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Analysis of NCDOT 'S Funding in Highway Construction Projects

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Abstract—This study examines a difficulty with highway building project scheduling under a hypothetical scenario of increased financing. It is common for large-scale highway building projects to depend heavily on state and federal financing sources. Transportation-related taxes and fees are the primary source of income. DOTs must be able to adjust to financing fluctuations in order to avoid going into overdraft or accruing unmanageable cash balances as a result of the economy's inherent unpredictability. In the event that future revenue is projected to fluctuate, a decision support system is offered for deciding how to adapt the let schedule. How the suggested technique may be used to massive, more than $10 million construction projects is shown via an analysis of NCDOT's (North Carolina Department of Transportation) case study. Constrained logistic models are used to predict the building costs of specific projects, and a method to analyze the effect of altering let dates is offered. Among the methods to use the proposed model are the rolling-horizon let scheduling, the study of funding changes, and the evaluation of financing project hazards.

"*Index Terms*—Decisions under risk and uncertainty, optimiza-tion,portfoliostrategies,projectplanning,projectscheduling.

1.INTRODUCTION

A financial scenario analysis for altering the release timetable of significant highway construction projects is discussed in this study. To let a project out for bidding is to open the project up to a wider range of potential suppliers. Even though this article focuses on North Carolina's Department of Transportation (NCDOT), the concept may simply be extended to other states. In the city's master plan, the Transportation Improvement Program (TIP) includes a broad variety of costly construction projects. Prior to awarding a construction contract, governments used the obligation basis, which required a certain sum of money to be available to obligate against the expected spending. From its inception in 2001, the NCDOT has used cash basis accounting to manage its total cash balance rather than project-specific expenditures [1], and this is the new norm for the management of total cash balances.

Almost all of the money in the state highway trust fund and the state highway fund comes from fees collected at the pump [3]. This ambiguity regarding financing is one of the primary risk factors that might lead to poor funding allocation and delays for TIP construction projects, even though these revenues can drastically diverge from predicted quantities due of the current economic concerns.Thus, although cash-based management allows for maximum spending on TIP development projects, this strategy has raised the danger of overdraft owing to a very little cash reserve kept. In an attempt to enhance financial management in North Carolina, a goal cash balance of 12 percent of the expected annual revenue was established [4]. Specifically, this implies that the NC-monthly DOT's cash balance must be at least 5% larger than the total outstanding obligation for all transportation project contracts.

The North Carolina Department of Transportation (NCDOT) must take appropriate action when predicted financial flows indicate a probable overdraft or exhaustion of available funds, respectively. The NCDOT, for example, might postpone the letting of certain building projects for many months in order to meet the requisite cash level. On the other side, certain projects' progress might be hastened in order to reduce an unmanageable cash flow. A group made up of representatives from several departments within the NCDOT has debated and ultimately decided on such measures. A key objective of this research is to provide quantitative guidance for the committee's decision-making process by giving an ideal release timetable under a new financing scenario. You may use an optimization model to establish the best timetable for leasing that minimizes the overall performance impact while maintaining a reasonable cash balance. As an added bonus, we will illustrate Due to the unique nature of this study's topic, it is difficult to locate other research that have dealt with it. For highway construction planning concerns, we present a short literature analysis in Section II of this study. A mathematical programming model is presented in Section III to discover the best possible let schedule for a certain funding circumstance. In order to put this strategy into action, it requires a forecasting model that can accurately anticipate the expenses of certain projects.NCDOT case study in Section IV shows how to construct payment forecasting models and how optimization models for rolling-horizon-based let scheduling are used, assessing the impact of funding shifts and identifying high-risk projects under funding changes. Section V concludes and

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sums up the findings of this study.

2.“REVIEWOFTHERELEVANTLITERATURE”

To the best of the authors' knowledge, there have been various studies of quantitative methods to transportation project planning in the literature, but none of them are directly relevant to the situation given here. Therefore, the publications assessed in this part fall within a broader category of transportation program management issues.

Benjamin [5] the public sector's multiple programs at the same time using a linear goal-programming technique. In the beginning, he selects a group of projects from a list of possible options. As soon as the projects have been selected, they are analyzed in terms of social, economic and political objectives within resource restrictions using a linear goal-programming model The multi-criteria strategy proposed by Taplin and Qiu [6] for a budget allocation problem in Australian public road construction is similar. In order to assess a project, this research looks beyond the traditional cost-benefit analysis. There are a number of criteria they have devised, including the state and national economy, tourism, time savings for individual and business travelers, as well as savings on running expenses for vehicles, all of which are scaled from 0 to 10.

To choose transportation projects, the following models are presented by Niemeier et al. [7].

1) ranking the projects according to priority without allowing for trade-offs between project costs and ranking
2) model that helps the decisions between project costs and ranks;
3) creating a specific target for each purpose in order to achieve policy goals
4) Budget models that require each project to reach or exceed the policy goal;
5) A model that considers both the project's budget and its relative importance.

Gao et al. [8] selected construction projects for road maintenance and infrastructure expansion using a mixed-integer nonlinear bilevel optimization strategy. As the cost of road construction and maintenance is taken into consideration, vehicle speed is affected. The optimization issue is solved using an extended Bender's decomposition approach.

According to Jensen [9], a member of Virginia's Highway and Transportation Research Council, other states were prioritizing projects in this manner at the time: Each criteria is graded on a scale of 100 points, and the research determines the subjective descriptors that apply to the various parts of the rating scale. Patidar et al. [10] advises prioritizing bridge repairs based on the incremental utility-cost ratio (IUC), Lagrangian relaxation, and pivot and complement approaches. Each performance requirement for a bridge in that research has a corresponding weighted utility scale. The IUC consistently outperformed the competition in terms of computational effort, accuracy, simplicity, and durability when it came to agency-wide bridge management. There is an approach to choosing transportation projects in Shang et al. [11] that incorporates feedback and dependence across many decision levels and criteria. Using the so-called Nominal Group Technique, a nine-person advisory committee divides the criteria into four primary categories: advantages (costs), opportunities (costs), and dangers. Establishing the relative relevance in relation to the overall purpose of several categories and their ancillary criteria is accomplished via comparative analysis. Our integrated method for selecting transportation projects includes the use of fuzzy Delphi, analytic process concepts and 0–1 goal programming to take into account the interrelationships between projects and criteria. [12].

It is important to highlight, however, that none of the aforementioned research can be directly applied and compared to our case. In subsequent sections, comprehensive solutions for dealing with the issue will be presented.

3.LET RESCHEDULINGPROBLEM (LRP)

The construction phase accounts for the majority of TIP project costs, despite the fact that the TIP normally comprises of three stages (preliminary engineering, right-of-way, and construction). A bidding method is used to begin the construction phase. The DOT will pay a construction project until it is completed if it has been awarded a contract. DOT may take steps on awarded projects to alter and regulate cash flows to some degree, however monthly expenditures are dispersed in accordance with the speed of development. Despite this, unanticipated shifts in real spending are still possible due to the cyclical nature of cost components.

There are other ways to deal with funding changes for the Department of Transportation, such as revising the future building timetable rather than restricting current construction projects' expenses. The significance of projects is one of several elements that might influence the decision to revise the let schedule. The North Carolina Department of Transportation (NCDOT) uses a priority rating technique that allows all construction projects to be evaluated according to their importance. Keep in mind that a project's priority score might be interpreted as a measure of the project's significance. Therefore, the

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priority score should be taken into account while determining the let schedule.

$$\sum_{i=1}\sum_{k=1} c^k x^k \leq B_0 + \Delta B \quad (3)$$

$$x_i^k \in \{0,1\} \text{ for } i = 1,2,\ldots,N+1 \text{ and } k = 1,2,\ldots,K. \quad (4)$$

Total penalties incurred throughout the planning period are the goal in (1). In order to meet the limitations in (2) and the binary constraints in (4), each project must only be able to be allowed once throughout the planning horizon. B).

The LRP is a binary integer programming problem with a finite number of solutions. Positive penalties are imposed if a major delay in the let date occurs, negative penalties are imposed if a significant delay occurs, and zero penalties are imposed if a significant delay occurs. Then assume project k was initially supposed to be awarded in period j. If this is the case, then Furthermore, let d and a " signify acceptable delays and advancements in the let date, respectively. “Thus, the penalty for a new let date I is defined as follows:

$$p_i^k > 0, \quad \text{if } i > j + \bar{d} \qquad p_i^k < 0, \quad \text{if } i < j - \bar{a}$$

$$p_i^k = 0, \quad \text{if } j - \bar{a} \leq i \leq j + \bar{d}$$

where a reward is represented by a negative penalty.”

Construction costs are regularly allocated once a project has been awarded. Assume that term I has been granted to project k. For the planning horizon's end, we can estimate its total building cost (i.e., N). Assuming that I is 1, 2,...,N and k is 1, 2,...,K, the total cost of constructing project k at period N when it is leased in period I is represented by the constant ck. Project 6's cumulative expenditure at period 36, when it is allowed in the 12th year, is c6 if the number of years N is 36. C6 is only utilized for 24 periods, not the previously reported 365 as was indicated. xk is an integer programming problem that can be solved using any off-the-shelf solution for I = 1, 2,...,N + 1 and k = 1, 2,...,K. We will come up with a timetable that minimizes penalties while allowing for the financing adjustment. The DOT must first identify parameter values such as pk and ck before drafting the LRP, though. In order to do this assignment, you must have a full grasp of the DOT's cash management system and the data accessible to you. There will be more discussion of parameter values in the case study of the North Carolina Department of Transportation (NCDOT).

“TABLEVII

PARAMETER VALUES FOR INDIVIDUALCONSTRUCTION COSTESTIMATIONMODELS

Type	No. of Projects	State Funded	Federal Funded	Total Estimated Cost (Smillion)
B	6	0	6	125.4
I	13	0	13	648.6
R	24	10	14	1,097.2
U	23	2	21	734.2
Overall	66	12	54	2,605.4”

LRPs are automatically updated to the next time period when they are successfully solved in a new period.This decision assistance tool is also useful when the NCDOT is dealing with changes in financing. Committees are formed when the NCDOT anticipates a change in financing, and these committees are made up of NCDOT staff members from several departments. Committing quality judgements on delaying construction project start dates has been standard procedure in the committee for some time. LRP rescheduled let dates may either be the committee's own answer or a starting point for debate. A three-year NCDOT let schedule from September 2014 to August 2017 is used as an example for this article. While this time period is open for bids on 66 different sorts of types of whales—all of which fall into one of four categories—federal and state funds are slated to be allocated to 54 projects. Estimated total costs for the project are $2,605,364 000 (see Table VII). If all 66 projects are awarded, this estimated cost represents the total amount that would be paid out. There will be $1 345 370 903 in construction costs if all projects are completed on time as planned, as indicated in Table V using the individual cost estimates model with the parameter values provided in Table V.

Consider a scenario in which the NCDOT needs to save $100 million on the project's construction expenses. We utilized fictional priority ratings for those projects in this analysis to minimize the danger of breaking confidentiality by utilizing real priority rankings. After constructing the LRP, the issue was solved using an open-source solver GLPK [14], which performed well in a recent evaluation of open-source solvers. pk.

Ten projects' start dates have to be altered, as shown in Table VIII, in order to arrive at the correct outcome. It is important to remember that priority ratings were produced at random for this investigation. As a consequence, the real outcome would be much different from this outcome. To ensure that there are no unforeseen consequences.

TABLE VIII: RESCHEDULED LET DATES UNDER A DEFICIT OF $100 MILLION

Projec ID	Old Let Date	New Let Date	Schedule Difference	Funding Sourc
I-28xx	11/1/2016	1/1/2017	2	Federal
I-54xx	10/1/2014	9/1/2014	-1	Federal
I-55xx	6/1/2017	7/1/2017	1	Federal
R-25x	12/1/2015	6/1/2016	6	State
R-25x	10/1/2015	6/1/2016	8	State
R-25x	3/1/2016	4/1/2016	1	State
U-25xx	10/1/2014	6/1/2015	8	State
U-33x	11/1/2014	9/1/2014	-2	Federal
U-34xx	11/1/2014	9/1/2014	-2	Federal
U-28x	5/1/2016	9/1/2016	4	Federal”

Projects on three interstates, three rural roads, and four cities have been postponed. The "schedule difference" column shows ad-vacating and delaying the lease dates, respectively, as negative and positive figures. I-54, U-33, and U-34) have had their completion deadlines moved up, but the other seven projects have been delayed. Putting off these seven initiatives gives us a window of opportunity to go forward with those three priority initiatives. Both the federal fiscal year (FY) and the North Carolina state fiscal year (FY) begin in October. As a result, the three federally supported projects have been rescheduled for September in order to take advantage of moving forward into the previous fiscal year. A larger penalty will be applied on delayed projects that are not completed during the current fiscal year. Seven of these projects are still slated for release within the current fiscal year, however. There have been delays to four state-financed projects: R-25 A and B; U-25; and U-25; while federally funded U-28 has been moved to September of the same financial year.

There would be a savings of $100 002 481 compared to the previous timetable's anticipated cost of $1 345 370 903 if construction expenses are followed according to the revised let schedule. Using the LRP's let schedule as a starting point, we may examine how to deal with fluctuations in the committee's financing. To round things up, the LRP may be used in conjunction with the FPRM. Project financing risks are identified, assessed, and prioritized using the FPRM (Teng et al. 2013). Identifying which initiatives are most vulnerable to funding changes and keeping an eye on them is critical to minimizing or eliminating the effect of undesirable outcomes. Simulating different financing circumstances may help find such ventures. Let us say we were able to portray our financing change as a percentage of the original predicted amount of misinformation by substituting the final two digits of the TIP numbers with "xx." We can tell them apart by adding capital letters in alphabetical order if they produce the same masked numbers as before. Consider the three TIP numbers in Table VIII that all begin with the same first two digits: R-25. Because of this, we added the suffixes A, B, and C after "xx" in order to distinguish the TIP numbers. B is equal to rB0, where r is the percentage of the total cost of the construction. We can identify which programs are more vulnerable to funding changes when we change the value of r. r = 5%, 4%,..., 1 percent, –1 percent, –2 percent..., –9% and 10% are all possible financing departures from B0 that we explore in the case study. Funding is in excess in the first five scenarios, while financing is in deficit in the last 10.

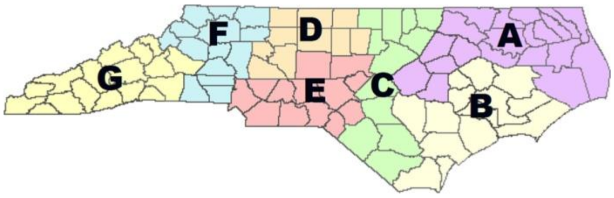

Figure.3. SevenregionsofNorthCarolina[18]."

The financing options seem to have little effect on the table. It is possible to utilize this information to evaluate project finance risk ratings for particular building projects based on the findings in Table IX.

A. AdditionalConsideration

When required, we may include extra criteria into the LRP in addition to budget constraints. According to the Eq- uity Formula, the NCDOT used to allocate funds among the state's seven regions using a specific formula [16]. Because to the introduction of a transportation investment plan formula, the NCDOT no longer uses the equity formula [17]. To show how these sorts of distribution formulae may be implemented into the LRP framework, we have included it in this study.

The North Carolina Department of Transportation's (NCDOT) budget has to be distributed around the state in accordance with a three-tiered equality system. The population, intrastate projects, and equitable distribution are the three requirements. According to the legislation, the DOT budget is split among seven separate zones, each with a population density of 50%. The remainder of the funding is divided based on the remaining intrastate system miles, with the state allocating 25% of the overall budget evenly among the seven regions. Projects that are not labeled "intrastate" fall under the urban or rural umbrella. There are strict rules in place to guarantee that 40 percent of the state's revenues are spent on rural initiatives.

Since there are seven regions in the NCDOT scenario, we will use M as a generic reference. K projects may be divided into M sub-projects as a consequence You may use the index set Km 1, 2,...,K to indicate the projects in the region m 1, 2,...,M. This notation is also explained:

"d_m= " populationsizeinregion$m = 1,2,\ldots,M$;

r_m= remainingmilesofintrastatehighwaysinregion$m$"= $1,2,\ldots,M$.

Let $d = \sum_{m=1}^{M} d_m$ and $r = \sum_{m=1}^{M} r_m$. Finally, the equity formula may be included into the LRP by adding the following restrictions on it:the equity calculation is based on Adding these limitations, the LRP solution will meet the regional distribution criteria.Models were applied to a variety of project types to ensure consistency with the NCDOT's project categorization (i.e. the B, I, R, and U categories). In view of the increasing number of megaprojects with large scale expenses, which may distort the construction cash flow curves, forecasting models may be created for groups of projects that are defined by project size rather than construction cash flow.

CONCLUSION

For highway construction projects, an LRP is considered in this article because of a projected financing shift in the future. Large-scale construction projects undertaken by the Department of Transportation often depend on state and federal financing. To prevent any overdrafts or excessive cash holdings, state and local governments must be able to deal with sudden changes in income resulting from a variety of taxes and levies, which are subject to dramatic fluctuations in the economy. Additionally, the LRP and FPRM are intertwined in that program managers use the LRP to identify projects that are at risk of funding changes and take necessary action.

For the purpose of determining the best time to release a film in light of fluctuating financial resources, we put out a mathematical programming approach. The North Carolina Department of Transportation's case study includes bridges, interstate, rural, and urban projects (NCDOT). Due to the enormous impact on cash flows of large-scale projects with high construction expenditures of $10 million or more, we exclusively examine them. In this case study, we use a formula and a constrained logistic model to predict the costs of construction for particular projects. To put this new LRP to good use, consider the following three ideas: As a means of raising money for construction projects, implement planning that takes into account potential funding changes as well as an evaluation of the associated risk. Research on highway construction projects at DOTs may easily be applied to other large-scale project management organizations, such as the military.

According to the study's methodology, only projects with a construction budget more than or equal to $10 million are included. An in-depth investigation to determine the appropriate threshold value may be addressed in future research, notwithstanding the NCDOT's strategic choice to employ $10 million as an exogenous element. At some point between one and two, M. Projects that have been authorized for building in Region m's planning horizon are on the left side of the limit. On the right side of this restriction, as seen in the figure, are the monies that can be granted to Region M at their maximum levels.

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