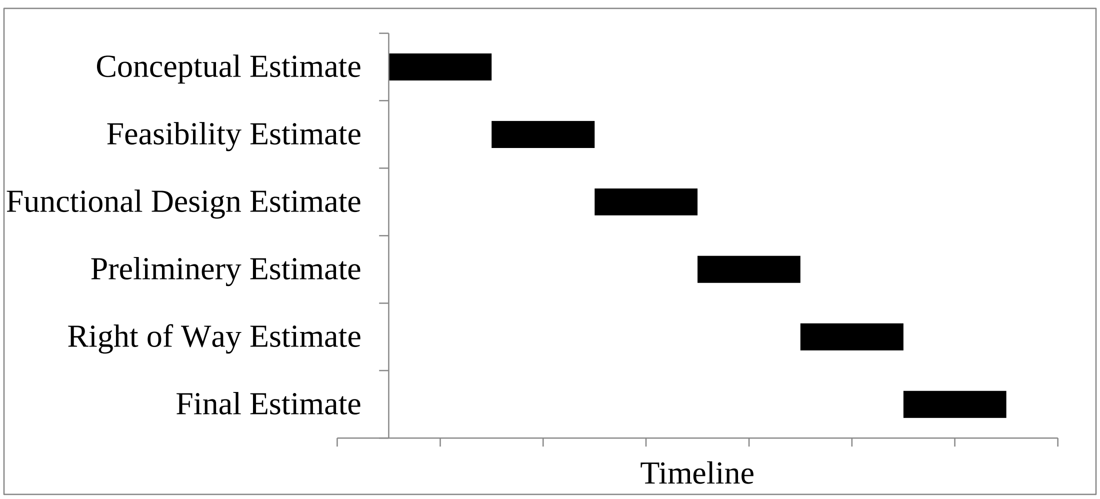

Figure 7.1 Six Phases of NCDOT Preconstruction Estimates (not to scale)

Based on the total itemized cost, the estimation accuracy is in a 45-55% range of uncertainty for the Conceptual Estimate, a 15%-45% range for Feasibility Estimates and Functional Design Estimates, 10%-35% for Preliminary Estimates, 10%-25% for Right of Way Estimates, and 5-10% for the Final Estimate. Those ranges of uncertainty are reflected as Misc. & Mob (Miscellaneous and Mobilization factor) in the estimate. The Misc. & Mob is then split into Structure & Utilities and Roadway. At the Final Estimation stage, usually 5-10% is given to Structure & Utilities and 10-15% to Roadway. Adding the Misc. & Mob cost to the total itemized cost yields the contract cost. The total construction cost includes contract cost and other costs such as those for engineering inspections and contingency which typically are set at

10% for State projects and 15% for Federal projects. The Estimation Management office of the Contract Standards and Development Unit is mainly responsible for the estimates.

7.1.2 Construction Phase

At the time construction begins the contractor provides NCDOT with an estimated payout curve for the entire project. This payout curve identifies the total estimated project cost and duration as well as the varying monthly payout amounts. However, only the total cost and duration are currently used by the Funds Administration Section to create the estimated payout curve (used internally) by dividing the total cost by the total project duration (in months) to yield an average payout per month for the project (a straight line estimate). This average then is used internally to estimate project payment needs over the duration of the project. The monthly estimates provided by the contractor are not used for this purpose.

The net result of the current process is that the average estimated project monthly payouts are satisfactory for all projects when they are aggregated together, but they do not provide a good monthly estimate of the actual expenditures on an individual basis. This is shown clearly in Figure 7.2 (true payout curve compared to the straight line estimate) which is further discussed in the next section. Thus, the goal of a new model is to more accurately determine the monthly amount of estimated expenditure so that aggregate values more accurately match actual values.

7.2 Improvements to the Current Approach

7.2.1 Preconstruction Phase

7.2.1.1 Marco Approach-Develop Statistical Models for Different Types of Mega Projects

The S-shaped or sigmoid model is the theoretical shape of construction cumulative payout curve. However, examining actual payout curves for completed DBB mega projects shows that they follow a convex shape curve (more like an inverted banana curve). The correlation between the total cost of the seven DBB mega projects and the average percentage difference from a Straight-line payout is -0.74. It means that there is a difference in the shape of the payout between larger and smaller projects. Smaller projects tend to be more convex; whereas, larger projects are shallower in convexity (see Figure 7.2). It is also worthwhile to note that the greater the maximum difference between actual and straight-line payments the higher the standard deviation, which indicates more variability in the payout values for projects less than $100M.

The first proposed approach to predict individual DBB mega construction payout curves during the preconstruction phase is the macro approach. It includes creating statistical models using past payout data. There are different factors that influence the shape of the payout curve as follows:

- Type (rural widening, rural new location, bridge, interstate)
- Location (Mountain, Piedmont, Coastal)
- Seasonality (Spring, Summer, Fall, Winter)
- Bid Amount
- Duration

Developing a standardized curve for each type of project requires understanding the characteristics of each project. For instance, in bridge projects the NCDOT compensates contractors for the superstructure when it is complete. A surge payment will occur after the superstructure is delivered. So, it is critical to predict when that payment will take place in order to plan ahead for such a significant payment.

Preliminary statistical analyses were performed for the following projects in Table 7.1:

Table 7.1 Projects used in the Analysis

Project STIP	Cost ($)	Duration (months)
R-977A	53,753,899.15	56
R-2552AA	126,171,425.86	38

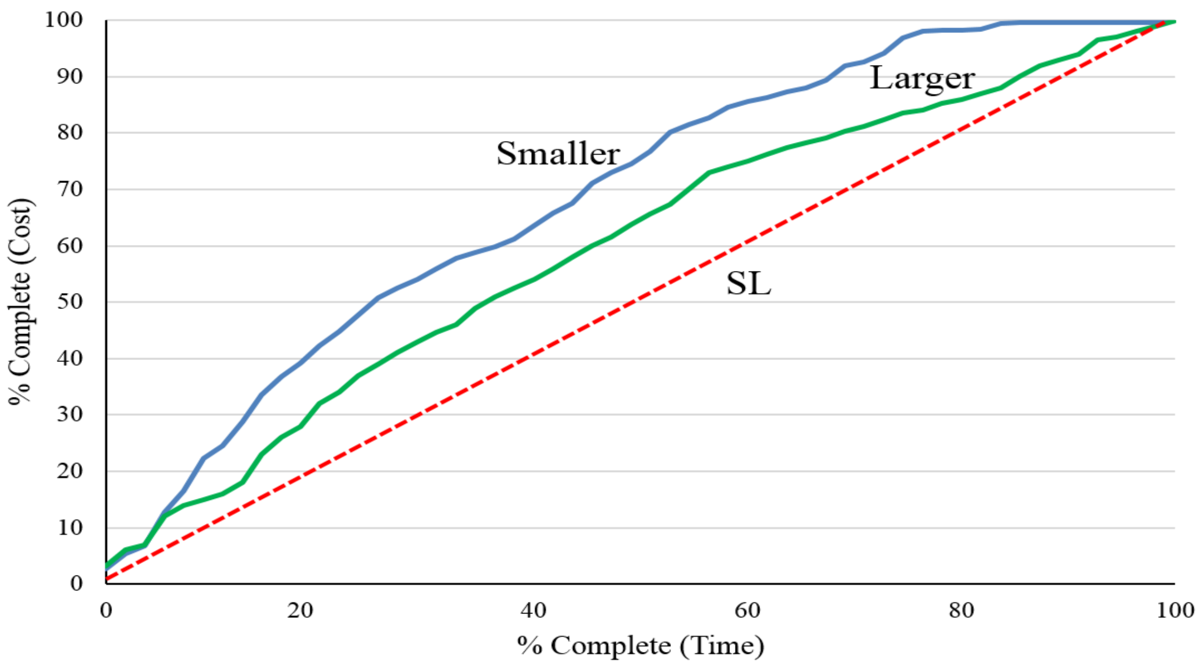

Figure 7.2 Impact of DBB Project Size on the Shape Payout Curve

Figure 7.3 shows that the straight-line approach below predicts the cumulative actual payout curve for both projects. Consequently, there is a need to develop a better payout model.

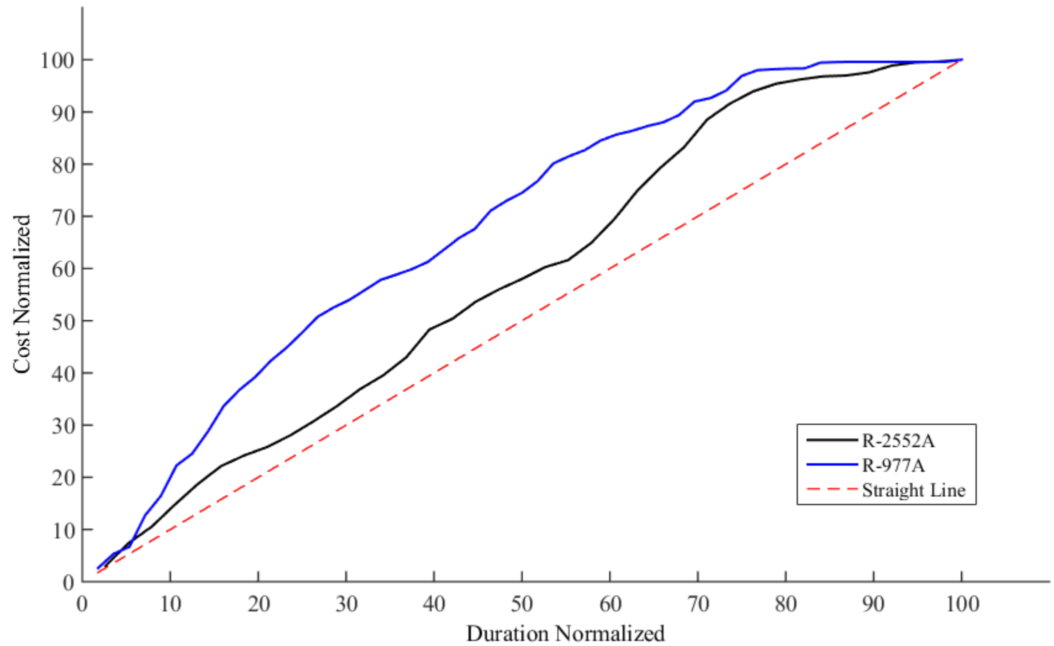

Figure 7.3 Comparison Between Actual Payout and the NCDOT Current Forecasting Approach

Table 7.2 shows eight models that were created for project R-977A using the software MATLAB. The sum of squares error (SSE) and the R-square statistics are examined to determine the best fit for the data. This analysis gives insights of the payout behavior for projects less than $100M. Figure 7.4 demonstrates the third order polynomial predictive curve plotted in comparison with the straight-line curve and the actual payout including the seasonality effect. The absolute average difference between the straight-line curve and the actual curve is 50% and between the third order and the actual curve is 4.08%.

Table 7.2 Statistical Models for Project R-977A

Function Name	SSE	R-Square	Function
1st order	3473	0.9279	Y= 18.75 + 0.9789*X
2nd order	184	0.9962	Y= 0.6283 + 2.026*X - 0.01029*X2
3rd order	177.2	0.9963	Y = -0.3955 + 2.142*X - 0.01311*X2 + 1.844e-05*X3
4th order	88.31	0.9982	Y= -4.915 + 2.965*X - 0.04873*X2 + 5.596e04* X3 -2.658e-06*X4
Exponential	8529	0.8229	Y = 34.21*exp(0.01257*x)
Gaussian	418	0.9913	Y = 101.4 *exp(-((x- 87.8)/ 50.5)^2) + 26.65* exp(-((x- 33.01)/ 24.12)^2)
Rational	253	0.9947	Y = (168.9*x -322) / (x + 57.94)
Exponential after the transformation of the Actual payout (using the natural logarithm	0.205	0.9939	Y = 3.918* exp(0.00186 *x) - 3.58* exp(-0.118*x)

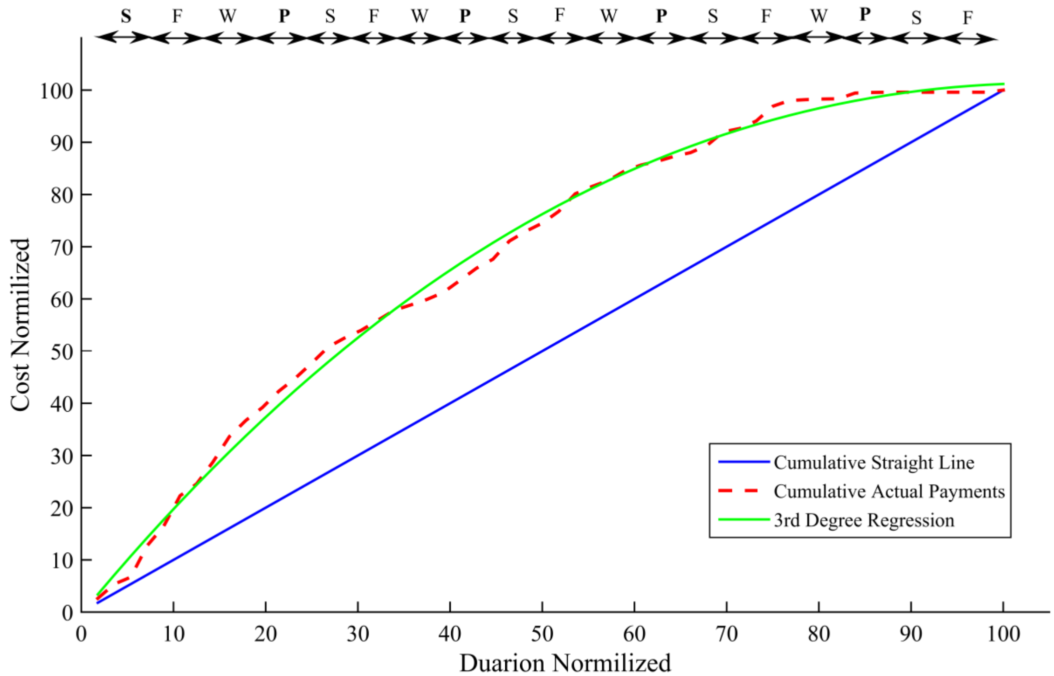

Figure 7.4 R-977A Payout Using 3rd Degree Regression Modeling

Another analysis was conducted on project R-2552AA to gain insights on the characteristics of mega projects above $100M. Six models were developed to predict the payout curve using MATLAB (see Table 7.3). The fourth order model generates the best-fitted curve that produces the least SSE and an R-square value near one as shown in Figure 7.5. The absolute average difference between the straight-line curve and the actual curve is 19.4% and between the fourth order and the actual curve is 2.78%.

Table 7.3 Statistical Models for project R-2552AA

Function Name	SSE	R-Square	Function
1st order	658.1	0.9824	Y= 4.068+ 1.077*X
2nd order	446.1	0.9881	Y= -1.647+ 1.402*X -0.003174*X2
3rd order	226.6	0.9939	Y = 5.801 + 0.5842*X + 0.0165*X2 - 0.0001278*X3
4th order	111.2	0.997	Y= -1.006+ 1.772*X -0.03404*X2 + 0.0006314*X3 -3.699e-06 *X4
Exponential	460.4	0.9877	Y = -5.49e+06*exp(-0.00257*x) + 5.49e+06 * exp(-0.002569*x)
Rational	473.6	0.9873	Y = (479.2*x -466.5) / (x + 340.3)

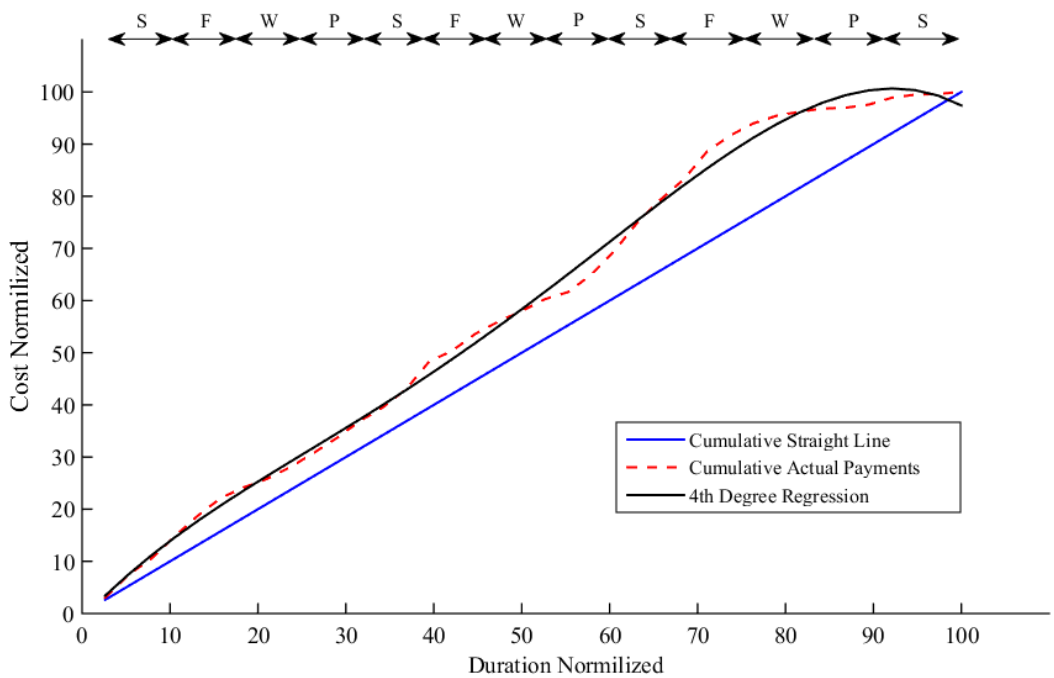

Figure 7.5 R-2552AA Payout Using 3rd Degree Regression Modeling

The statistical model is expected to generate a sophisticated payout model for individual DBB mega projects than the current NCDOT approach. Standardized curves will be modeled for different project types, and they will be adjusted to the factors that apply to the forecasted projects (e.g., location, seasonality, bid amount, and duration). The accuracy of the different models relies on including large data sets of actual historical expenditures. The current data set includes seven completed projects. To overcome the limited number of projects, the data sets can include older projects after applying inflation factors. In addition, including older projects that are above $30-40M to the data set will enhance the accuracy of forecasting. The inputs to the forecasting tool will be:

- One of the following: the bid amount, conceptual estimate, feasibility estimate, functional estimate, design estimate, preliminary estimate, right of way estimate, and final estimate
- Project duration
- Date of the first payment
- Project type
- Location

After inserting the above inputs, the forecasting tool will provide the monthly expenditures for the project. For example, if the design estimate for a project R-XXXXAB, a fictitious project, is $55M and the typical duration of such a project size is 40 months, the tool will generate the cumulative monthly payout for the project based on its characteristics (type, location, seasonality). If the estimating department provides a new estimate in the preliminary stage for the same project, $70M, and the correlated duration is 50 months, a new cumulative curve can be produced. Figure 7.6 shows the design estimate and the preliminary estimate cumulative payout curves for the same project assuming the 3rd order model applies for the project.

The forecasting tool will also have the ability to adjust the curve when a time extension or a supplemental is granted. Also, the curve can be adjusted for user specified scenarios. For example, if the user wants to produce the monthly expenditures for a bridge project a user expects that it will be 15% behind schedule in terms of cost or duration, the tool will be able to generate the monthly expenditure of the adjusted time for the project by adjusting the standardized curve for the typical bridge project. Furthermore, the forecasting tool will generate the cumulative monthly expenditures for the included portfolio of projects. The contribution of this tool will enable the NCDOT to forecast the DBB construction payout curve after the project is programmed during the preconstruction phase.

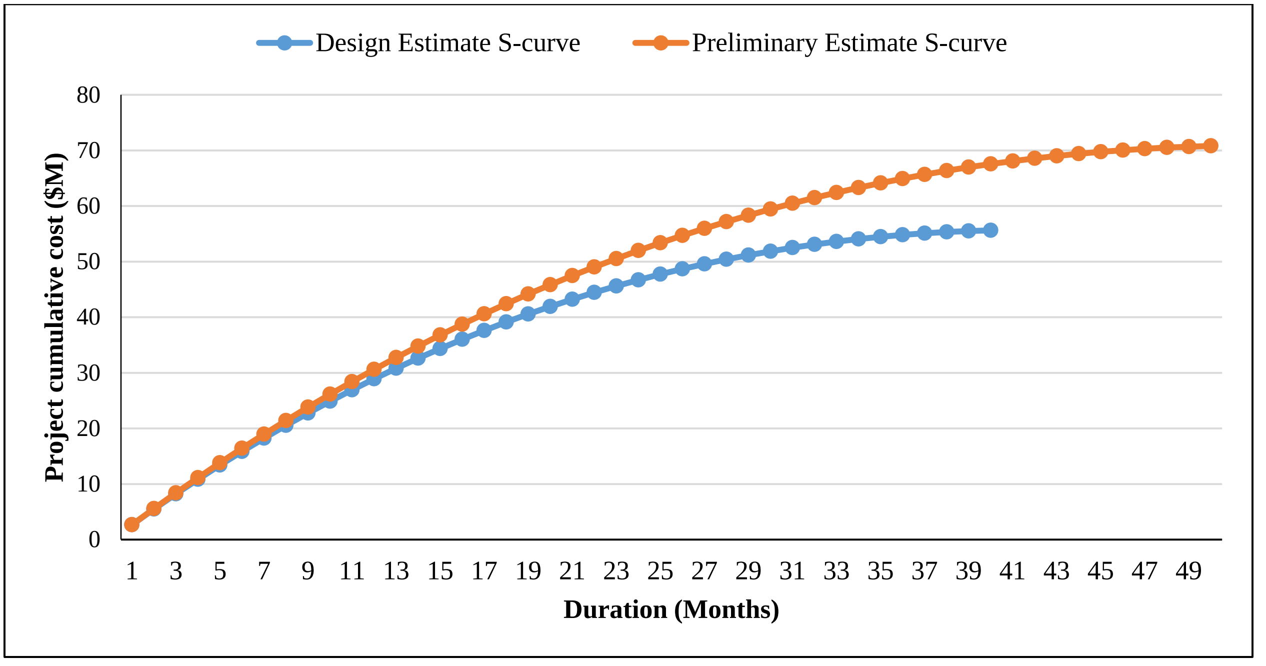

Figure 7.6 Cumulative Payout Curves for a Fictitious Project using a Different Estimate Basis

7.2.1.2 Micro Approach-Build a Generic Resource Loaded Schedule for this Type of Project

A second proposed method is called Micro Approach, which requires to generate the project cost and schedule from the bottom up. Thus, a more customizable payout curve can be created for each type of project.

NCDOT has published Bid Averages books annually since 2001. This comprehensive database has project characteristic descriptions on all projects let every year. It includes let date, TIP number, contract number, project number, county, vendor name, total project cost, project length, lane fill depth, bridge superstructure type, bridge span & width, bridge length, area, division, location, etc. It also contains a bid average on each item, including item description, item quantity, average unit bid, etc. This bid average was calculated for state average and each individual division's average. This rich database can provide a solid foundation to develop a model using a bottom-up approach for improved construction payout curve estimation. The micro approach model development includes the following steps.

Step 1. Determine major general construction activities/items for each type of mega project. This requires studying past mega projects to develop a list of major activities for various types of projects and then validating or refining this list through interviews with engineers from the Estimation Management office. For example, a typical roadway project may include Mobilization, Erosion/Traffic Control, Clearing & Grubbing, Grading, Drainage, Aggregate Base Course, Asphalt Pavement, Box Culvert, Bridges, Permanent Signs, and Miscellaneous.

Step 2. Develop a database of unit cost for construction activities. Statistical data analysis will be conducted to identify the cost range and distribution for major and general construction activities. The first task will be to investigate the pattern based on project location. The bid average for each item for all 14 divisions for the past 14 years will be collected from the Bid Averages book. The next step is to compare and study whether project location is a key factor impacting item price. More bid average data based on project size, letting date, new or existing, and complexity level will also be collected as well. A clustering analysis can be employed to study the data collected above. Clustering analysis is the task of grouping a set of objects in such a way that objects in the same group (called a cluster) are more similar to each other than to those in other groups or clusters.

The appropriate clustering algorithm and parameter settings depend on the individual data set and its characteristics. Expert knowledge will be considered in clustering analysis. For example, when we discussed with the engineers in the Estimation Management office of the Contract Standards and Development Unit, it was pointed out that project size and new or existing projects are the key factors impacting unit cost in estimation. In general, the larger the project, the lower average unit cost is used. Widening projects usually require higher unit costs on items such as Clear & Grubb and Grading because there is more level of effort in this area.

Step 3. Collect sequence and productivity data for general construction activities. Interview NCDOT personnel of the Estimation Management office and Construction unit to identify average productivity for major construction activities and adjustment factors.

Step 4. Develop an Excel based tool to estimate project payout curves. The findings from Steps 1-3 will be used to develop the tool. Project characteristics such as size, location, type, complexity level, item quantity, and special requirements will be collected to estimate cost and payout curve. The tool will be structured by first identifying project characteristics (e.g., type, size, and location). Project characteristics such as size, location, type, and complexity level will be used to select the appropriate major construction items and associate unit costs. The tool will then multiply quantities of work with unit costs for those items. In addition, a Gantt chart can be developed based on activity sequence, productivity, and quantity. A payout curve will be generated based on the Gantt chart and cost estimates for each activity. Adding the Misc. & Mob cost and E & C cost will provide the Contract Cost and Construction Cost as well.

A simplified example is provided in Figure 7.7. In this roadway project, there are six major activities identified. They are Clearing & Grubbing, Grading, Drainage & Utilities, Base & Paving, Structure, and Miscellaneous. The unit cost of Clearing & Grubbing is $19,762/LS. The total area is estimated to be 200 LS and productivity is 10 LS/week. The estimated cost for this activity is $3,952,400 and duration is 5 months. Repeating the similar process for all activities, the tool can calculate the total project cost, duration, and develop a Gantt chart and payout curve as shown in Figure 7.7.

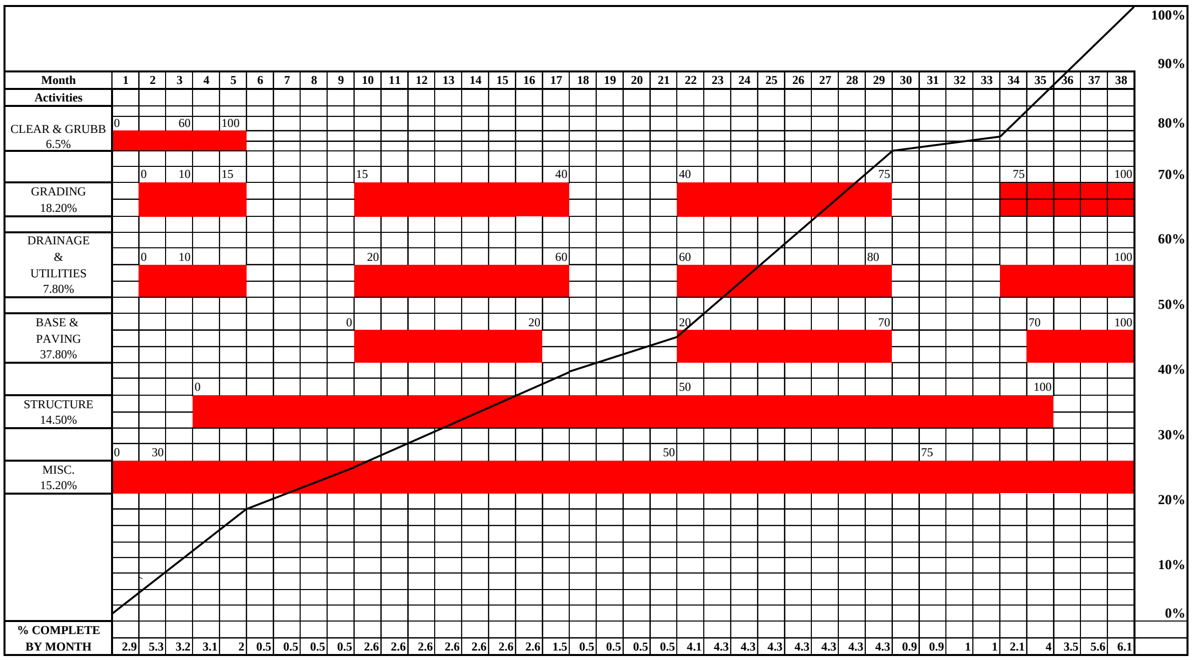

Figure 7.7 An Example of the Micro Approach Model

Step 5. Validate and refine the payout curve estimation tool. The payout curves developed from the estimation tool will be used to compare with the actual payout curves for validation and improvement purpose.

7.2.1.3 Discussion of Method Selection

Up to this point we have described two different standalone approaches for determining the project cash flows during the preconstruction phase. The next question to consider is which one should be used by NCDOT. As an alternative, another promising approach would be to investigate the use of both methods during the preconstruction phase. For example, use the macro approach early on when there is less scope and work definition available and switch to the micro approach when more detail is known about the project. We anticipate that we will explore this question further in the next phase of the project to clearly ascertain which of these approaches is most appropriate.

7.2.2 <u>Construction Phase</u>

Construction is an advanced engineering discipline that uses sophisticated scheduling tools to plan and execute the construction process. Those tools articulate all of the activities associated with a construction project including their cost, their duration, the labor required, and the equipment needed to perform the activities and execute the process. To be competitive contractors use these tools, especially on large projects such as those mega projects which are the subject of this work. To be effective it is essential that contractors create a detailed schedule and perform a detailed cost analysis. And then maintain the schedule and budget. Such a process results in the estimated project cost curve provided to NCDOT prior to be beginning of construction. No one is more keenly aware of his actual costs and anticipated expenditures than the contractor doing the work. For this reason the research team believes that the most accurate, up to date, and reliable source of estimated monthly payments for a mega project is the contractor in charge of the work.

During the course of construction, as time passes, many events occur to change the schedule and expenditures from the original. These events may be caused by weather, labor disputes, changes in project scope, and numerous other reasons. Each one results in a change in the future plan, thereby invalidating earlier plans. Such changes also invalidate earlier future monthly payout estimates. However, new estimates can then be generated that take into account the changes. Fortunately, NCDOT receives such change notification in the form of quarterly estimated payout curves. These updates take into account any new situations in the construction process on a quarterly basis. Thus, at the beginning of each quarter the NCDOT has a new estimate of monthly expenditures from that point in time onward to the project end (prior to that point in time any cost is an actual cost that has already been expended). However, each quarterly estimate is valid only for the next 3 months from the time the quarterly report was generated.

It is the contention of the research team that the contractor quarterly reports should be the most accurate source of cost estimates available to NCDOT. However, numerous problems prevent us from performing a complete and comprehensive analysis to verify this hypothesis at this time.

- First, NCDOT does not always receive the quarterly updates from the contractor. As a result, we did not have the necessary data to perform a complete or representative analysis.
- Second, NCDOT does not necessarily receive quarterly reports but may receive reports based on an uneven time period. As a result, the results are variable and inconsistent between time periods as the time periods themselves are not uniform.
- Third, the Funds Administration Section does not receive the quarterly updates from construction. As a result they were unavailable to the research team and they are also unavailable to the Funds Administration Section.

To address the first issue a follow on study could seek to obtain all the possible data that NCDOT has available in the Construction Unit. That data should be supplemented with data obtained directly from the contractor. An alternative is to seek all of the data from the contractor who is in possession of it.

The second issue would also be addressed by obtaining missing data. It is anticipated that if the NCDOT does not have the quarterly estimated payout curves then perhaps the contractor does. If not, a definitive study comparing quarterly estimates to actual costs cannot be done and would have to wait until resolution of the third issue.

The third issue in an internal item that can be addressed through business process improvement to ensure that data needs are identified and data is made available to those who need it.

Once the data is available the research team recommends a more comprehensive study to assess the contractor supplied estimates. As an example, the reader is directed to Figure 7.8 below which shows a portion of the cost curve for an NCDOT project. This cost curve is based on the data from Tables 7.4 and 7.5, also shown below. Unfortunately, even though the project started in August of 2012 no data for estimated costs (quarterly reports) was available prior to April of 2014 nor after May of 2015.

Figure 7.8 shows the actual project costs for the portion of the project from January of 2014 through May of 2015. It also shows the monthly estimated costs for 5 quarterly reports. Again, unfortunately, the data is inconsistent. The quarterly reports provide data for 3, 4, 3, 3, and 2 month periods of time rather than consistent 3 month quarterly reporting cycles. This leads to overlap and duplicate reporting. These time periods are shown in Figure 7.8 as quarterly curves. Note that all but the last quarterly report estimate costs at less than the actual. However, cumulatively, the estimates, as seen in Figure 7.8, are not divergent from the actual cumulative cost in a clearly perceptible way.

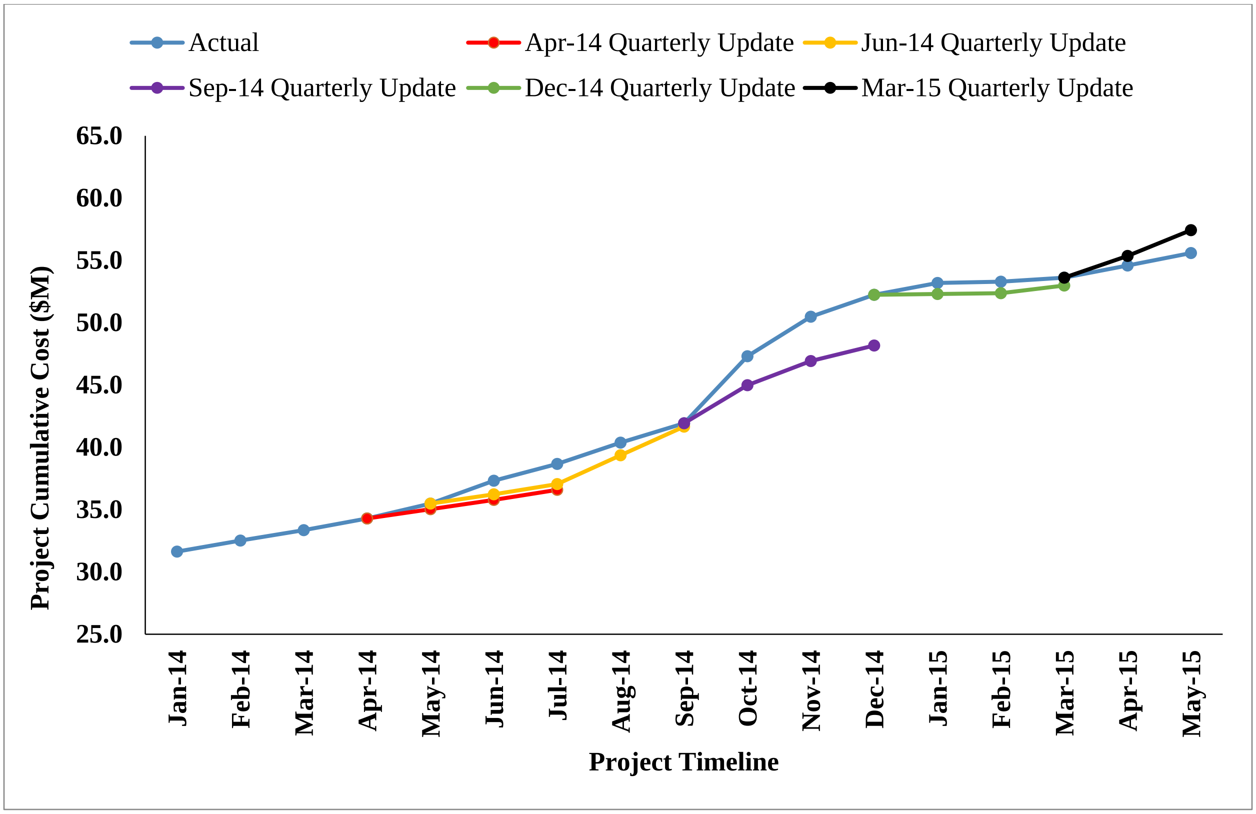

Figure 7.8 Comparison of Actual and Estimated Total Expenditures

Table 7.4 compares actual and estimated monthly expenditures and Table 7.5 compares actual and estimated total expenditures. Table 2 shows % differences that are mostly at or less than 4% except for a few months. This is clearly encouraging news. However, Table 1 shows significant differences between the monthly estimates and actual expenditures. For example, in May of 2014 monthly actual costs exceeded estimates by a factor of about 1.6. In June the factor was about 2.4. In January of 2015 the factor was about 150, clearly an anomaly. In other cases (August of 2014, September of 2014, March of 2015, and April and May of 2015) the factor was between 0.5 and 0.7 meaning that the estimate exceeded the actual cost by a factor of about 2. It is clear from these tables that an in depth study of the data is needed.

Table 7.4 Comparison of Actual and Estimated Monthly Expenditures

Month	Actual	Estimated	% Difference*
04/30/2014Quartely Update			
May-14	$1,199,292.52	$742,130.97	38.12
Jun-14	$1,829,991.42	$749,273.89	59.06
Jul-14	$1,355,169.10	$811,713.38	40.10
06/15/2014 Quarterly Update			
Jun-14	$1,829,991.42	$747,920.63	59.13
Jul-14	$1,355,169.10	$811,713.38	40.10
Aug-14	$1,700,897.33	$2,310,261.17	-35.83
Sep-14	$1,555,884.29	$2,310,261.17	-48.49
09/30/2014 Quarterly Update			
Oct-14	$5,378,896.47	$3,059,995.14	43.11
Nov-14	$3,173,833.56	$1,935,624.22	39.01
Dec-14	$1,759,795.18	$1,248,789.82	29.04
12/31/2014 Quarterly Update			
Jan-15	$956,830.12	$62,439.49	93.47
Feb-15	$93,924.13	$62,439.49	33.52
Mar-15	$326,638.53	$624,394.91	-91.16
03/31/2015 Quarterly Update			
Apr-15	$977,327.13	$1,748,305.75	-78.89
May-15	$995,923.46	$2,060,503.20	-106.89

* (Actual-Estimated)/Actual

Table 7.5 Comparison of Actual and Estimated Total Expenditures

Month	Actual	Estimated	% Difference*
04/30/2014Quartely Update			
May-14	$35,485,716.03	$35,028,554.48	1.29
Jun-14	$37,315,707.45	$35,777,828.37	4.12
Jul-14	$38,670,876.55	$36,589,541.75	5.38
06/15/2014 Quarterly Update			
Jun-14	$37,315,707.45	$36,233,636.66	2.90
Jul-14	$38,670,876.55	$37,045,350.04	4.20
Aug-14	$40,371,773.88	$39,355,611.21	2.52
Sep-14	$41,927,658.17	$41,665,872.38	0.62
09/30/2014 Quarterly Update			
Oct-14	$47,306,554.64	$44,987,653.31	4.90
Nov-14	$50,480,388.20	$46,923,277.53	7.05
Dec-14	$52,240,183.38	$48,172,067.35	7.79
12/31/2014 Quarterly Update			
Jan-15	$53,197,013.50	$52,302,622.87	1.68
Feb-15	$53,290,937.63	$52,365,062.36	1.74
Mar-15	$53,617,576.16	$52,989,457.27	1.17
03/31/2015 Quarterly Update			
Apr-15	$54,594,903.29	$55,365,881.91	-1.41
May-15	$55,590,826.75	$57,426,385.11	-3.30

* (Actual-Estimated)/Actual

7.3 Tool Design

The Construction Payout Tool will be developed based on the models described in Section 7.2. The tool will be based on Microsoft Excel program. It provides two different models for payout curve prediction at preconstruction phase and one model at construction phase. The tool will consist of five main sections: User Manual, General Information, Marco Approach for Preconstruction Phase, Micro Approach for Preconstruction Phase, Recommendations for an Improved Approach in Construction Phase, and a Sensitivity Analysis.

The User Manual section introduces the tool structure and briefly describes how to use the tool. General Information section requires the user to provide project's basic information and current status. According to the chosen current status of a project, the tool directs the user automatically to the corresponding input screen. In the Input section, users are asked to provide values of input variables for different models. The output section shows the results with a sensitivity analysis function.

The sensitivity analysis allows users to change factors to evaluate their impact on payout curves and cash flow balance. An example of testing the impact of changing let date is shown below. As more details are developed for the models, sensitivity analysis on other factors such as project size, location, or seasonality can also be developed. Table 7.6 lists the monthly expenditures and cumulative monthly expenditures as planned for various DBB mega projects.

Table 7.6 Monthly Expenditures and Cumulative Monthly Expenditures

	1	2	3	4	5	6	7
Project ID	**6/1/2005**	**7/1/2005**	**8/1/2005**	**9/1/2005**	**10/1/2005**	**11/1/2005**	**12/1/2005**
R-0609IA							
R-977A	$1,407,244	$1,472,166	$715,687	$3,241,460	$1,992,274	$3,152,961	$1,215,448
R-2518A							
R-2552AA	$3,828,299	$5,513,036	$3,972,905	$53,784	$5,277,814	$5,010,987	$4,302,682
R-2554BA							
U-2519E							
X-0002BC							
Planned	$5,235,544	$6,985,202	$4,688,592	$3,295,244	$7,270,088	$8,163,948	$5,518,130
Accumulative Plar	$5,235,544	$12,220,746	$16,909,337	$20,204,581	$27,474,669	$35,638,617	$41,156,747

Users can adjust the number of delay months as shown in the Column 1 of Table 7.7. Two months of let date delay was entered from the Project R-977A and three months of delay was entered for R-2552AA. The change of associated monthly expenditures are reflected in column 3-5 for those projects.

Table 7.7 Sensitivity Analysis for Let Date Delay

Max Delay: 24 m

Delay (month) (1)	Project ID (2)	6/1/2005 (3)	7/1/2005 (4)	8/1/2005 (5)	9/1/2005 (6)	10/1/2005 (7)	11/1/2005 (8)	12/1/2005 (9)
0	**R-0609IA**	$0	$0	$0	$0	$0	$0	$0
2	**R-977A**	$0	$0	$1,407,244	$1,472,166	$715,687	$3,241,460	$1,992,274
0	**R-2518A**	$0	$0	$0	$0	$0	$0	$0
3	**R-2552AA**	$0	$0	$0	$3,828,299	$5,513,036	$3,972,905	$53,784
0	**R-2554BA**	$0	$0	$0	$0	$0	$0	$0
0	**U-2519E**	$0	$0	$0	$0	$0	$0	$0
0	**X-0002BC**	$0	$0	$0	$0	$0	$0	$0
	With delay	$0	$0	$1,407,244	$5,300,465	$6,228,723	$7,214,365	$2,046,058
	Accumulative With delay	$0	$0	$1,407,244	$6,707,710	$12,936,433	$20,150,797	$22,196,855

Figure 7.9 illustrates the delay in a Gantt chart. The bars on the top in a darker color represents the original planned schedule. The bars below in lighter colors represent the adjusted schedule. The horizontal bars in brown show the original and adjusted schedule for R-977A and the bars in purple are for R-2552A.

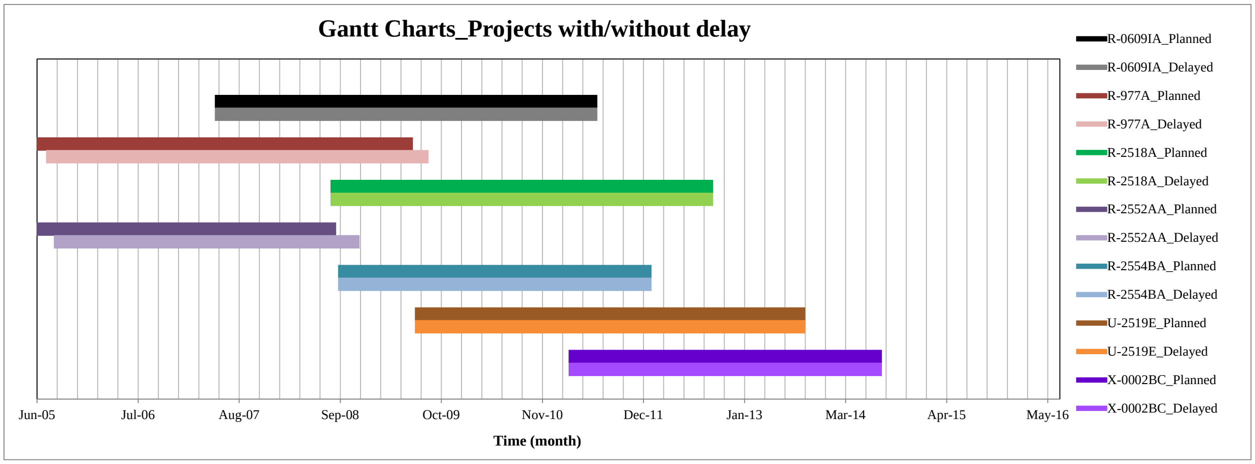

Figure 7.9 Gantt Charts for Original and Adjusted Project Schedule

A comparison of the original and delayed monthly payout curves are shown in Figure 7.10. The curve in blue is the delayed monthly payout and the one in black is the original planned payout curve. The blue curve maintains the original pattern in general, but is shifted to the right a little as the starting of the two projects are delayed for two and three months.

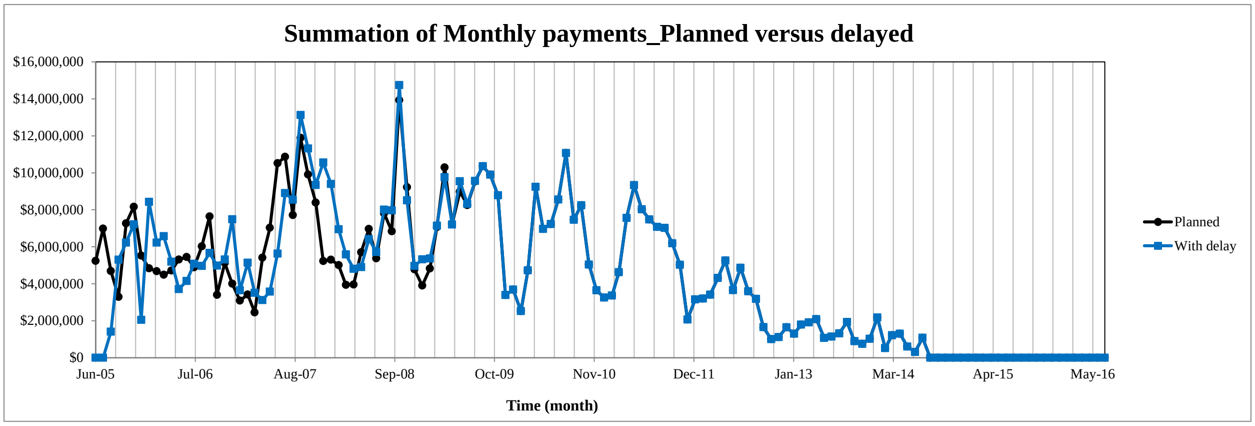

Figure 7.10 Comparison of Monthly Payout Curves

A similar comparison for cumulative payout curves are shown in Figure 7.11. It shows that the total expenditures with the delayed schedule is slightly below the planned curve for most duration of the projects as the expenditures are shifted.

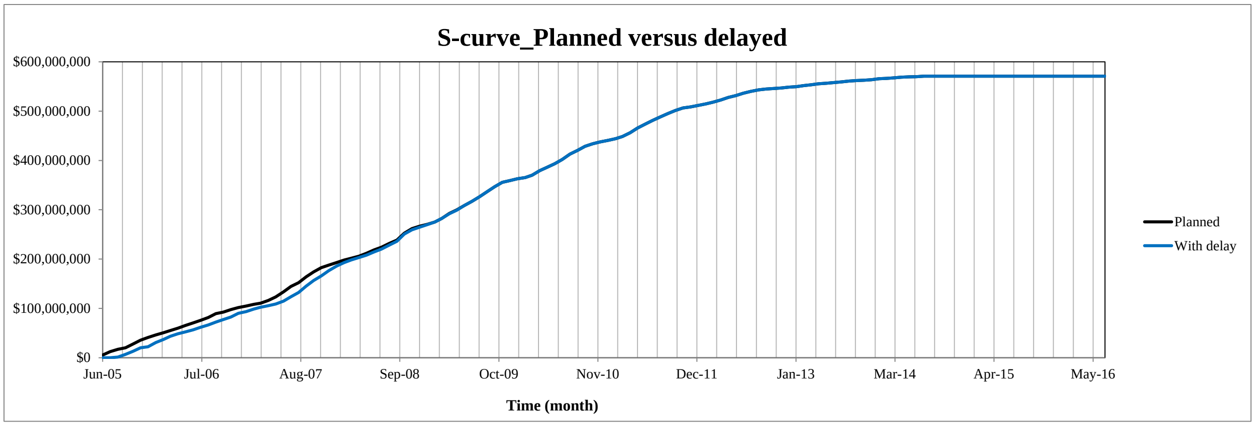

Figure 7.11 Comparison of Cumulative Payout Curves

8 CONCLUSION AND RECOMMENDATIONS

This research has made three significant contributions to better understand the area of payout curve estimation for NCDOT.

1. The first contribution is a literature review of seven relevant studies to better understand causes for let date delays and research methodologies which have been developed to create payout prediction models for DOT projects.
2. The second contribution is a series of twenty three interviews with NCDOT experts and contractors and a discovery of key factors for improvement related to portfolio management, preconstruction phase, bidding phase, and construction phase. Checklists of major milestones to meet let date were developed.
3. The third contribution is the development of a set of model design concepts to better estimate construction payout curves. Based on the study of payout curve patterns of completed DBB mega projects, the research team proposed Macro and Micro model designs for the Preconstruction phase and a new model design for the Construction phase.

The current focus of the research team is on determining how to obtain accurate monthly payout values for a mega project at any point in time from project conceptualization to project completion. The Macro approach addresses the time prior to the start of construction and proposes to create statistical models using cumulative construction payout data from past projects and adjusted models to estimate payout curves for new projects.

The Micro approach also addresses the time prior to the start of construction and is a “bottom up” approach that builds the project payout curve based on the anticipated construction activities, the associated unit costs, estimated durations, the construction sequence, and productivity data. Data for unit costs will be obtained from detailed NCDOT project bid data from 2001 to 2014. Based on this database and on expert knowledge from NCDOT engineers, activity sequence, characteristic, and quantities will be used to develop payout curves, construction costs, and schedule durations.

Finally the Model for the Construction Phase addresses the time between the start and end of construction and recommends the use of the contractor’s estimated construction expenditure forecast at the beginning of every quarter of a project’s schedule as a basis for payout curve estimation for the Construction phase. The research team also recommends a comprehensive study to quantify the accuracy of the contractor’s estimates by comparing them to actual expenditures. If the analysis proves that indeed, the contractor is the best source of cost data then business process enhancements are recommended to obtain that data.

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10 TERMINOLOGY

- DBB: Design Bid Build
- DB: Design Build
- CE: Categorical Exclusion
- CEI: Construction Engineering Inspection
- CIA: Community Impact Assessment
- CPM: Critical Path Method
- DBE: Disadvantaged Business Enterprise
- DOI: Department of Interior
- FONSI: Finding of No Significant Impact
- EA: Environmental Assessment
- EEP: Eco System Enhancement Program
- EIS: Environmental Impact Statement (Includes the full merger process, all concurrence points through 4B, and significant coordination with other agencies.)
- FEMA: Federal Emergency Management Agency
- GIS: Geographical Information System
- Let Schedule: Schedule based on funding availability
- LEDPA: Least Environmentally Damaging Project Alternative
- MMT: Merger Management Team
- NEPA: National Environmental Policy Act
- PDEA: Project Development and Environmental Analysis
- PEV: Private Engineering Firms
- Production Schedule: allows for acceleration of a project given that there is sufficient funding and other resource availability
- ROD: Record of Decision
- ROW: Right of Way
- Shelf Projects: Projects that are in the program that went through the preconstruction process and were qualified for funding
- SPO: Strategic Planning Office—determines the project prioritization for the STIP
- STaRS: Scheduling, Tracking, and Reporting System
- STI: Strategic Transportation Investments
- STIP: State Transportation Improvement Program
- T&E: Threatened and Endangered species

11 APPENDICES

Contents

11.1 Interview Guide

Research Project RP 2015-22:
Design of a Construction Expenditure Forecasting and Monitoring Tool for NCDOT Mega Projects

Date______________

Name__________________________ Dept.__________________________

The objectives of this study are to collect data to 1) understand factors that influence let date, 2) identify the start of construction expenditures, and 3) determine the shape of the construction payout curve. The scope of this research focuses on mega projects (>$50M). Your responses will remain anonymous as your name and the name of your department will be kept confidential.

PART 1 – Understand factors that influence let date

1. Identify a list of influencing factors (internal and external) that affect project let date changes. A list of potential factors is given below. Please set a rate of impact for each factor from one to seven. One means that the factor has a minor impact and seven means that the factor has a major impact. Please explain why and add new factor(s) if needed.

Factor	Rate (1 to 7)	Why
I- Planning		
1- Document Incomplete	______	______
2- Scope Change	______	______
3- Merger / Agency Coordination	______	______
4- Public Involvement	______	______
5- Scope Change Public Involvement	______	______
6- Awaiting Traffic Analysis	______	______
7- Resources	______	______
8- Agency Coordination FHWA	______	______
9- RR Coordination	______	______
10- Insufficient Time	______	______
11- Document Change	______	______
II- Funding		
12- Cash Management Delay	______	______
13- 1989 Outdated Equity Formula	______	______

Factor	Rate (From 1 to 7)	Why
14- Balanced Letting		
15- Bid Optimization		
16- ARRA		
17- Cash Management Accelerate		
18- Equity Balancing Accelerate		
19- Strategic Transportation Investments		
III- Design		
20- Late Input		
21- Scope Change		
22- Design Revision		
23- PEF Coordination		
24- Insufficient Time		
25- Scope Change Public Involvement		
26- Public Involvement		
27- Traffic Analysis		
IV- Environmental		
28- Agency Coordination FHWA		
29- Merger / Agency Coordination		
30- Archaeology		
31- Noise and Capacity Analysis		
32- T&E		
33- Wetland File		
34- CIA		
35- Historic Resources		
36- NRTR		
37- Permitting		
V- External Action		
38- Municipal Agreement		

Factor	Rate (From 1 to 7)	Why
39- Legal		
40- Municipal R/W Acquisition		
VI- Utilities		
41- Utility Owner /External		
42- New Info		
43- Easement Acquisition		
44- Redesign/ rework		
VII- Strategic Letting		
VIII- Contract Preparation		
IX -Bids Rejected		
X- Division Managed		
XII- R/W		
Other Factors:		
Other Factors:		

2. Provide a list of suggested corrective actions to improve a project's chance of meeting the scheduled let date.

PART 2 – Understand factors that influence the start of construction expenditures

1. For Design-Bid-Build projects, what are the typical variation between let date and start of the first construction payment?

2. What are the causes based on their impact? Please prioritize.

3. For Design-Build projects, what are the typical variation between let date and start of the first construction payment?

4. What are the causes based on their impact? Please prioritize.

PART 3 – Determine the shape of the construction payout curve

1. Identify a list of internal and external influencing factors that affect the construction payout curve, and evaluate their impact

2. Provide recommendations on corrective actions to reduce overall NCDOT payout curve balance variation if there is a let date change.

3. The research team plans to develop a tool to help DOT manage project payout curve for mega projects. In your opinion, what would be the expected function, performance, and parameter?

11.2 List of Interview Participants

Contact list							
	Name	Interview Date	Needed information	Division	Unit	E-mail	Telephone
1	Tyeryar, David	12/02/2014	Factors affect the behavior of payout curve	Financial Mangmt.	_	dtyerya1@ncdot.gov	(919)707-4320
2	Lewis,Robert(Bobby)	11/21/2014	Factors affecting let date	Chief Deputy Secretary	Chief of Staff	bobbylewis@ncdot.gov	(919)707-2800
3	Roerden, Jeff	11/13/2014	Factors affecting let date	Governance Office	Management Engineer	joerden@ncdot.gov	(919)707-2850
4	Holder, Michael	12/4/2014	Factors affecting let date	Highway	_	mholder@ncdot.gov	(919)733-9428
5	Leggett, Calvin	11/14/2014	Factors affecting let date	Strategic Planning	Program Development Branch	cleggett@ncdot.gov	(919)707-4611
6	Barbour, Deborah	11/14/2014	Preconstruction factors that affect let date	Highway	Preconstruction	dbarbour@ncdot.gov	(919)707-2540
7	Bowen, Frank	10/30/2014	Factors affecting the behavior of payout curve	Financial Mangmt.	Funds adminstr.	fhbowen@ncdot.gov	(919)707-4327
8	Al-Ghandour, Majed	10/30/2014	Factors affecting let date	Strategic Planning	Program management Unit	maalghandour@ncdot.gov	(919)707-4621
9	Harris, Jennifer	11/20/2014	Factors affecting let date	Highway	Project Development - Western Region	jhharris1@ncdot.gov	(919)707-6025
10	Hanson, Rob	12/05/2014	Factors affecting let date	Highway	Project Development - Eastern Region	rhanson@ncdot.gov	(919)707-6024
11	Allen, Ronald	11/17/2014	1- Export data from STAR schedule system 2- Schedule change reports	Technical Services	Transportation Program Management	rallen@ncdot.gov	(919)707-6635
12	Garris, Randy	11/17/2014	1- Factors affecting construction starting 2- How often are all bids rejected? 3- How often do legal issues arise?	Technical Services	State Contract Officer	rgarris@ncdot.gov	(919)707-6900
13	Grimes, Steve	11/24 /2014	1- Get the ROW factors on let date 2- The utilities factors on let date	Highway	Preconstruction/ROW Unit/Negotiations	sgrimes@ncdot.gov	(919)707-4366
14	Hancock, Ron	11/21/2014	1-Contact contractors for interviews 2- Pull information from HiCAMS 3- Pull given contractors payout predictions	highway	Construction	rhancock@ncdot.gov	(919)707-2400
15	Hopkins, Joey	12/04/2014	Factors affect the behavior of payout curve	highway	Division 5	jhopkins@ncdot.gov	(919)220-4600
16	Midkiff, Eric	11/20/2014	1- Environmental factors that affect let date	Highway	Project Dvelp. and Envrnt. Analysis/preconstruction	emidkiff@ncdot.gov	(919)707-6030
17	Rochelle, Roger	11/25/2014	Preconstruction factors that affect let date	Technical Services	Administrator of the Technical Services	rdrochelle@ncdot.gov	(919)707-2900
18	Tasaico, H.A."Burt"	11/14/2014	1- Delay factors for Design/Build projects 2- Design/Build factors that affect Payout curve	Legislative Affairs and Policy	Program Analysis	htasaico@ncdot.gov	(919)707-2831
19	Thomas, Roger	11/17/2014	1- Obtain Factors that affect design	Highway	Roadway design Unit	rthomas@ncdor.gov	(919)707-6200
20	Paul C. Worley	12/05/2014	Factors affecting let date and payout curve	Rail	_	pworley@ncdot.gov	(919)707-4700
21	Wing, Leigh	12/02/2014	1- Factors affect let date from Value Eng.	Technical Services	Value management Unit	lmwing@ndot.gov	(919)707-4806
22	Vick, Ricky	12/05/2014	1- Delay factors for Design/Build projects 2- Design/Build factors that affect Payout curve	S.T. Wooten Corporation/ design-build contractor		_	(252) 399 -3555
23	Ted Kirk, VP Heavy Civil Division	12/10/2014	1- Delay factors for Design/Build projects 2- Design/Build factors that affect Payout curve 3- Factors affect the behavior of payout curve?	Flatiron/design-build and DBB contractor		_	(919) 723-1299 (cell)
24	Bruton, Teresa*		1- Delay factors for Design/Build projects 2- Design/Build factors that affect Payout curve	Technical Services	Transportation Program management	tbruton@ncdot.gov	(919)707-6610

*The research team was unable to schedule this interview.

11.3 List of Mega Projects

NO.	TIP Number	contract type	Project Type (Bridge, Interstate, Rural, Urban)	New Location or Widening	Location Description	Bid Amount ($)	Percent Complete as of (11/21/2014)
1	B-2500	Design Build	Bridge	New Location	REPLACEMENT OF HERBERT C BONNER BRIDGE ACROSS OREGON INLET FROM BODIE ISLAND TO HATTERAS ISLAND.	215,777,000	9
2	B-2500A	DBB	Bridge	New Location	LONG TERM IMPROVEMENTS (PHASE II) TO PEA ISLAND ON NC-12.	79,656,263	10
3	I-2304AC	Design Build	Interstate	Widening	I-85 FROM NORTH OF SR-2120 (LONG FERRY RD) TO NORTH OF NC-150.	136,019,702	100
4	I-2304AD	Design Build	Interstate	Widening	I-85 FROM NORTH OF NC-150 TO JUST NORTH OF I-85 BUS.	65,492,465	100
5	I-2808A	Design Build	Interstate	Widening	I-77 FROM SOUTH OF SR-1125 IN YADKIN COUNTY TO US-21.	59,490,000	100
6	I-3802A	Design Build	Interstate	Widening	I-85 FROM NORTH OF NC-73 (EXIT 55) TO NORTH OF LANE STREET (EXIT 63).	186,687,000	7
7	I-3803B	Design Build	Interstate	Widening	I-85 FROM SOUTH OF SR-2894 (BRUTON SMITH/CONCORD MILLS BLVD) TO NORTH OF NC-73 (DAVIDSON HWY).	125,159,110	99
8	I-3819A	DBB	Interstate	Widening	I-40/I-77 INTERCHANGE, I-40 FROM WEST OF SR-2003 TO SR-2158 AND I-77 FROM SOUTH OF SR-2321 TO SOUTH OF SR-2171.	89,072,361	49
9	I-4744	Design Build	Interstate	Widening	I-40 FROM SR-1728 (WADE AVE MP-289) TO EAST OF I-440/US-64 (MP-302) AND I-440/US-64 AT I-40 TO I-40 NEAR SR-2544.	49,005,000	100
10	I-5110	Design Build	Interstate	New Location	FUTURE I-73 FROM EXISTING SR-2085 (JOSEPH M BRYAN BLVD) / AIRPORT PKWY INTERCHANGE TO SOUTH OF US-220 NEAR HAW RIVER.	176,550,000	11
11	I-5311	Design Build	Interstate	Widening	I-40/US-64 FROM WEST OF SR-1319 (JONES FRANKLIN RD) CONTINUING ALONG I-440/ US-64 TO NORTH OF US-64/US-264.	130,129,000	42
12	R-0609IA	DBB	Rural	New Location	US-311 (HIGH POINT EAST BELT) FROM US-29 & 70 TO NORTH OF SR-1929 (SPENCER RD) FUTURE I-74 CORRIDOR.	104,252,294	100
13	R-2123CE	Design Build	Rural	New Location	I-485 (CHARLOTTE EASTERN OUTER LOOP) / I-85.	92,162,250	99
14	R-2237C	Other	Rural	Widening	US-321 FROM SOUTH OF SR-1500 TO US-221 AT BLOWING ROCK.	66,438,147	46
15	R-2248E	Design Build	Rural	New Location	I-485 (CHARLOTTE OUTER LOOP) FROM WEST OF NC-115 TO WEST OF I-85.	139,457,130	87
16	R-2303A	DBB	Rural	Widening	NC-24 FROM WEST OF SR-1006 (MAXWELL RD/CLINTON RD) TO SR-1404 (DOWDY RD) IN SAMPSON COUNTY.	61,587,384	31
17	R-2303D	DBB	Rural	Widening	NC-24 FROM SR-1303 (MITCHEL LOOP RD) TO US-421/701 AND SR-1296 (SUNSET AVE).	49,108,724	22
18	R-2309AB	DBB	Rural	Widening	US-220 FROM SR-2182 (HORSEPEN CREEK RD) TO EXISTING NC-68 & US-220 INTERSECTION.	96,195,465	40
19	R-2507A	Design Build	Rural	Widening	US-13/158 FROM US-158/NC-45 IN WINTON TO US-158 BYPASS IN TARHEEL.	54,500,000	84
20	R-2510B	Design Build	Rural	New Location	US-17 FROM SOUTH OF SR-1149 (PRICE RD) TO US-17 NORTH OF SR-1509 (SPRINGS RD).	192,040,143	100

NO.	TIP Number	contract type	Project Type (Bridge, Interstate, Rural, Urban)	New Location or Widening	Location Description	Bid Amount	Percent Complete as of (11/21/2014)
21	R-2518A	DBB	Rural	Widening	US-19 FROM I-26 IN MADISON COUNTY TO SR-1336 (JACK'S CREEK RD).	107,876,545	100
22	R-2552AA	DBB	Rural	New Location	US-70 BYPASS (CLAYTON BYPASS) FROM I-40 TO US-70, WEST OF SR-1560.	123,473,643	100
23	R-2554A	DBB	Rural	New Location	US-70 FROM WEST OF NC-581 TO SR-1300 (SALEM CHURCH RD).	62,439,491	75
24	R-2554BA	DBB	Rural	New Location	US-70 (GOLDSBOBO BYPASS) FROM EAST OF SR-1300 (SALEM CHURCH RD) TO EAST OF SR-1556 (WAYNE MEMORIAL DR).	65,530,177	100
25	R-2554BB	Design Build	Rural	New Location	US-70 (GOLDSBORO BYPASS) FROM EAST OF SR-1556 (WAYNE MEMORIAL DR) TO EAST OF SR-1323 (PROMISE LAND RD).	104,414,724	60
26	R-2606B	Design Build	Rural	New Location	U-311 BYPASS (FUTURE I-74) FROM NORTH OF SR-1929 (SPENCER RD) TO US-220.	99,746,802	100
27	R-2616	Design Build	Rural	Widening	US-601 FROM NORTH OF THE SOUTH CAROLINA STATE LINE TO NORTH OF SR-2105 (MARION LEE RD).	53,783,000	100
28	R-2633AA	Design Build	Rural	New Location	WILMINGTON BYPASS (FUTURE I-140) FROM NC-87 TO US-74/76.	81,664,356	100
29	R-2633BA	DBB	Rural	New Location	US-17 (WILMINGTON BYPASS) FROM US-74/76 EAST OF MALMO TO SR-1430 (CEDAR HILL RD)	79,683,199	20
30	R-2633BB	DBB	Rural	New Location	US-17 (WILMINGTON BYPASS) FROM SR-1430 (CEDAR HILL RD) TO WEST OF US-421 NORTH OF WILMINGTON.	124,368,203	22
31	R-2813B	Design Build	Rural	Widening	NC-146 (LONG SHOALS RD) FROM WEST OF SR-3501 (CLAYTON RD) TO EAST OF I-26.	54,222,185	100
32	R-3307	DBB	Rural	Widening	US-70 FROM EXISTING 4 LANE AT RADIO ISLAND TO US-70 NORTH OF SR-1429 (OLGA RD).	66,437,774	12
33	R-3421C	DBB	Rural	Widening	I-73/74 FROM SW OF SR-1304 (HARRINGTON RD) TO I-73/74 INTERCHANGE, SOUTH OF ELLERBE.	49,840,729	18
34	R-3601	Design Build	Rural	Widening	US-17/74/76 FROM NC-133/SR-1472 INTERCHANGE TO THE US-421/NC-133 INTERCHANGE.	55,551,252	23
35	R-4902	Design Build	Rural	Widening	I-485 FROM SR-3624 (REA ROAD) TO I-77.	83,290,000	83
36	R-977A	DBB	Rural	Widening	US-64 FROM US-19/74 & 129 IN MURPHY TO EAST OF NC-141 IN PEACHTREE.	47,999,080	100
37	U-0209B	DBB	Urban	Widening	US-74 (INDEPENDENCE BLVD) FROM NC-24/27 (ALBEMARLE RD) TO EAST OF WALLACE LANE.	51,669,285	39
38	U-2519CB	DBB	Urban	New Location	FAYETTEVILLE OUTER LOOP FROM SOUTH OF SR-1400 (CLIFFDALE RD) TO EAST OF SR-1007 (ALL AMERICAN FREEWAY).	125,477,521	2
39	U-2519DA	DBB	Urban	New Location	FAYETTEVILLE OUTER LOOP FROM EAST OF SR-1415 (YADKIN RD) TO WEST OF NC-24 (BRAGG BLVD).	54,356,430	76
40	U-2519E	DBB	Urban	New Location	FAYETTEVILLE OUTER LOOP FROM WEST OF NC-24 TO 1.3 MILES EAST OF NC-87/NC-210.	52,553,158	100
41	U-2524C	DBB	Urban	New Location	GREENSBORO-WESTERN LOOP FROM SOUTH OF SR-2137 (OLD OAK RIDGE RD) TO NORTH OF US-220 (BATTLEGROUND AVE).	122,804,389	19
42	U-2525B	DBB	Urban	New Location	GREENSBORO EASTERN LOOP FROM NORTH OF US-70 TO US-29 NORTH OF GREENSBORO.	111,683,421	6

NO.	TIP Number	contract type	Project Type (Bridge, Interstate, Rural, Urban)	New Location or Widening	Location Description	Bid Amount	Percent Complete as of (11/21/2014)
43	U-2925	Design Build	Urban	Widening	SALEM CREEK CONNECTOR FROM SR-4326 (RAMS DR - FORMERLY STADIUM DR) TO SR-4325 (MARTIN LUTHER KING JR DR).	68,925,000	45
44	U-3326A	DBB	Urban	Widening	US-29 BUS (FREEWAY DR) FROM SR-2670 (S SCALES ST) TO NC-14 IN REIDSVILLE.	50,749,005	39
45	U-3810	DBB	Urban	Widening	SR-1406 (PINEY GREEN RD) FROM US-17 TO NC-24 IN JACKSONVILLE	50,543,692	48
46	U-4438	DBB	Urban	Widening	US-158 FROM US-17B (N ROAD ST) TO EAST OF PASQUOTANK RIVER IN ELIZABETH CITY.	57,137,126	77
47	X-0002BC	DBB	Urban	New Location	I-295 (FAYETTEVILLE OUTER LOOP) FROM NC-87/210 (MURCHISON RD) TO WEST OF US-401.	55,258,773	99
48	R-2606A	DBB	Rural	New Location	US 311 FROM SOUTH OF SR 1920 (TUTTLE RD) TO NORTH OF SR 1929 (SPENCER RD) FUTURE I-74 CORRIDOR	Part of R-609IA	100

11.4 PE Distribution

In this analysis, the PE ratio is defined as PE Cost/Total Construction Budget. After combining some of the related projects (e.g., project R-2554 included projects R-2554BA and R-2554A) and removing the Bonner Bridge project (B-2500) as an outlier, there are total of 39 projects used for the PE cost distribution analysis, including 20 DBB projects and 19 DB projects.

For the DBB projects, most have PE ratios in the range of 3%-14%, except two outlier projects. R-2303 (widening) has a PE ratio of 38.47% and U-2519 (new location) has a PE ratio of 44.55%. Those projects were treated as outliers and not included in the analysis. The PE ratio distribution is illustrated in Figure 10.1. The average PE ratio is 9.3%. The highest PE ratio is 13.9%. Six projects are in the range of 8-10%.

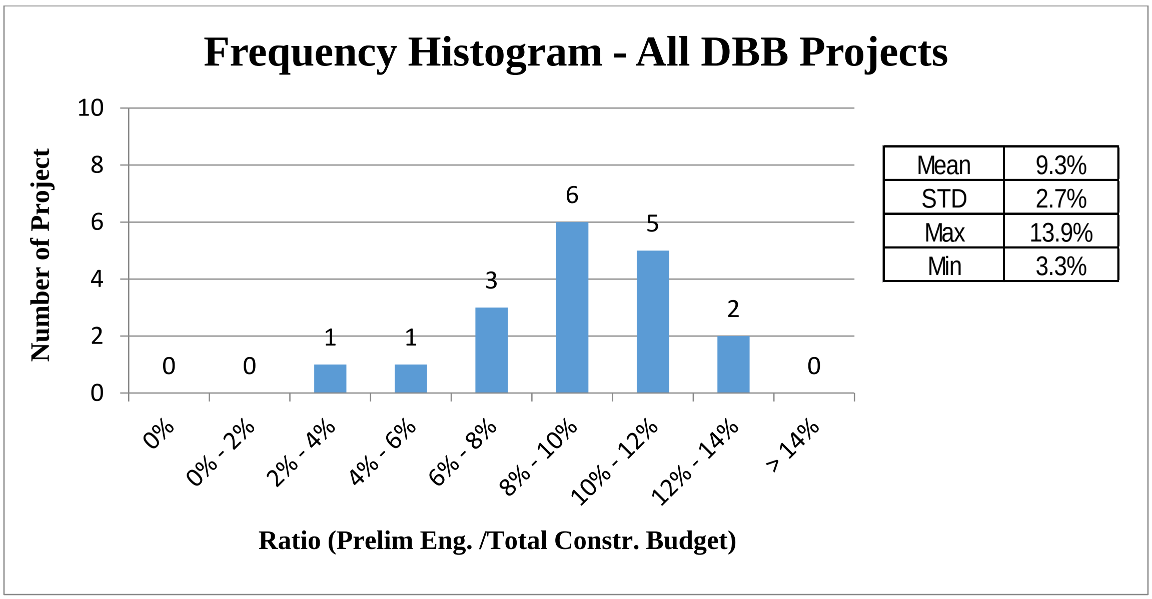

Figure 11.1 PE Ratio Distributions of DBB Projects

For the DB projects, R-2633AA and R-2554BB both have a recorded PE ratios of 0%, which are treated as outliers and not included in the analysis. The average PE ratio is 3.8%, much lower than the average of DBB projects (9.3%). This is because a large portion of design is not included in PE for DB projects. The PE ratio distribution is illustrated in Figure 10.2.

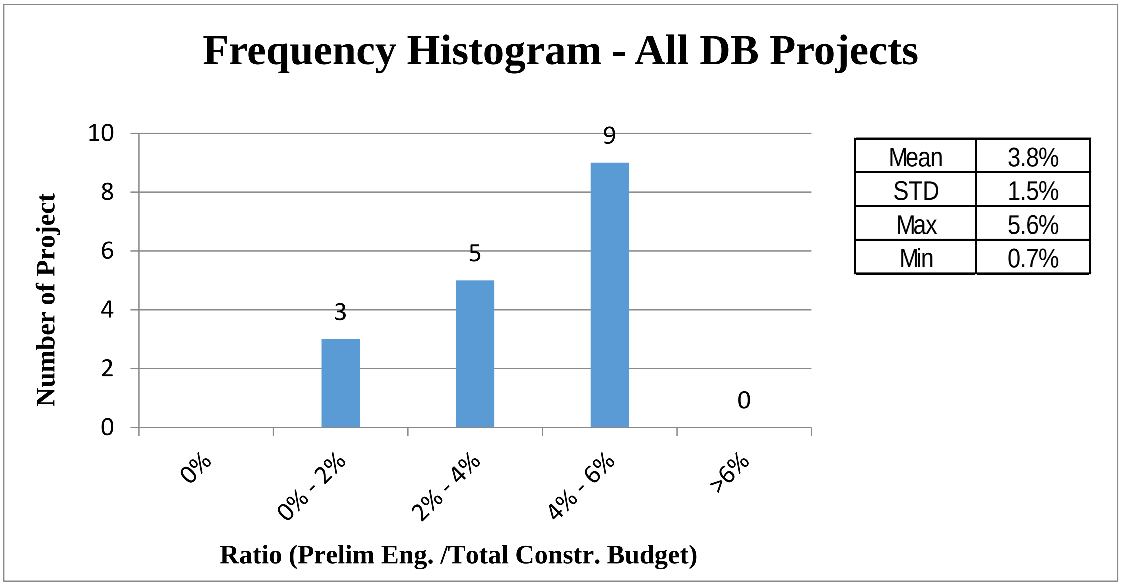

Figure 11.2 PE Ratio Distributions of DB Projects

11.5 Meetings Minutes

North Carolina Department of Transportation

Design of a Construction Expenditure Forecasting and Monitoring Tool for NCDOT Mega Projects

Meeting Minutes **Mann Hall 412 02/24/2015 at 10:30 a.m.**

Attendees:

Dr. Majed Al-Ghandour
Frank Bowen
Dr. William Rasdorf
Dr. Larry Goode
Dr. Edward Jaselskis
Dr. Min Liu
Abdullah Alsharef

Agenda:

1- Academic Team presentation

- Dr. Jaselskis began the meeting with the academic team presentation. He stated the overall goal as designing a model that predicts DBB mega projects more accurately than the NCDOT current tool and monitoring the performance of the model.
- Dr. Jaselskis reviewed the results that were delivered in the interim report.
- The construction model will assume that the let date is met and will be based on that assumption.
- Mr. Bowen stated that the SAS phase 1 model can predict overall project expenditures in aggregate and the SAS model accounts for the delay between letting and construction starts. The model can also forecast independent projects.
- The SAS phase 2 proposal is for preconstruction, forecasting both the aggregate expenditures and durations.
- Mr. Bowen stated that when seasonality effect is not included in the SAS model, the model would produce a result similar to what he has been using in forecasting (flat curve) up to now.
- Mr. Bowen tried to average projects and produce a curve that represents the average, yet the variation was too high and this approach was deemed to be infeasible.
- Mr. Bowen currently uses a linear (Slope = Total cost / Total duration) curve as a better forecasting tool.
- Mr. Bowen stressed the fact that there is limited data to subcategorize projects.
- Dr. Rasdorf proposed a method to develop the shape of the payout curve from a Gantt chart schedule. At any given point in time costs can be summed to determine daily, weekly, and monthly costs.

- Mr. Bowen stated that the NCDOT obtains (from the contractor) estimated payout schedules for every project above 10M$ when it is awarded, but it he believes they are not accurate for DBB projects and he does not rely on them. On the other hand, he does depend on the payout schedule from design-build contractors.
- The engineering estimates are significantly accurate compared to the winning bid.
- Dr. Al-Ghandour stated that the STIP estimates are updated frequently on the web, but engineering estimates are confidential.
- Mr. Doug Lane is responsible for generating the STIP estimates.
- The bid selection committee is required to justify the selected bid if it is more than 10% different from the engineering estimate. If it is not justified the NCDOT offers the project for bidding again.
- Dr. Goode said that the engineering estimate is performed when final plans are submitted.
- The engineering estimate is usually higher than the STIP estimate.
- Mr. Bowen obtains the project duration (with the first payment) from the contractor. The duration is not in the contract.
- Mr. Ron Davenport creates the engineering estimate.
- Mr. Bowen wants to determine ahead of time whether or not a project will have a problem in terms of how it will pay out. He wants to identify projects ahead of time that may have a deviation between forecasted and actual payout.
- Dr. Jaselskis suggested that NCDOT should contractually ask contractors to produce a more accurate payout curve since contractors already know how activities will be sequenced.
- Dr. Al-Ghandour suggested discussing Dr. Jaselskis' recommendation with Mr. Ron Hancock.
- Dr. Liu showed a model for a total expenditure S-curve that can be adjusted for delays in letting and as a result will produce an adjusted S-curve for a portfolio of projects.
- Mr. Bowen suggested including contingency in designing the model (about7% is what he sees as an average).
- The model should be able to reforecast if a change order is granted.
- Mr. Bowen stated the first thing that should be done is creating the model that forecasts expenditures.
- Next, validate the forecasting model with completed projects, and check to determine if it follows the actual expenditures (not necessarily month to month) and identifies outliers. In other words, identify where the red flags will happen.

Action Items

- Reestablish contact with SAS (Mr. Bowen).
- Schedule a meeting with Mr. Randy Garris (meeting held 3/20/15).
- Check with Mr. Ron Hancock to determine whether or not the contractors payout schedule is updated by contractors.

Questions

- This discussion focused on cost, the engineering estimate, and the STIP estimate.

- What are the equivalent items for duration? Who determines these and when?
- Does the NCDOT generate a payout curve with the engineering estimate?

North Carolina Department of Transportation

Design of a Construction Expenditure Forecasting and Monitoring Tool for NCDOT Mega Projects

Meeting Minutes **Century Center 03/20/2015 at 10:00 a.m.**

Attendees:

Randy Garris
Marsha Sample
Doug Lane
Ron Davenport
Frank Bowen
Dr. Larry Goode
Dr. Edward Jaselskis
Dr. Min Liu
Abdullah Alsharef

Agenda:

- Dr. Jaselskis began the meeting by stating the need for NCDOT to obtain a more accurate payout curve than what the department is presently utilizing.
- Mr. Bowen asked, what kind of information could be obtained early to predict payments? Could it be project complexity, different activities? Do estimates rely on a standard CPM schedule for each category?
- In general, most payouts occur in the summer (construction season).
- Mr. Bowen noted that NCDOT currently forecasts total expenditures in aggregate. The NCDOT wants to determine early how much it will spend for construction next year and the year after.
- Mega projects comprise fewer than 10% of the total projects but comprise more than 50% of program expenditures. Therefore, forecasting mega projects early will significantly affect the department's overall forecast.
- Mr. Garris said the engineering estimate is completed 8-12 weeks prior to let date.
- Mr. Garris suggested that one way to address the problem of a small sample would be to adjust projects before 2005 for inflation.
- The STIP estimates can change up to the time of the engineering estimate. The changes in the STIP estimates are due to scope changes or changes in the design according to Mr. Lane.
- In general, if there is not a significant scope change, the conceptual estimate will not change a lot and the engineering estimate will be about that number.
- Costs are allocated 35% to miscellaneous and contingency during functional design, 25% to ROW, 35% to preliminary engineering, and 5-10 % to final design.
- According to Mr, Davenport, there is no contingency in the engineering estimate.
- With every change of the estimate (update), a verification letter is sent to explain the change.

- Dr. Al-Ghandour will have a record of the reasons for every change in the estimate.
- State funded projects will have a 10% contingency and federal projects will have a 15% contingency.
- Fuel adjustment factor is one reason to add contingency.
- The project duration estimate is made sometime before 8-12 weeks ahead of let date. There are guidelines for production rates for different project categories (new location, widening, etc.). The project duration also accounts for the time for relocation of utilities. (They use AGC rates?)
- Traffic control plans are also important in estimating the project duration.
- There is not a time estimate in the STIP cost estimates.
- The time estimate is based on final plans. The personnel responsible for the time estimate consults with different DOT Departments to determine the time for different activities.
- The time estimate includes a moratorium. In other words, NCDOT thinks like contractors.
- Success rates for time estimate are above 80%.
- To estimate the final project duration, activities are sequenced and overlapped based on experience and consulting. There is not a standard CPM schedule of activities.
- During advertisements, if contractors object to the project duration estimate, the estimate is revisited and justified, but it is rare.
- The engineering estimate department has different project activity production rates that are based on past studies for different categories of work. If there is a new activity that the NCDOT does not have any data about, they contact contractors and experts to get the production rates. As far as prices, these are based on previous contracts.
- Indirect costs are based on project category.
- Dr. Jaselskis argued that the indirect percentage for bigger projects should be less than the percentage for smaller projects that fall within the same category. The question is: does the NCDOT consider that reduction factor in its estimation or not?
- For the STIP estimates, the estimator gets a request from the administrator to estimate a project. The estimator uses a county map and identifies the location. Based on his experience and the type of the project (+50 years of experience) he estimates the quantity of materials. He also estimates ROW and utility relocation.
- Mr. Bowen mentioned that the utility department has a model that produces a cost estimate for utilities.
- Based on past project history, the STIP estimator has a unit cost per square foot (if he knows what the project type is). If the scope of work is not clear, he predicts what the material cost will be for that project type, then obtains his best estimate for quantities and multiplies them by unit costs.
- The unit used in all estimation is today’s dollars
- Mr. Bowen thinks it would be beneficial to subcategorize projects and see how they are paying out historically.
- Mr. Garris stated that bids are rejected if they are above 10% of the engineering estimate.
- The STIP estimate is in current dollars.
- The lowest bidder is awarded the project.

- The first STIP estimate is usually performed as a feasibility study and is based on a request from the upper management.
- Dr. Goode said that contractor project duration is usually less than NCDOT project duration estimates.
- Mr. Bowen stressed the need for an accurate forecast to be able to predict project payouts 2-3 years in advance.
- Mr. Bowen suggested making a CPM schedule for each subcategory of projects, i.e., a collection of representative project schedules based on project type.
- Traffic control plans are made before 12 weeks ahead of the let date (This is late according to Mr. Bowen).
- Dr. Goode suggested that when ROW plans are submitted, (4 years before the let date in general) they should give a good idea about the project's duration.
- Mr. Bowen suggested that 2001-2002 be the cut off for projects adjusted for inflation.
- Dr. Goode stated that using the Construction Cost Index as the method to adjust projects for inflation.

Action Items

- Send a list of projects categories to NCSU (Mr. Davenport).
- Obtain updated version of the let list that tracks the history of estimates. (Mr. Bowen).
- Obtain the reasons for changing in estimates. (Dr. Al-Ghandour)
- Obtain a copy of a traffic control plan.

North Carolina Department of Transportation

Design of a Construction Expenditure Forecasting and Monitoring Tool for NCDOT Mega Projects

Meeting Minutes **Century Center 04/08/2015 at 2:00 p.m.**

Attendees:

Randy Garris
Doug Lane
Ronald Davenport
Dr. Edward Jaselskis
Dr. William Rasdorf
Dr. Min Liu
Abdullah Alsharef

Notes:

- Mr. Davenport began the meeting by explaining the different preconstruction estimate types. The first type of estimate is the State Transportation Improvement Program (STIP) estimate and the second type is called an engineering estimate.
- The sequence of different STIP estimates are as follows:
    - Conceptual estimate
    - Feasibility estimate
    - Functional design estimate
    - Preliminary estimate
    - Right of Way (ROW) estimate
    - Final estimate

  All six STIP are prepared by Mr. Lane. The STIP estimates are prepared without the use of engineering drawings and specifications. Each STIP estimate has a cost associated with it. Only the final estimate has a project duration associated with it. The duration is provided by Ms. Marsha Samples. The engineering estimate is prepared by Mr. Davenport.
- Mr. Lane stated that the conceptual estimate is performed based on a request from a board member. To create the conceptual estimate, he anticipates what the elements of the project will be and prices them (such as pavements, excavation, water and sewer, and sound barrier walls).
- Mr. Lane compiles all estimates based on available information. For instance, in the conceptual estimate phase he might provide the estimate from just the county map. He stressed that the accuracy of any estimate relies on available information and time.
- Dr. Rasdorf ascertained whether the method used in the conceptual estimate could be a unit cost per area or volume, and Mr. Garris confirmed that it could.
- Mr. Lane adds to each estimate two factors in percentages:
  1. Engineering and contingency (E&C) factor
  2. Mobilization factor

In the conceptual estimate, the miscellaneous factor could be 50%. The percentage decreases in subsequent estimates when more information becomes available.

- In the feasibility estimate phase, Mr. Lane stated that he estimates different alternatives from aerials, alignment, and the description of the section. In regards to quantities, he uses tonnage to take off paving and earthwork activities. He is responsible only for construction estimates. Utilities and ROW estimates are determined by other divisions. The feasibility unit combines different estimates to one total estimate (the engineering estimate).
- Mr. Lane affirmed that the Project Development and Environmental Analysis Unit (PDEA) selects the best alternative.
- Mr. Davenport stated that an example of a list of different items that are considered when preparing an estimate could be found on the roadway design website.
- Dr. Rasdorf explained that one objective of this research is to understand what information is available and when (from the estimation department) in order to provide a more accurate estimate for the eventual project payout curve.
- Dr. Jaselskis stated that another objective of this research study is determining the shape of the payout curve. Mr. Davenport agreed with Dr. Jaselskis that the type of the project is driving the shape.
- According to Mr. Garris, seasonality is another factor that plays an important role in predicting the payout curve. Additionally, the sequencing of activates in the project schedule could also affect the shape of the payout curve.
- Mr. Davenport noted that HiCams could be another beneficial source for obtaining the sequence of typical activates for a project.
- Mr. Garris claimed that the NCDOT has an 80% success rate for delivering projects within the estimated time. It is worthwhile to note that if a project is granted a time extension and the contractor successfully delivered the project, it would not be considered a late project.
- Mr. Garris stated that the projects are awarded to the lowest responsible bidder who does not exceed the engineering estimate by 10% and does not fall behind the engineering estimate by 15%. There have been cases in which projects were awarded to bidders who exceeded the 10%, but there were reasonable reasons for awarding those projects. For instance, the extra costs the department will incur in administration process for rejecting the bid, safety factors, and time of the year. It is a committee decision to let a project whose bid is over 10%.
- Mr. Lane conducted a study in the past to compare final project costs with different estimates. He found the difference between his feasibility estimate and the actual bid price to be about 55%. Of this, the mobilization factor accounts for 5-10 and Mr. Lane refers to the remaining 45-50% as a miscellaneous factor.
- According to Mr. Lane, the miscellaneous factor is not a contingency because the term contingency is used by NCDOT when adding 15% on federal funded projects and 10% on State funded projects. Those percentages cover the costs for the construction department to perform administrative activities such as inspecting the project. This miscellaneous percentage, on the other hand, is simply a measure of how far from the actual cost any of the previous STIP estimates are.

- Dr. Liu inquired whether the estimating department has a typical timeline for different estimates, and Mr. Lane stated that they do not have such a time line.
- Mr. Lane stated that at the time the preliminary engineering estimate is created, approximately 80% of items should be apparent. Examples of construction items are including clearing and grubbing, erosion control, guardrail, curb and gutter, sidewalks, traffic control, signing and signals, and box culverts. At the time of the final estimate, 100% of all items are known.
- Mr. Garris pointed out that there is a difference between construction cost and contract cost. Contract cost is what NCDOT is charged, by contractors, to deliver the project. Construction cost includes both the contract cost and administrative cost (including inspections).
- According to Mr. Davenport, construction engineering and contingency (E&C) should cover any expected supplemental agreements besides administrative costs.
- Dr. Jaselskis inquired whether the estimating department has a generic schedule for different types of projects and Mr. Davenport stated that the estimating department does not generate such a schedule.
- According to Mr. Garris, the contract time engineer, Ms. Marsha Samples, estimates the project duration according to a schedule but it is not a critical path method (CPM) schedule. She determines the duration of the project before 8-12 weeks prior to the let date. There are exceptions where she determines the duration earlier if a special request has been received.
- Mr. Garris stated that a contractor would typically submit a project bar chart schedule when he awards the project. This schedule shows the monthly % complete for the project on a monthly basis and it is updated quarterly by the contractor.
- According to Mr. Garris, the construction unit verifies material quantities and the amount of work done monthly.
- Dr. Jaselskis volunteered to review payout items in HiCams to gain insights into the sequence of activates for different project categories.
- Mr. Davenport stated that it is not possible to anticipate supplementals at the time of the the engineering estimate.
- Mr. Davenport and Mr. Lane showed examples of a preliminary estimate to the NCSU team.
- Mr. Garris believes that the rate of spending on widening projects would be slower than on new location projects due to traffic control. In addition, the cost of new location projects varies by counties.
- Mr. Davenport recommended the Academic team to contact the construction unit to inquire whether or not a detailed schedule is typically provided by contractors (a later visit verified that indeed it is).
- According to Mr. Garris, traffic control plans are received before 8-12 weeks of let date, and are kept internal. They are used solely in the engineering estimate.
- Mr. Garris suggested that the Academic team could obtain information regarding the sequence of activities from Design-Bid-Build projects.

TO DO LIST

- Verify whether Mr. Bowen is interested in contract or construction cost.
- Schedule a meeting with the construction unit to understand the sequence of activities for different project categories (Done on 04-13-2015).

North Carolina Department of Transportation

Design of a Construction Expenditure Forecasting and Monitoring Tool for NCDOT Mega Projects

Conference Call Meeting Minutes **04/10/2015 at 10:00 a.m.**

Attendees:

Mr. Frank Bowen
Dr. Majed Al-Ghandour
Dr. Larry Goode
Dr. Edward Jaselskis
Dr. William Rasdorf
Dr. Min Liu
Abdullah Alsharef

Notes:

- Dr. Jaselskis began the meeting by reporting the main points of the 04-08-2015 meeting with the estimating department, and stating the next step is to schedule a meeting with the construction unit.
- Mr. Bowen suggested contacting the Design-Build unit, and he recommended scheduling a meeting with Ms. Teresa Bruton.
- Dr. Al-Ghandour offered to arrange a one-hour training session for the statistical software JMP in Mann Hall.
- Mr. Bowen stated that he was preferably interested in Excel being the implementation platform for the forecasting tool. Dr. Rasdorf noted that implementation was outside of the scope of the current project.
- Dr. Liu inquired whether the forecasting tool should include the administrative costs or just the bidding amount. Mr. Bowen is solely interested in forecasting the pay out curve from the bidding amount.
- Mr. Bowen noted that in every STIP estimate, the E&C percentage is already embedded at the note of 15% for federal projects and 10% for State projects. This amount is not in the engineering estimate nor is it in the bid.
- Mr. Bowen is interested in forecasting the project from the point of time that it enters the STIP program. It could be as early as ten years before the let date.
- Mr. Bowen expected a more accurate pay out forecasting at least three years prior to the let date.
- Mr. Bowen suggested asking Mr. Doug Lane anything about preconstruction estimates.
- Mr. Bowen noted that some old projects' payouts might not be in HiCams.

To Do List

- Establish a meeting time with the construction unit. (04-13-2015 at 2:00 pm)

- Verify which alternative estimate (one alternative estimate or all of them) is used in feasibility estimate (Mr. Lane).
- Verify whether E&C (Engineering and Contingency) percentage is included in the engineering estimate (Mr. Davenport).

North Carolina Department of Transportation

Design of a Construction Expenditure Forecasting and Monitoring Tool for NCDOT Mega Projects

Meeting Minutes **The Construction Unit 04/13/2015 at 2:00 p.m.**

Attendees:

Phillip Johnson
Lamar Sylvester
Dr. Edward Jaselskis
Dr. William Rasdorf
Dr. Min Liu
Dr. Larry Goode
Abdullah Alsharef

Notes:

- Prior to the beginning of the meeting, Dr. Goode explained the difference between construction cost and the project cost. Project cost includes what the Department spends on resident engineers and inspections, whereas construction cost includes only the bid amount. In addition, Dr. Goode noted that all STIP estimates contain E&C percentages, but the engineering estimate does not include the E&C percentage. On federal projects there are more administrative costs than on State projects.
- Dr. Rasdorf began the meeting by inquiring about what information the construction unit has when the contract is awarded regarding cost, duration, and schedule. Additionally, what information does the construction unit have during the lifetime of the project?
- Mr. Sylvester stated that at the beginning of the project, the construction unit has the bidding amount and the duration that is estimated by the NCDOT contract time engineer. It is the period that is established by the NCDOT and the contractor has to finish the project by that time to avoid liquidated damages. For DBB projects the NCDOT project duration is calculated based on quantities and production rates. For Design-Build projects the NCDOT relies on the contractors' duration because of the prequalification process.
- Dr. Goode noted that the NCDOT duration will be used unless it is A + B Bidding in which the contractor will bid for both the duration and the cost.
- Mr. Sylvester stated that contractors can deliver the project for a shorter duration, but in general, the contractors' progress is typically according to the NCDOT duration.
- Mr. Sylvester said that the NCDOT obtains a cash-time schedule from the contractor when the project is awarded. It is not a CPM schedule. It shows how the contractor is expecting to spend over the project's duration. Every contractor provides the cash-time payout schedule at the beginning of the project. For Mega projects, the contractor is required, contractually, to submit an updated quarterly anticipated payout schedule for the remainder of the project. Mr. Sylvester provided the Academic team with an example of a cash-time payout schedule.

- The cash-time schedule depicts the anticipated S-curve, yet each quarterly payout schedule shows the expected payouts in percentages and dollar amount.
- According to Mr. Sylvester, the purpose of the cash-time schedule is to track contractor progress throughout the life of the project. The schedule is updated if a contractor is granted a supplemental or a time extension. If a contractor is behind the schedule by 15% or more there are severe consequences, such as a removal from future bidder lists.
- Dr. Jaseslskis asked about the accuracy of the baseline as compared to the actual. Mr. Sylvester said it depends on the project, but, in general, the actual payout tracks pretty well.
- According to Mr. Johnson, the contractor should not be ahead of a schedule by more than 15% due to stipulations in fiscal abilities to pay them.
- Mr. Sylvester stated that the construction unit is trying to avoid the front-loading of construction items by contractors, so the unit expects a smooth curve throughout the lifetime of the project.
- Mr. Sylvester stated that the construction unit provides the Funds Administration Section with the new project duration when a time extension is granted. On the other hand, the Funds Administration Section does not obtain any forecasted payouts for non-mega projects.
- Mr. Sylvester stated that the main reasons for deviation from the expected payout schedules are field issues, unknown utilities, the weather, and contractors performance. Supplementals will extend both the time and cost, and when granted, the contractor submits a new cash-time schedule to track its progress.
- According to Mr. Sylvester, at any point in time, there are 15-20 mega projects (on average) under construction.
- Mr. Johnson stated that the payout curves for projects in the mountains are usually flat from January to March.
- For non-mega projects, Mr. Sylvester suggested using the cash-time schedule in forecasting, for which a quarterly update is not provided.
- Dr. Liu asked about the consistency of each quarterly payout schedule. Mr. Sylvester stated it is somewhat stable unless a major supplemental is granted.
- Mr. Sylvester stated that if a contractor is granted fewer than 30 days, the NCDOT will not request a revised cash-time schedule.
- Mr. Sylvester noted that when a contractor is 5% behind schedule, the NCDOT starts communication with the contractor regarding the reasons for being behind schedule. There are typical reasons for being behind schedule which may be acceptable. For instance, on bridge projects the NCDOT does not compensate contractors for the superstructure until all the work is done. This causes a flat period in the payout curve followed by a jump in the payout curve due to a significant payout.
- Mr. Sylvester indicated that if a contractor is 10% behind schedule, the NCDOT negotiates possible solutions such as working on weekends.
- Mr. Sylvester indicated that HiCams is the place where resident engineers insert progress payments. Actual quantities determine the deviation between planned and actual performance.
- Mr. Sylvester stated that the NCDOT estimates the payment period from the 7th, 15th, and 22nd of the month and at the end of the month. Subsequently, the NCDOT certifies a

progress payment within seven working days after the estimating period. The NCDOT does not hold retainage on projects (since around 2006).

North Carolina Department of Transportation

Design of a Construction Expenditure Forecasting and Monitoring Tool for NCDOT Mega Projects

Meeting Minutes The Funds Administration Section 04/13/2015 at 3:30 p.m.

Attendees:

Frank Bowen
Terry Whitley
Dr. Edward Jaselskis
Dr. William Rasdorf
Dr. Min Liu
Dr. Larry Goode
Abdullah Alsharef

Notes:

- Mr. Bowen remarked that the cash-time schedule varies by project type and by contractor. The anticipated payouts from contractors vary significantly from actual payments. This is in contrast to Mr. Sylvesters' observations. It is worthwhile to look at similar activities for each project category.
- Mr. Whitley is responsible for the payout of GARVEE projects. These are a subset of projects for which the NCDOT has to monitors their payouts accurately.
- Mr. Whitley stated that the Funds Administration Section obtains the payout curves directly from contractors. They use the contractors' curves on GARVEE projects. The contractor provides a new adjusted payout curve based on a request during the construction of the project. It is not provided quarterly. This is in contrast to Mr. Sylvesters' observations.
- Mr. Bowen pointed out an instance where the NCDOT should have spent monthly around $3M, yet the NCDOT spent only $1M/month. There are many projects behind schedule. One of the reasons for this delay is uncertainly of the weather.
- Mr. Whitley stated that the Funds Administration Section does not receive revised quarterly payout curves from the construction unit.
- Mr. Bowen stated that the payout curves provided by a Design-Build contractor are more accurate than those from Design-Bid-Build contractors.
- Mr. Bowen showed the performance of Design-Builds on an aggregate monthly basis. Last month, the actual expenditures were lower than forecasted expenditures by about $32M. In December 2014, actual expenditures were $13M behind forecasted expenditures. It is a massive variance, and the variance is greater on Design-Bid-Build projects.
- Dr. Rasdorf suggested establishing a meeting that includes representatives from the construction unit and the Funds Administration Section to better understand the differences.

- Mr. Whitley is interested in GARVEE WBS elements associated with the project. He is solely concerned with GARVEE expenditures on the project.
- Mr. Bowen recommended contacting Mr. Sylvester to obtain the actual payouts from HiCams.

Research Tasks

- Assess the accuracy of the quarterly payout projections.
- Perform a study to compare the actual expenditures to cash-time schedule.

North Carolina Department of Transportation

Design of a Construction Expenditure Forecasting and Monitoring Tool for NCDOT Mega Projects

Conference Call Meeting Minutes **04/24/2015 at 10:00 a.m.**

Attendees:

Mr. Frank Bowen
Dr. Majed Al-Ghandour
Dr. Larry Goode
Dr. Edward Jaselskis
Dr. Min Liu
Mr. Abdullah Alsharef

Notes:

- Dr. Jaselskis began the meeting by summarizing the Academic team meeting on 04/13/2015 with the construction unit. The Academic team was informed that contractors provide the NCDOT with an anticipated payout curve at the beginning of the project, and it is adjusted when a supplemental occurs. Another point of that meeting is the construction unit believes that the contractor's curve is accurate as long as it is within the 15% allowable tolerance. In addition, the contractor is obligated to provide the NCDOT with expected monthly payments every quarter.
- Dr. Jaselskis stated the next step as verifying the accuracy of contractor's curve with actual payment and a request was made to the construction unit by the Academic team to validate the actual payouts with the anticipated payouts. The notion the Academic team has after the meeting with the construction unit is that the contractor's payout curve is accurate during the construction phase.
- Mr. Bowen stated that the construction unit informed him that the contractors are proving the NCDOT with a forecasted payout curve and he found their curves are highly variable compared to the actual payments for Design-Bid-Build projects. However, the curves provided by Design-Build contractors are better, and he relies on them in forecasting. In addition, he believes that the shape of the curve is different from contractor to another contractor.
- Mr. Bowen noted on the tolerance allowed by the construction unit to be a significant amount of money for mega projects and, as a result, the NCDOT needs to program that amount of money in advance. Frank is concerned with the NCDOT cash balance running over what has been forecasted.
- Dr. Jaselskis stated that he is comfortable with the provided information by the construction unit, yet some of the detailed information in the provided spreadsheets needs more elaboration by the construction unit such as the formula for the fuel charges.
- Mr. Bowen noted that the project identification number (ID number) of mega projects in HiCams could include landscaping projects. Landscaping projects are in the range of $1M. He recommended extracting those projects from the actual payout data.

- Dr. Jaselskis summarized the three ideas to model the payout curve. During the preconstruction phase, use the convex shape of different level of convexity as an alternative to the current method (straight line). The first method is a macro approach that looks at past projects data for Design-Bid-Build projects. It could include looking at the construction part of Design-Build projects. Additionally, more mega projects could be added by adjusting projects before 2005 for inflation**.** The payout could be modeled as early as the conceptual estimate is established. There are factors that could influence the shape of the payout including utilities, project type, seasonality, and location. Look at past shapes and investigate the shape of the payout for different categories. The micro approach includes creating a generic schedule for each type of projects and resource load the schedule.

  The provided time-cost curves from contractors have the breakdown of activities in percentage.
- Dr. Liu stressed the need for scheduling a meeting with the estimating management to obtain the available information for different project categories at different milestones to produce a cost estimate for typical items.
- Dr. Jaselskis Stated that the Academic team requested from the construction unit a contractor expected payout schedule to compare it with the actual pay out to validate the accuracy of the contractor's forecasting.
- Dr. Al-Ghandour asked whether or not there is a need to establish a communication with SAS group. Mr. Bowen added that the Academic team needs to address the platform of the forecasting tool by the end of June.
- Dr. Jaselskis argued that the goal is to select the best method for producing the payout curve at the preconstruction and the construction phase. Then, we need to identify the needed data tpo create the curve. Subsequently, the platform for the forecasting tool should be determined. Excel is preferred, but the Academic team is open for other platforms.
- Dr. Jaselskis asked if it is possible for SAS to study the correlation between the size of the project and the shape of the payout.
- Mr. Bowen expects the design of the forecasted tool, the approach, identification of the data, the platform, and the recommendations to be delivered in the final report. He also expects answering the question: is this tool going to improve the current approach for forecasting future payouts for mega projects?

To Do List

- Schedule a meeting with the estimating management.

North Carolina Department of Transportation

Design of a Construction Expenditure Forecasting and Monitoring Tool for NCDOT Mega Projects

Riverwood Conference Room, Century Center **05/07/2015 at 2:00 p.m.**

Attendees:

Dr. Min Liu
Dr. William Rasdorf
Mr. Ron Davenport
Mr. Doug Lane
Mr. Abdullah Alsharef

Notes:

- Dr. Liu began the meeting by asking the estimating management representatives about the major components considered when estimating different types of projects.
- Mr. Lane stated that when he estimates a project, he does not assign percentages for different items. In the conceptual estimate, Mr. Lane estimates quantities for different items including cleaning and grubbing, pavement design, earthwork, bridges, erosion control, drainage per mile, and guardians (minor item). Some items can be found in different types of projects such as clearing and grubbing, earthwork, erosion control, traffic control, bridges, culverts, retaining walls, and lighting at latter stages. Miscellaneous factor covers the other items since the scope is not clear.
- Dr. Rasdorf asked Mr. Lane about the method that he used to estimate the quantities for different items without having the finals plans. Mr. Lane uses the internet to obtain an aerial map for the location and applies basic construction measures to calculate the quantities in volumes or areas.
- Mr. Lane stated that he does not use typical unit prices for each item. The unit price relies on the quantities and the location of the project. The unit price for a new location project is more expensive than a widening project, and the unit price in urban areas is more expensive than in rural.
- Mr. Lane believes that the clearing and grubbing are more expensive near coastal areas than in the mountains.
- Mr. Davenport stated that the NCDOT maintains bid averages on the NCDOT website. The bid averages are broken by divisions and show the comparison of prices of different items between divisions. It shows the actual quantities of different items in each division and the bid prices as well. The bid averages include all types of projects.
- Mr. Davenport said that contractors bid on different items in the bid proposal.
- Mr. Lane calculates the square yard of the material and multiplies the quantities by a unit price, or he estimates the weight of the material and multiplies the weight by a tonnage unit price.
- Mr. Lane states that he adds 45-55% as a miscellaneous factor for roadway projects in the conceptual estimate, 45% of feasibility and functional estimate, 35% for preliminary

estimate, 25% for right of way estimate, and 10-15% for final estimate. In regards to miscellaneous factor for the structure estimate, it starts at 15% for conceptual, feasibility, and functional estimate, and 10% for preliminary estimate and right of way, 5-10% of final estimate. For Federal funded projects, 15% is added as a contingency factor, and 10% is added for State funded projects. The PE costs are not included in the percentages above.

- Mr. Lane stated that the scope always creeps. What might have started as a typical two lanes section might end up as four lanes.
- Mr. Lane stated that when he receives a request to estimate a project, he is provided with a limited information including the start and the end points, the location, typical section, and the percentage of the clearing and grubbing, the cut of cut and fill height for earthwork, and the pavement design. If the desired pavement design is nor provided, Mr. Lane guesses the pavement design. Mr. Lane also asks that if the project has bridges and if it does, he refers to the bridge maintenance map to obtain the structure number. In general, the more provided information to produce, the better the estimate.
- Dr. Rasdorf asked Mr. Lane what are his sources for maps, and Mr. Lane said that his sources for aerial images are Google maps, visiting the site and PDEA. Also, he requests scaled maps from the Photogrammetry Squad.
- Mr. Lane stated that the estimating management has a cost per square foot for certain types of structures.
- Mr. Lane stated that prior to the PDEA chooses the LEDPA (least environmentally damaging practicable alternative), he might carry out more than one estimate, and he provides the STIP unit with the average of all estimates.
- The major components of every estimate are clearing and grubbing, earthwork, structure, drainage, pavement, erosion control, traffic control. Miscellaneous items include retaining walls, box culverts, signs signals, noise walls, and ITS (intelligent transportation system).
- The Funds Administration Section receives the available estimate from the estimation management when the project is programmed and has a STIP number. In most cases, the functional estimate is the first STIP estimate.
- According to Mr. Davenport, the STIP unit has the verification letters for all projects. A verification letter is sent for every updated estimate. For bridge projects, the first estimate is performed by the bridge maintenance unit and Mr. Lane and his squad performs the following estimates. In regards to the project duration, the STIP unit estimates the project duration from typical past projects data. The project duration is rounded using year unit.
- Mr. Davenport stated that Ms. Samples, the contract time estimator, has the productivity rates for different activities and the knowledge of overlapping activities. The contract time estimate accounts for whether as well as the seasonality effect. Ms. Samples does not implement a computer software nor Mr. Lane. The contract time is approved by a committee, and the contractors rarely complain the duration during the advertisement period.
- Mr. Davenport recommended obtaining the payout data from HiCams and use old projects data to depict the shape of the payout curve.

To Do List

- Obtain an Excel sheet format of the 2014 bid averages.

North Carolina Department of Transportation

Design of a Construction Expenditure Forecasting and Monitoring Tool for NCDOT Mega Projects

Conference Call Meeting Minutes **05/08/2015 at 10:00 a.m.**

Attendees:

Mr. Frank Bowen
Dr. Majed Al-Ghandour
Dr. Larry Goode
Dr. Min Liu
Mr. Abdullah Alsharef

Notes:

- Dr. Liu began the meeting by reporting the outcomes of the meeting with the estimating management on 04/08/2015. Additionally, the results of comparing the actual payments to the contractors forecasted payouts. In regards to the payout comparison, the Academic team received three projects data from the construction unit, two files are in pdf format that makes it difficult to analyze. The construction unit will request contractors to provide the data in Excel format. The average monthly difference for the project provided in Excel format is $0.5 M.
- Mr. Bowen believed that the analyzed project performed well. He is interested in the individual performance of projects. Nevertheless, he is more interested in the cumulative expenditures on a monthly basis of all programmed projects.
- Dr. Al-Ghandour suggested depicting the forecasted curve in the future in dashed lines or using a different color than the actual.
- Dr. Liu stressed the need to obtain more data from the construction unit to compare the estimated cost by the contractors with the actual payments.
- Mr. Bowen is interested to understand the contractor's methodology for creating the estimated payout curve.
- Mr. Bowen is conducting the same analysis for design-builds projects. He has not completed the analysis on the day of this meeting. The results of the analysis for about 10 undergoing projects is about 22% behind on average on monthly cumulative. Some projects are running more than 100% behind due to litigations.
- Dr. Liu stated the outcomes of the meeting with the estimating management. She explained the data bid averages for different items that can found online. The estimating management has been updating the list yearly. The latest version is 2014. The cost depends on the location, the quantity, the type of the project, and the time of the year. In the conceptual phase, Mr. Lane has the knowledge to produce the quantities and multiplies them by the unit cost. He added a miscellaneous factor of 45-55% in the conceptual phase. As the he obtains more information, the accuracy of the estimate improves and the miscellaneous factor decreases for the roadway estimate. In regards to

the structure components estiamtion, the contingency at the conceptual estimate is about 15% and 5-10% of the final estimate.

- Dr. Lui noted that from the bid average data, it is worthwhile to observe how different characteristics affect the unit cost. Then as a result, we could use the unit costs that apply for future project characteristics. The data is provided in Excel format, and it is on the website as a pdf format.
- Dr. Al-Ghandour would like to understand the correlation between the project's payout curve and the duration besides the correlation between item size and unit cost.
- Mr. Bowen stated that the cumulative actual payout for December, January, February are usually significantly below the forecaster payout.
- Mr. Bowen is more interested in comparing the accumulative payout curve, on a yearly basis. Every month Mr. Bowen is asked how much the department is going to spend the next 12 months.
- Dr. Liu stated that the next step as being finish writing the report that will include the road map for designing the payout model.
- Dr. Al-Ghandour suggested scheduling a meeting with the steering committee before delivering the final report.

To Do List

- Schedule a steering committee meeting.

North Carolina Department of Transportation

Design of a Construction Expenditure Forecasting and Monitoring Tool for NCDOT Mega Projects

Status Update Meeting Minutes **06/02/2015 at 10:00 a.m.**

Attendees:

Mr. Frank Bowen
Dr. Majed Al-Ghandour
Dr. Larry Goode
Mr. Abdullah Alsharef
Dr. Edward Jaselskis
Dr. William Rasdorf
Mr. Ronald Allen
Mr. Randy Garris
Mr. Roger Thomas
Mr. Neil Mastin
Mr. Rasay Abadilla
Mr. Abdullh Alsharef
Dr. Xia Qi

Notes:

- Dr. Al-Ghandour began the meeting by briefing the attendees about the research project and stating the goal of the meeting as being to update the steering committee members on the progress of the research project. He also encouraged feedback.
- Dr. Jaselskis delivered a general project status update.. He stated that in the first four months of the project the research team was investigating reasons for let date delay and in the following four months the research team had been developing the background necessary to define the concept for a tool that forecasts the shape of the construction payout curve during the preconstruction and construction project phases for individual design-bid-build mega projects.
- Dr. Jaselskis stated that the research team submitted an interim report on December 31st, 2014 that identified factors that influence let date, specified the typical duration between let date and the availability date, provided recommendations to meet the let date, and provided a checklist for meeting the let date for both design-build and design-bid-build projects.
- Dr. Rasdorf discussed the survey results (meetings with NCDOT personnel) that outline the main planning and design factors that delay the let date during preconstruction.
- Mr. Bowen noted that if a project is delivered within the 12-months window from the original let date, it is not considered to be late project delivery. However, any slipping from the original let date will affect NCDOT's budget forecast.

- Mr. Bowen noted that the scope of the research project changed due to an urgent need for fast tangible results within a short duration. (Originally the project focused plan was to focus on a model for better predicting project payout. However, the first four project months focused on causes of delays. This ended up resulting in a project scope reduction on the payout work.)
- Dr. Jasesksis illustrated the first approach to forecast the payout curve by using completed mega project data. He discussed different statistical models to forecast the payout curve.
- Mr. Thomas asked why the scope excludes modeling design-build expenditures, and Mr. Bowen stated that the behaviour of design-build and design-bid-build are different. Additionally, the Funds Administration section uses design-build contractor's forecasted payout curves because they are deemed to be accurate.
- Mr. Bowen suggested including more projects in the research team's future study by applying inflation to past projects. He has, and can make available, the payout data for projects between 2000 and 2005.
- Dr. Rasdorf explained two proposed approaches to creating a payout curve during preconstruction. One is to create a payout curve by using existing NCDOT project cost data (from project conception to bid) and summing the individual activities and costs (% of total) to obtain predicted monthly payouts at each major stage in the project development process. This approach is rooted in understanding the project as it evolves from concept through bid. The second approach is to use predictions based on experience gained from past projects, their characteristics in common with new projects, and their past performance.
- Dr. Rasdorf also explained an approach to create payout curves during construction. This approach uses the known payout curves provided by the contractor at the beginning of the project and as well as those updated quarterly.
- Mr. Bowen stated that he would like the research team to recommend the best approach to forecast the payout curve.
- Mr. Allen asked if the payout model will rely on meeting strategic milestones in the preconstruction phase in forecasting. Mr. Bowen said that meeting the let date is a separate research project.
- Dr. Rasdorf stated that phase two of the research project will include an assessment of the two approaches and recommendations for determining which approaches are most promising.