

DEVELOPMENT OF FUNDING PROJECT RISK MANAGEMENT TOOLS

Final Report # 2012-06

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<p>16. Abstract</p> <p>Funding project risk management is a process for identifying, assessing, and prioritizing project funding risks. To plan to minimize or eliminate the impact of negative events, one must identify what projects have higher risk to respond to potential project delays due to funding issues quickly. Funding project risk management becomes essential for NCDOT as part of Executive Management's decision-making processes.</p> <p>The objectives of this research project are to (1) investigate current risk management and funding risk management business processes and practices in transportation areas, (2) analyze project risk management and funding risk management practices in DOTs of other states, (3) analyze best practices in the other states, especially California Department of Transportation's practices, and appraise the potentials for possible implementation, and (4) develop a funding project risk management tool to assist NCDOT staff members for better decision-making in budget/cash management, funding risk management, and project management under frequent funding change environment.</p> <p>In this project, the research team has investigated current risk management and funding risk management processes, and evaluated the best practices among DOTs in the US. An in-depth study has been conducted to appraise the potentials for possible implementation of the best practices. A funding project risk management tool, <i>funding risk register</i>, has been developed with optimization and simulation capability. This register can produce a potential adjustment of the project let schedule under 15 preset funding change scenarios as well as a user-specified funding change, which can help NCDOT staff members and Executive Management Leaders to make better decisions in budget management, cash management, and project management.</p>			
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DISCLAIMER

The contents of this report reflect the views of the authors and not necessarily the views of the University of North Carolina at Charlotte (UNCC). The authors are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of either the North Carolina Department of Transportation (NCDOT) or the Federal Highway Administration (FHWA) at the time of publication. This report does not constitute a standard, specification, or regulation.

Specifications and cost estimates used in this research study are based on project bids and informal quotes obtained from certain manufacturers. They cannot to be considered as a uniform standard or purchase price.

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EXECUTIVE SUMMARY

Due to the uncertainty of the current economic environment, funding uncertainty becomes one of the main risk factors for budget/cash management, project management, and its implementation. Therefore, it is desirable for the North Carolina Department of Transportation (NCDOT) to incorporate funding risks into the project risk management process for better decision-making in budget management, cash management, project management, and implementation under changing funding conditions.

Funding project risk management is a process for identifying, assessing, and prioritizing funding project risks. In order to minimize or eliminate the impact of negative outcomes, one must identify what projects have higher risk to avoid potential project Let delays or funding issues. The idea behind using risk management practices is to protect organizations and businesses from being vulnerable in project implementations. Hence, funding project risk management becomes essential for NCDOT as part of decision-making processes.

In 2011, it became vital for NCDOT to carry out a study to understand the risks involved in funding source changes and other uncertain environments, and to develop a tool or guideline in order to cope with such risks in budget/cash management, project management, and implementation. A research project, Development of Funding Project Risk Management Tools, was commissioned to the team in the Systems Engineering and Engineering Management Program at the University of North Carolina at Charlotte.

The objectives of this research project are to (1) investigate current risk management and funding risk management processes in transportation areas, (2) analyze project risk management and funding risk management practices in DOTs of other states, (3) analyze best practices in the other states, especially California Department of Transportation's practices, and appraise the potentials for possible implementation, and (4) develop a funding project risk management tool to assist NCDOT staff members and Executive Management Leaders for better decision-making in budget/cash management, funding risk management, and project management under the frequently changing funding environment.

The investigations of current risk management and funding risk management processes in transportation areas revealed a lack of funding risk management. The research team also reviewed handbooks and manuals of other DOTs and sent out a short survey to DOTs in 49 states. After the review of the documents and the survey responses, the investigation has been focused on several states including California, Florida, Iowa, Minnesota, and Washington States. Based on the investigation, the research team found no indication that DOTs in these states are explicitly implementing funding project risk management tools. Instead, funding risks are managed as part of the project risk management, which is typically undertaken and documented by the project manager with help from project team members. The research team also observed that California DOT (Caltrans) is one of pioneers implementing the project risk management process, and hence, an in-depth review on Caltrans' practice was conducted.

The in-depth review showcased that Caltrans has identified detailed risks in different areas of transportation project such as Environmental, Design, Right of Way, Construction, Engineering, Organization, etc. with advanced and unique risk mitigation approaches. Particularly for Funding Risk Management, Caltrans has a Fund Estimate program which shows a five year projection of available resources and estimates State Transportation Improvement Program (STIP) & State Highway Operation and Protection Program (SHOPP) capacity. Another recent development in Caltrans is the California Transportation Infrastructure Funding System (CTIFS) which is an integrated system encompassing programming, project implementation, and funds management. More details are provided in Chapter 4 of this report.

The research team has developed a funding risk register tool that primarily offers two major functions. The first primary function is to assess funding risks on individual construction projects via the impact and the likelihood of funding changes. Accordingly, the register highlights relatively high impact and/or high likelihood as the indication that the project needs a special attention for a potential funding issue. The second major function of the register tool is to provide an optimized adjustment to the Project Let schedule in order to mitigate funding issues. The register formulates and solves a mathematical optimization problem that corresponds to a funding change scenario for a

given time window. As a result, the register provides a revised Project Let schedule that complies with the funding change while minimizing the impact of schedule changes.

Several versions of the funding risk register have been developed over the research period. The final version of the risk register incorporates the features that include forecasting individual payout curve, accepting only high-impact large-scale projects, incorporating the project delivery rate as a part of the performance measure, extending the time window for monitoring cash flows to 36 months, and employing a data-driven estimate of lead time. The final version simulates 15 scenarios of funding deviation from the basis of the original funding level, which consist of 5 scenarios from one percent to five percent of funding surpluses and 10 scenarios from one percent to ten percent of funding deficits.

In summary, the research team has investigated current project risk management and funding risk management processes, and evaluated the best practices among DOTs in the US. An in-depth study has been carried out to appraise the potentials for possible implementation of the best practices. A funding project risk management tool has been developed with optimization and simulation capability. The tool is capable of assessing funding risks on individual construction projects, and providing a potential adjustment of the project Let schedule under 15 funding change scenarios as well as for a user-specified funding change scenario. The adjusted schedule is optimized to curtail the impact of the funding change, and can serve as a basis for NCDOT staff members and Executive Management Leaders, particularly in Funds Administration Section, Program Development Branch, and Prioritization Office, to make decisions in budget management, cash management, and project management.

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CHAPTER 1: INTRODUCTION

Funding project risk management is a process for identifying, assessing, and prioritizing project funding risks. In order to plan to minimize or eliminate the impact of negative events, one must identify what projects have higher risk to avoid potential project delays or funding issues. The idea behind using risk management practices is to protect organizations and businesses from being vulnerable in project implementations.

1.1 Introduction to Report

This report serves to document the research approaches, findings, and products produced by the research team in the Systems Engineering and Engineering Management (SEEM) Department at the University of North Carolina at Charlotte (UNCC). This report reviews, analyzes, and discusses how to plan for project risk management and funding risk management in other state transportation departments. Current funding and cash management practices, needs, and available data in the North Carolina Department of Transportation (NCDOT) are identified and turned into statistical and decision-making models that can predict the individual construction payout curve and solve a let scheduling problem. These models are incorporated into a product called the funding risk register (Register) that can be utilized to assist decision-making processes related to funding project risks in NCDOT.

1.2 Need for Research

Very few states have financial or funding risk management programs for the operations in their transportation department yet risk management plays a key role in strategy and is widely seen as essential. Given the complexity of the risks companies and organizations face, the management of those risks is seen as a high priority, as shown in a survey by KTMG, a Swiss tax company (KPMG International, 2013).

The results of this survey are shown in Figure 1.

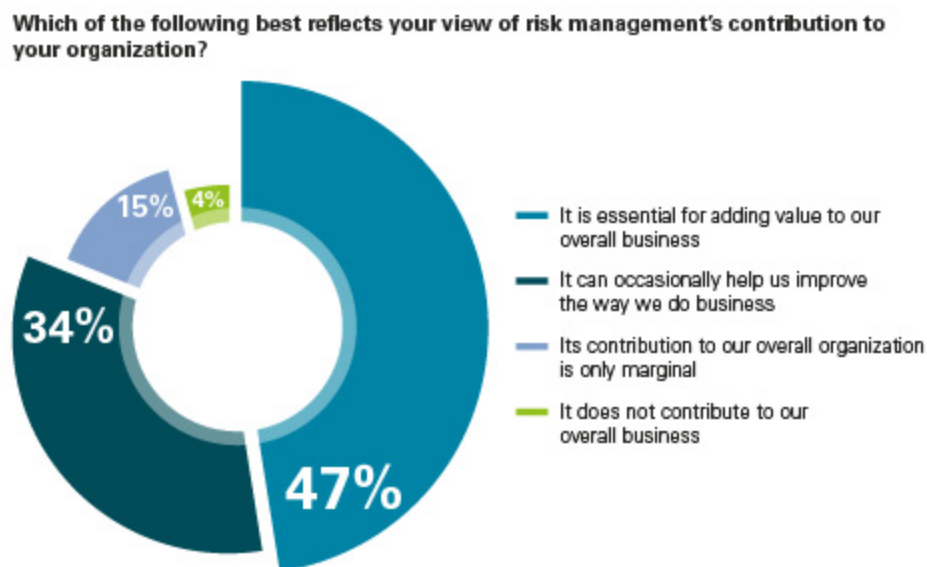


Figure 1 Survey of the Importance of Risk Management

Given that 47% of respondents say that risk management adds value to their business and 34% say that it improves the way business is done, it is perplexing that more state departments do not implement risk management programs

for their operations and projects. Department of Transportation risk management needs to be studied and implemented to increase the overall value of state transportation projects. NCDOT recognized the importance of the project risk management, but there are not any tools available that can analyze risks involved with transportation construction projects. In particular, since those projects typically require large-scale funds, funding risk is one of the major factors that may affect the performance of construction projects. Therefore, it is necessary to investigate available funding risk management practices, and develop a funding risk analysis tool that analyzes the impact of funding risk and provides a scientific solution.

1.3. Research Objectives

The objectives of the proposed research project are to:

- 1) Investigate current risk management and funding risk management processes in transportation areas,
- 2) Survey project risk management and funding risk management practices in other states,
- 3) Analyze best practices in the other states, especially Caltrans' practices, and appraise the potentials for possible implementation, and
- 4) Develop a financial risk management tool to assist NCDOT staff members for better decision-making in budget/cash management, funding risk management, and project management under frequent funding change environment.

1.4. Organization of the Report

The remainder of this report comprises 8 chapters. A review of existing literature is shown in Chapter 2. Data collection consisting of funding risk items, surveys, and various DOT practices are shown in Chapter 3. A study of the best practices is detailed in Chapter 4, and models are developed in Chapter 5. The development of the funding risk register, Excel based VBA programs along with an open source solver that can identify project funding risk and provide an optimal adjustment of the let schedule, is discussed in Chapter 6. This includes the user's guide and application. Further issues of the funding risk register are discussed in Chapter 7. Conclusions of this report, its implementation, and future research and development, are discussed in Chapter 8.

CHAPTER 2: LITERATURE REVIEW

The literature review on the funding project risk management was carried out in three stages. Stage 1 included an extensive study of articles, academic/published papers and presentations on project risk management (PRM) in transportation projects, to get a clear understanding of the problem statement. Stage 2 encompassed around the funding risk management concept to determine the technical tools used for financial analysis of project cost and cost-related risk mitigation strategies. To get an insight on how such problems were resolved at the Department of Transportation (DOT) in other states, Stage 3 was a comparison of risk management strategies conducted by certain states' DOTs. The states considered in this comparison were California, Florida, Iowa, Minnesota and Washington. The results of the comparison showed California's DOT (Caltrans) to be relatively well documented and reliable in terms of managing their funds and overall cash balance. It was also observed that most of the other DOTs followed a similar risk management process to that of Caltrans. This chapter also provides a brief review on optimization models related to the transportation programming problem, which is a part of the tool developed in this research.

2.1 Project Risk Management

Project risk as defined in PMI Body of Knowledge (PMI, 2013) is “an uncertain event or condition that, if it occurs, has a positive or negative effect on one of more project objectives such as scope, schedule, cost, and quality.”

Project is a planned set of interrelated tasks to be executed over a fixed time period, within certain cost and other limitations. The risks encountered in projects are unexpected events or circumstances that have a chance of occurring and that may prevent a project from meeting its schedule and cost estimate. The three main aspects of a project are scope, cost and schedule. A certain risk factor is associated to each of the three aspects of a project. An increase or any change in the risk factor has an interlinked effect on each aspect and the overall result of the project. Figure 2 depicts the relation between scope, schedule, and cost, and the associated risk factor that affects each aspect. Thus PRM is defined by United States DOT (USDOT) as a process of managing the risk factor of a project such that it does not hinder the results and if possible compliments the project performance.

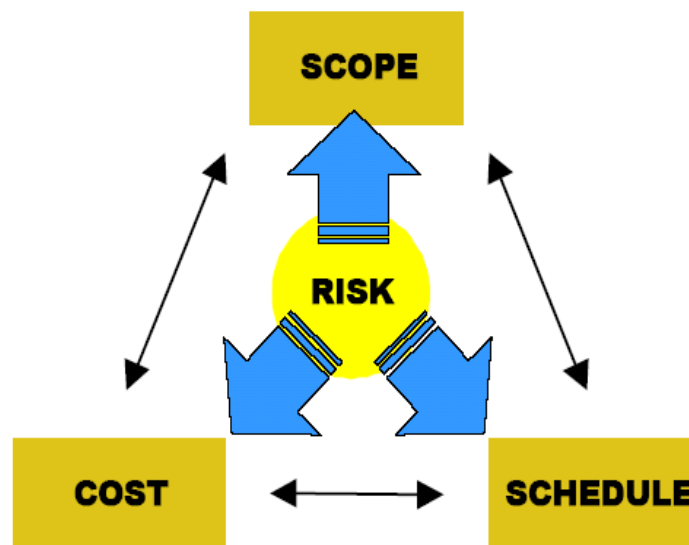


Figure 2 Relationship between Scope, Schedule, Cost, and Risk Factor

2.1.1 Types of Risk

- **Budget/Finance Risks:** Uncertainty in budget elements which could deviate the cash from the estimate.
Examples: deviations in unit prices, deviations in quantities.
- **Event Risks:** Risk of internal or external events that force the project team to work beyond the estimate just to meet the Project Scope and Statement of Work.
Examples: Extreme weather, contractor non-performance.
- **Scope Risks:** Risk of significant changes to project scope due to external pressures or change in leadership.
Examples: community pressures for changes in alignment or station location.

2.1.2 Risk Impact Assessment and Prioritization

Risk impact assessment is the process of assessing the probabilities and impacts of risk events when they are realized. The results of the assessment are then used to prioritize risks to develop a most-to-least-critical importance ranking. The common practice for prioritization of risk followed by USDOT is to establish a prioritization matrix with a horizontal Impact row and a vertical Probability column. Figure 3 shows an example of a simple prioritization matrix, where the Impact has four rankings from 'Minor' to 'Catastrophic' and the Probability column also has four possibilities from 'Unlikely' to 'Almost certain'. As seen in the matrix, the section corresponding to 'Catastrophic/Major' and 'Almost certain/Likely' is highlighted in dark red color to draw attention to that particular risk event. Similarly, the section corresponding to 'Minor/Moderate' and 'Unlikely' is highlighted in green color which signifies that the risk can be addressed later or even ignored. Thus, ranking risks in terms of their criticality or importance provides insights to the project's management on where resources may be required to manage or mitigate the realization of high probability/high consequence risk events.

		IMPACT			
		MINOR	MODERATE	MAJOR	CATASTROPHIC
PROBABILITY	ALMOST CERTAIN	SIGNIFICANT	MAJOR	CRITICAL	CRITICAL
	LIKELY	SIGNIFICANT	SIGNIFICANT	MAJOR	CRITICAL
	POSSIBLE	MINOR	SIGNIFICANT	SIGNIFICANT	MAJOR
	UNLIKELY	MINOR	MINOR	SIGNIFICANT	SIGNIFICANT

Figure 3 Prioritization Matrix (Merkhofer, 2013)

2.1.3 Project Risk Management Process

A diagram of the project risk management process is shown in Figure 4.

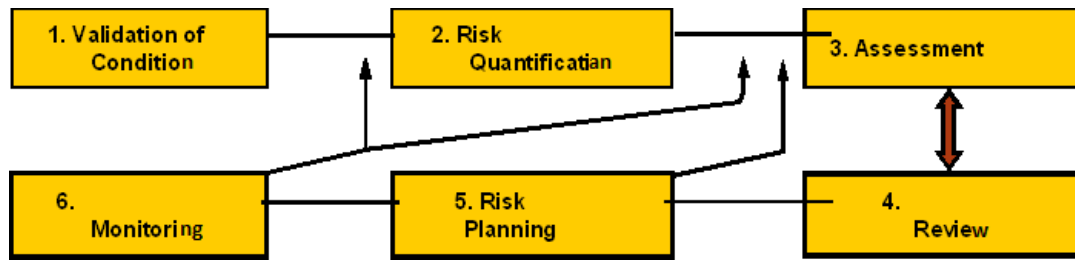


Figure 4 Project Risk Management Process

The steps involved in the project risk management process are shown below:

- I. Validation of Base Conditions
 - This stage includes collection of data on the scope of the project. The data is used to schedule the project timeline and establish budget limits
 - The validation of data is given for expert independent reviews
 - The reviews are characterized for reasonableness and accuracy of information
 - The findings for risk identification and quantification are documented
- II. Risk Identification & Quantification
 - Prepare long list of the potential risks to major phases in a project
 - Use expert panel/workshop and other comparable projects as sources of risks
 - Estimate impacts in terms of cost, schedule delay, screen for significant risks
 - Document in risk register
- III. Risk Assessment (Modeling)
 - Risk Prioritization
 - Identify appropriate assessment method
 - Evaluate risk cost and schedule effects on the total project independently or integrated
 - Verify results
 - Validate adequacy of the project
- IV. Discussion/Review
 - Discussion on the proposed model and reviewing of the assessment. This stage is in co-ordination with the risk mitigation planning stage.
- V. Risk Mitigation Planning
 - Identify unacceptable risks
 - Identify potential causes (risk drivers)
 - Establish mitigation measures
 - Estimate implementation requirements (time, costs)
 - Prioritize risk mitigation strategies
 - Assign mitigation responsibility
 - Allocate risks to owner, contractor, other parties
- VI. Implementation/Monitoring
 - Management approvals
 - Allocate funding
 - Change design/change construction approach

- Contact the construction
- Field changes (e.g., change orders)
- Monitor contractor performance and field conditions
- Re-evaluate and implement corrective actions, as appropriate

2.2 Funding Risk Management (FRM)

Funding risk management is a specific branch of risk management that deals with the financial side of the project or organization. FRM involves assessing and prioritization of cost related risk to maintain the overall cost-balance within the specified limit. Projects awarded by the DOT have a long-time schedule ranging from a year to 10 years or more. Thus, “the development of a sound financial plan is critical in securing adequate financing for a project” (FHWA, 2013). In the same vein, awarding the right projects at the right time is an important decision affecting the cash balance of the DOT for a long period. FRM provides statistical and optimization tools to help management make a confident decision on which projects to award and which should be delayed to maintain required cash flow for the future.

2.2.1 *Project Cost and uncertainly over time*

The project cost is divided as per the phases in the project. Each phase might have a certain risk factor attached to it. To understand the cost-related risks associated with each phase in a project a construction project example is considered. The initial phases like the defining of the concept to preliminary engineering give an estimated cost which is the most likely cost. The final design stage is just before the bidding stage gives the most likely cost. Once the bidding is done and the project goes to the next stage of construction then there is the need of actual money spent which resembles the actual cost. The deviation between the actual cost and the estimated 'most likely cost' is a risk factor. If the actual cost is well within the estimated cost then, the process is smooth and there is no risk associated with it. However, if the actual cost exceeds the estimated cost then it becomes a budget risk. Here the idea is to plan the awarding of projects well in advance to mitigate the possibility of a budget risk in any of the construction projects in the future.

2.2.2 *Different Technical Methods for Quantifying Risks*

Different technical methods for quantifying risk are shown below.

I. Simulation or Modeling Methods (Monte Carlo) Appropriate for:

- Evaluating Complex Projects and Risks
- Integrated Cost and Schedule Assessments
- Dynamic Critical Path Schedule

Example: Each cost estimate line item and each risk item is assigned a probability curve. Probability curves are chosen by evaluating the behavior of each risk item. Probability curves whose parameters can easily be understood and estimated by project members are preferred.

Exponential distribution is a commonly-used distribution, shown in Figure 5.

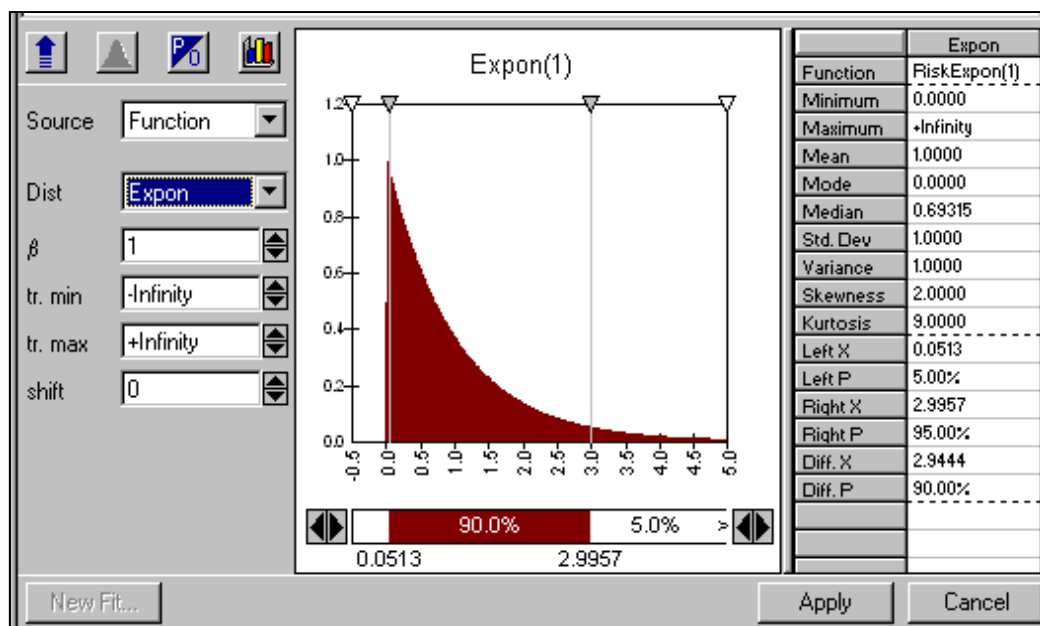


Figure 5 Simulation/Modeling Method - Exponential Distribution (Palisade Corporation, 2013)

II. Non-Simulation Methods (Expected Value and Variance, PERT) Appropriate for:

- Risks are Not Complex; Events are Independent
- Cost or Schedule Assessment
- Stable Critical Path Schedule
- Current Year or Cost Estimates

Example: Figure 6 shows an example of simple analysis chart of Risk Priority Index (RPI) versus Risk Type for the Top 5 risk types in Transportation projects (excerpt from FTA, 2004). As seen in the graph, construction related risk has the highest RPI. Such graphs provide good visuals for better assessment of risks.

III. Other Tools and Techniques:

- a. Flowcharts, Force-Field Analysis or Grass-Roots Analysis.
- b. Focus Group and Problem-Selection Matrix.
- c. SAS Enterprise Risk Management.
- d. Decision Tree Models (What If Analysis).
- e. Spreadsheets (plot histograms, charts, and databases).

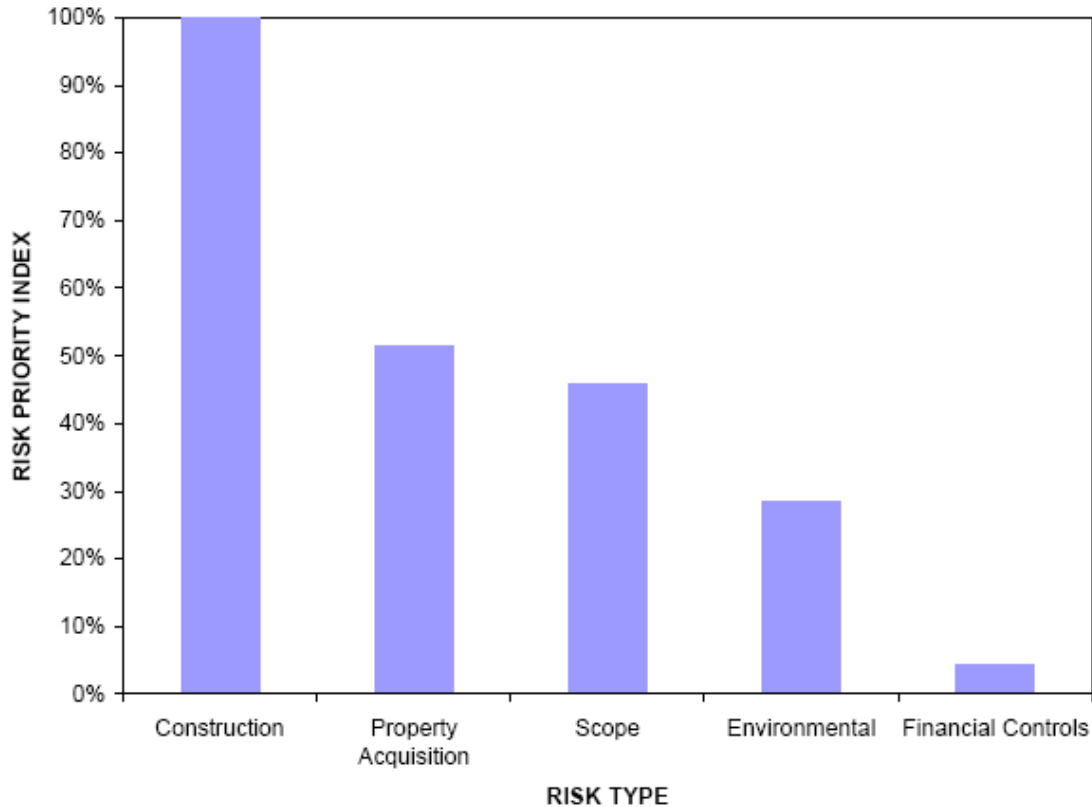


Figure 6 Top Five Risks Schedule (USDOT, 2004)

2.2.3 Risk Mitigation Strategy

Risk mitigation strategies were found to consist of the following:

- I. **Management Action:**
Quick actions taken by project management or higher management.
Example: Fraud, waste, and abuse may be mitigated by developing and implementing strict financial controls with multiple checks and balances in the approval chain. An example talking about the actions taken to avert dangerous traffic situation in Washington, D.C. is another example in management action (USDOT, 2010).
- II. **Contracts:**
Intelligent contracts may share/transfer risks to other project execution team members (subcontractors, consultants, etc.).
Example: Contractor non-performance risk may be mitigated by including liquidated damages in contracts. A real example dealing with contracts is about how Missouri DOT contracting their Traffic Management system to external contractor/consulting company to transfer/share the traffic risk (TransCore, 2011).
- III. **Insurance:**
Purchase of insurance to mitigate project asset risk.
Example: Risk of construction accidents may be mitigated by purchasing builder's risk insurance. USDOT provides the example of an insurance program for the builder/contractor rather than the traditional owner insurance program in its Construction Program Guide (USDOT, 2011).

IV. Contingency:

Contingency agreement on unallocated project cost and schedule (schedule float).

Example: The risk of scope changes may be mitigated by having a contingency agreement. There is an example that talks about the operational contingency planning in the Federal Aviation Administration to ensure safety and continuity of services in the National Airspace System (USDOT, 2013).

2.2.4 Effect of Mitigation on Total Cost Variances

Implementing technical methods for quantifying risks and using the mitigation strategies to eliminate those risks ahead of time, will make the project graph leaner and ensure smooth cash in-flow and out-flow. As seen in the graph in Figure 7, the green thin line represents the project cost without implementing any risk mitigation strategies. This graph shows a peak in the cost in the middle of the project as well as at the end with extended time. Comparing it with the dash line which represents project cost with mitigated risks, the dash line graph is leaner and only has a peak project cost in the middle of the project timeline with no additional cost towards the end and shorter time. Similarly the third graph, the dotted line which represents project cost with mitigated risk and realized opportunities, has a peak project cost (construction cost) well before the other two graphs with the shortest completion time. Thus, mitigating risks before their realization and realizing opportunities, reduces the project timeline and project cost.

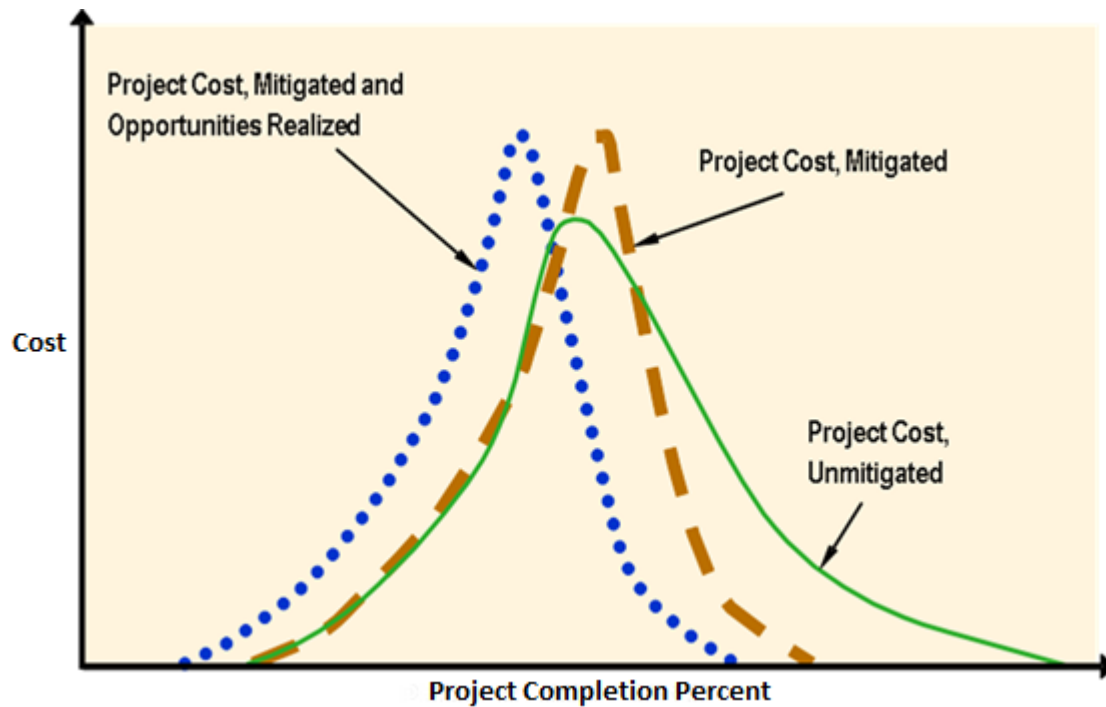


Figure 7 Effect of Mitigation on Total Cost Variances (USDOT, 2004)

2.3 Funding Risk Management Strategies and Tools by Other States' Department of Transportation

To get an insight into the funding risk management procedure, strategies and tools used at other DOTs, an in-depth research was conducted on other states' risk management approach. The results of the research showed that the state of California, Florida, Iowa, Minnesota and Washington State had a standardized and functional risk management process. To understand the risk management process at each state, their procedures were compared to derive the most efficient and sustainable risk management model.

Each of the state's PRM procedures and management tools were reviewed, to determine the differences, similarities, pros and cons. For an analytical comparison of each state's processes, a common comparison platform was developed. The comparison platform included all the risk management process steps which were commonplace, essential and followed by all the DOTs included in the research. Caltrans' six risk management process steps (Caltrans, 2007) shown below are used for comparison:

1. Risk Management Planning
2. Risk Identification (Threats/Opportunities)
3. Qualitative Risk Analysis
4. Quantitative Risk Analysis and Prioritization
5. Risk Response Planning
6. Risk Monitoring and Control

Results of the comparison revealed that Caltrans' PRM procedure is the original model for almost all other DOTs. Other DOTs' PRM is based on what Caltrans has done with some shifts or expansion. Generally, different DOTs are using different management tools, which are built based on Caltrans' PRM model. The way how they quantify the risk is similar, but with different scoring systems or sequences. Hence, it was determined that Caltrans has a more advanced process, which insinuated a thorough evaluation of Caltrans risk management practices. The results of the research of other DOTs, comparison of DOTs and evaluation of Caltrans practices are explained in detail in Section 3.4.

2.4 Review of Optimization Models

In literature, several highlight approaches are used to transportation programming problems, but none are easily adaptable to the methodology, data, and schedule constraints of this project. The articles presented in this section do present a solid foundation for a new model, and are particularly useful for a more general study of the problems facing transportation program managers.

In a linear goal-programming model for Public-Sector Project Selection, Colin Benjamin offers a linear programming process to evaluate public-sector projects (Benjamin, 1985). The first step in his process is to choose a set of projects from a feasible project list. After the projects are selected, they are then organized using linear programming, based on the resource allocation and other factors such as social, economic and political goals. A model is developed, and the projects are evaluated and chosen to provide the greatest benefit based on the goal and resource constraints. This article helps to provide a guideline for developing the model to evaluate the Department of Transportation projects.

Taplin and Qiu developed a multi-criteria model for the allocation of funds to Australian public road projects (Taplin and Qiu, 1995). This model directly relates to our research task and provides insight into one method for solving the problem. The authors explored how to go beyond the basic cost benefit analysis to evaluate a project. They developed multiple criteria, and then used goal programming to choose the best projects based on the criteria. Goal programming is an extension of linear programming where the objective is to minimize the weighted deviations from goals. Some of the goals that were used for this study were developmental, state and national economy, tourism, savings in private and commercial travel time, and savings in vehicle operating costs. These goals can be adjusted on a scale of 0-10. This paper provides a direct basis from which we can draw upon and will be very helpful when we develop our model.

The Institute of Transportation Studies at the University of California at Davis published a study on transportation project programming (Niemeier, Zabinsky, Zeng, and Rutherford, 1995). This article takes a slightly different

approach than Taplin and Qiu. The authors here developed five optimization models for selecting transportation projects. The five models that they developed are 1) a priority index to rank the projects but does not facilitate trade-offs between project costs and the ranks, 2) a model that does facilitate the trade-offs between project cost and rank, 3) a model that addresses policy objectives by setting a fixed goal for each objective, 4) a budget model with the requirement that each project meets or exceeds the policy objective, and finally 5) a model that unifies budgetary constraints and relative rankings of the projects. This different approach gives us yet another procedure from which to draw upon as we develop our own method for selecting projects.

The authors of Integrated Maintenance and Expansion Planning for Transportation Network Infrastructure used the Generalized Bender's Decomposition as the basis for an algorithm to optimize the entire project selection process (Gao, Xie, Zhang, and Waller, 2011). Road maintenance and road expansion problem were formulated together as a mixed-integer, nonlinear, bi-level optimization problem. This model is much more complicated than is necessary for the current problem, but presents numerous applicable considerations. Among these are the influence of road roughness on vehicle speed and the relative cost per kilometer of maintenance, expansion, or a combination of the two.

An earlier study published in the Transportation Research Record, presents several algorithms for determining the priority of bridge repairs (Patidar, Labi, Morin, Thjompson, & Sinha, 2011). The algorithms include the incremental utility-cost ratio (IUC), Lagrangian relaxation, and pivot and complement methods. The authors concluded that for agency-wide bridge management, IUC consistently performed the best in terms of computational speed, accuracy, simplicity, and robustness. While the specific models in the study are not useful for the current problem, the formulation of the objective function, constraints, and variables are applicable. The authors also converted each of the bridge performance criteria into scaled utilities with weighted coefficients. We expect to use a similar method for the current research project.

Shang, Tjader, and Ding developed a transportation project selection method which allows feedback and interdependence among various decision levels and criteria (Shang, Tjader, and Ding, 2004). The authors used the Nominal Group Technique with a nine member advisory council to divide the criteria into four groups: benefits, opportunities, costs, and risks. Using pair-wise comparison, they were able to establish the importance of each group and its subordinate criteria with respect to the overall goal. While time and resource constraints will prevent this project from assembling and consulting an advisory council, the techniques utilized for establishing the relative weight of the criteria is sound and should be considered for future research into transportation project selection.

Wey and Wu used the Fuzzy Delphi process to determine the goals and priorities for their study (Wey and Wu, 2005). The techniques used in this paper demonstrate a novel method for representing the interdependencies of multiple criteria in transportation infrastructure problems. Similar to Patidar et al. (2011), this study includes a number of constraints that can be considered in our own model.

A July 1981 study conducted by the Virginia Highway and Transportation Research Council outlines the then-current step-by-step approach used by several states when prioritizing projects (Jensen, 1981). This study uses a 100 point scale for each criterion, and defines the subjective descriptors applicable to different portions of the rating scale. We expect to use a similar method in formulating the model for the current research following Jensen's approach.

Roise, Shear, and Bianco of North Carolina State University studied the relationship between wetland values and transportation construction costs (Roise, Shear, and Bianco, 2004). The objective of the study was to minimize the total cost of construction and wetland impacts resulting from a specific transportation corridor. The model finds the best path through the wetlands based upon a set of individually weighted constraints. The authors then performed a sensitivity analysis to determine how the optimal path would change in response to changes in the coefficients.

Other than the mapping function, this model is fundamentally a linear programming model subject to a number of constraints. As such, the methodology is directly applicable to the current research project.

CHAPTER 3: INVESTIGATION OF BEST PRACTICES AND DATA COLLECTION

This section discusses collecting data to analyze the current practices at NCDOT and other state DOTs and the determination of states best practices. The analysis of the data presented in this section is shown in Chapter 4.

3.1 Initial Data Collection

The first step of collecting data was to familiarize the NCDOT funding process through interviews with personnel in the Program Development Branch. The results generated from these interviews led to the development of a preliminary influence diagram for the initial funding risk management tool and its subsequent revisions. A pilot study was used to determine the correlation coefficients for each of the identified influences with respect to funding changes. This study focused on 58 projects known to have had funding changes in 2011, with the aim of validating methodology. Prioritization rankings for the road and highway projects were found. We appreciate the great help from in locating and getting useful data for this project and for their valuable comments and discussions.

3.2 Identification of Funding Risk Items

The research team obtained Project Management Unit (PMU) Master Reports with the help of the Steering and Implementation Committee members, Ms. Lisa Gilchrist, Mr. Bill Martin, and Dr. Majed Al-Ghandour and their colleagues at NCDOT. The PMU master reports obtained are for all bridge, rural, urban, and interstate road projects. Since there is no searchable entry available in the SAP database for projects that have had funding issues, the research team has obtained text description of 66 funding issues out of 65 projects that occurred in 2011. The research team reviewed each of these 65 projects to determine when, why, and by how much the project funding changed. The team cross-referenced these projects with the SAP “long text” output and the Board of Transportation (BOT) agenda to determine the reason(s) for the funding change.

3.3 Short Survey to State DOTs

In the project progress meeting held on April 27, 2012, it was advised that the literature review discussed in Chapter 2 is expanded to include a survey on the actual implementation of funding project risk management tools in Caltrans and other DOTs. A draft of the survey questions was prepared by the UNC Charlotte research team, Mr. Burt Tasaico, and Dr. Majed Al-Ghandour. The survey would help the research team identify DOTs that implement the funding project risk management, and locate the person who is in charge of implementing it.

The first draft of the survey questionnaire was prepared by the research team. The purpose of the survey is to ascertain whether DOTs implement a formal funding project risk management or not. Furthermore, if it is being implemented, we intend to learn further details of their procedure by directly contacting the unit that is responsible for the funding project risk management. On the other hand, if no such process currently exists, we are also interested in learning their potential planning for a funding project risk management process that can be implemented within next three years. With this intention, a short survey comprising three questions was developed. An opening remark that explains the background of this survey was added by Dr. Majed Al-Ghandour based on Mr. Tasaico’s feedback. A complete survey is displayed in Figure 8.

NCDOT's Research Program along with a Research Team of the University of North Carolina at Charlotte has an ongoing research project looking at the "Development of Funding Project Risk Management Tools". A task of the research project includes the investigation of current best practice in funding risk management. Your participation in a short 3 questions survey (see below) will be helpful to our efforts to understand your funding project risk management process and where you implement the process within your funding project risk management cycle. Please forward this request to appropriate staff in your agency for a response.

If you have any questions please contact Majed Al-Ghandour (contact info at the end of this message). Thank you in advance of your participation.

QUESTIONS

1. Is your Department of Transportation currently using a formal risk management process to manage risks in your funding to transportation projects?

Yes _____ (go to Question 2)

No _____ (go to Question 3)

2. Please provide the requested contact information of the person in charge of your funding project risk management process?

Name:

Title:

Unit/Department:

Phone Number:

Email Address:

3. If the answer to Question 1 is "No", does your department plan to incorporate a funding project risk management process in the near future (within next 2 years)?

Yes _____

No _____

Please respond to:

Majed Al-Ghandour, Ph.D., P.E.

Assistant Branch Manager - Engineering Manager

Program Development Branch - NCDOT

1534 Mail Service Center, Raleigh, NC 27699-1534

Direct Phone: 919-707-4621

Fax: 919-733-3585

email: malghandour@ncdot.gov

Figure 8 Short Survey to Ascertain Funding Project Risk Management Practices in Other DOTs

The survey was distributed to the DOTs in all of the other states and 14 out of 49 responded. Of those, five responded 'yes' to the question, "Is your Department of Transportation currently implementing a formal risk management process to manage risks in your funding to transportation projects?" Of the five states responding 'no', two responded that they intended to start doing so this year or in 2014.

The research team took a deeper look into the publicly available materials from the five 'yes' states to help guide development of follow-up survey questions. The research team was unable to find any evidence that other DOTs currently implement funding risk management at the program level; rather, funding risk is managed solely at the project level.

Since most other states' project management methodologies are closely related to and perhaps inspired by that of Caltrans, the research team focused on developing a follow-up survey to acquire more information from Caltrans. This survey begins with a short summary of this research project and describes the research team's current understanding of Caltrans' risk management framework, and then follows by a set of questions from the research team for gathering more detailed information about the implementation of funding risk management in Caltrans' operations. A copy of the survey is attached in Appendix A.

3.3.1 Short Survey Results

The survey responses for the question "Is your Department of Transportation currently implementing a formal risk management process to manage risks in your funding to transportation projects?" are shown in Figure 9.

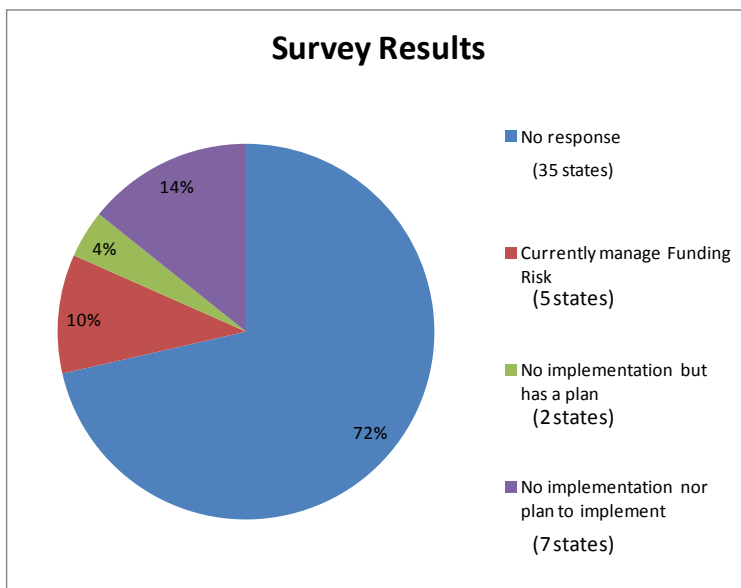


Figure 9 State DOT Survey Results

These states with formal risk management processes to manage risks in funding transportation projects are CA, KS, MO, PA, and UT.

Of the nine states responding 'no', two responded that they intended to start doing so in the next two years (MS and SD). Among 14 states that responded, seven states provided contact information of the person who is responsible for current (or future if not currently implementing) funding risk management (see Table 1).

Table 1 Corresponding Personnel for Funding Risk Management

State	Name	Title	Department
CA	David Youmans	Principal Transportation Engineer, Assistant Division Chief	Project Management Division
KS	Bruce Burditt, CPA	Chief of Financial and Investment Management	Office of Financial and Investment Management
MS	Randy Battey, P.E.	Assistant Chief Engineer	Operations
MO	Machelle Watkins	Transportation Planning Director	Central Office
PA	Brian D. Hare, P.E	Division Manager	PennDOT Center for Program Development and Management

SD	Joel Jundt	Director	Division of Planning & Engineering
UT	Fred Doehring	Deputy Preconstruction Engineer	Central Preconstruction

The research team took a deeper look into the publicly available materials from the five states with risk management programs to help guide development of follow-up survey questions. The research team was unable to find any evidence that other DOTs currently implement funding risk management at the program level; rather, funding risk is managed solely at the project level.

3.3.2 The In-depth Survey

As one earliest adopters of the risk management process, documentation available from Caltrans indicates funding risks are managed as one element of project risk management, while our review on other states (even those who responded ‘yes’) did not reveal any procedural handbook or manual pertaining to funding risks. Therefore, the research team decided to conduct an in-depth survey with Caltrans. The research team has developed survey questionnaire shown in Appendix A. The questions from that survey are shown below.

1. We would appreciate to know if there are additional articles or documents available in Caltrans’ funding risk management implementation process, in addition to the above documents. If there are additional available documents, can we get these documents?
2. Is funding risk a consideration when prioritizing projects?
3. When considering funding risk, are risk categorized? If so, what are the categories and their definitions?
4. Do you use qualitative method(s) to assess and analyze funding risk? If yes, please provide the method(s) you implement and any applicable documentation.
5. Do you use quantitative method(s) to assess and analyze funding risk? If yes, please provide the method(s) you implement and any applicable documentation.
6. What models (e.g., probability distribution or forecasting model) do you use to describe funding risks?
7. How do you measure the impact of funding risks?

3.4 Comparison of Risk Management by Other States’ Department of Transportation

The DOTs involved in this comparison include California Department of Transportation (Caltrans), Florida Department of Transportation (FDOT), Iowa Department of Transportation (IowaDOT), Minnesota Department of Transportation (MnDOT) and Washington State Department of Transportation (WSDOT). By reviewing their PRM procedures and management tools, the differences, similarities, pros and cons are determined.

3.4.1 Caltrans

While there was no indication that other DOTs specifically implement a funding project risk management process, a generic project risk management procedure is in place at some DOTs. In this report, we review the project risk management procedure of Caltrans that describes its implementation with respect to the entire project management process.

Project risk management in Caltrans consists of six process steps: Risk Management Planning, Risk Identification, Qualitative & Quantitative Risk Analysis, Risk Response Planning, and Risk Monitoring and Control. All six steps are the responsibility of the project manager, who leads the project team. Since the project risk management is part

of activities conducted by the project team, it is necessary to understand the overall project management process performed by the project team. A project team is comprised of every person who works on a project, including state employees, consultants, contractors, utility companies, resource agencies, and property owners (Caltrans, 2002). Among those in the project team, key members comprise a project development team (PDT). A typical set of PDT members is shown in Figure 10.

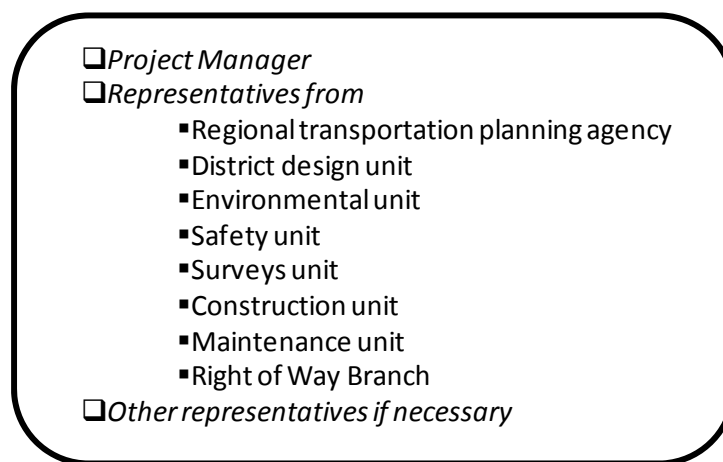


Figure 10 Typical Project Development Team

The main role of the PDT is to address significant project issues that may arise in the project life cycle. The project life cycle in Caltrans is depicted in Figure 11.

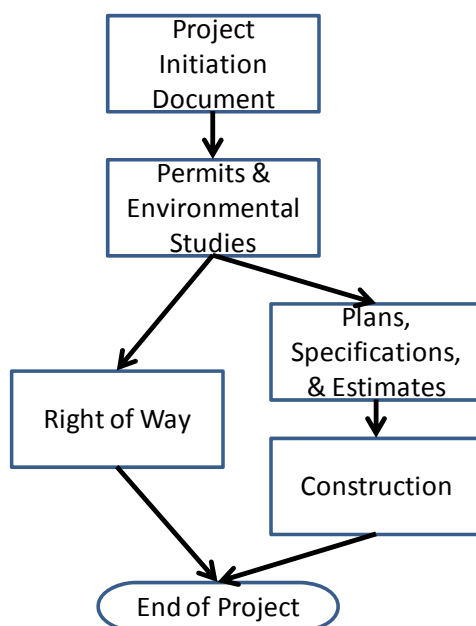


Figure 11 Caltrans' Project Life Cycle

In the project initiation document (PID) phase, the project team prepares a so-called risk management plan. The risk management plan is a form that is part of PID. This form is prepared by a project engineer and approved by the

project manager. In this risk management plan, the team determines the scope of the project risk management, and indicates risk analysis methods that will be used for the project (see Figure 12). This form also indicates the frequency of risk management meetings (Figure 13), and budget for risk management (Figure 14).

Risk Analysis Methods Used			
Qualitative Risk Analysis attempts to rank the risks into high, medium and low risk categories based on their probability of occurring and impact on an objective. (The objective with the most impact, at a minimum).			
This project will	_____	will not	_____ use qualitative risk analysis
This project will	_____	will not	_____ use District RM Web tool
Quantitative Risk Analysis attempts to estimate the risk that the project and its phases will finish within objectives taking into account all identified and quantified risks, estimates the contingency needed for cost and schedule and identifies the best decisions using decision tree analysis. (See <i>Project Risk Management Handbook</i> for additional information and when to use Quantitative Risk Analysis).			
This project will	_____	will not	_____ use quantitative cost risk analysis
This project will	_____	will not	_____ use quantitative schedule risk analysis
This project will	_____	will not	_____ use decision tree analysis
This project will	_____	will not	_____ use other quantitative methods

Figure 12 Excerpt from the Risk Management Plan Form: Risk Management Methods

Period of Risk Management Meetings and Full Review of Project Risk	
Meetings for the purpose of discussing and making decisions on Project risk will be held:	
Weekly _____	Bi-Weekly _____ Monthly _____ Other _____
The risk management identification, analysis and response planning process shall occur during project initiation document (PID). A full review and update of risk register will occur at the beginning of each subsequent phase of the project.	

Figure 13 Excerpt from the Risk Management Plan Form: Frequency of Risk Management Meetings

Budget Allocated for Risk Management		
Staff allocated and assigned for risk management activities include:		
PMSU Chief	@ _____	Hrs
Risk Officer	@ _____	Hrs
PM	@ _____	Hrs
Environmental	@ _____	Hrs
Design	@ _____	Hrs
R/W	@ _____	Hrs
DES/Structure	@ _____	Hrs
Const.	@ _____	Hrs
Traffic Operations	@ _____	Hrs
Maintenance	@ _____	Hrs
	@ _____	Hrs
Total:	_____	Hrs
_____ Hrs. × \$ ____ /Hr = A total of \$ _____ is allocated for Risk Management on this project.		

Figure 14 Excerpt from the Risk Management Plan Form: Risk Management Budget

In the subsequent phases of the project life cycle, project risk management activities are embedded in project management activities, which consist of five process groups: Initiating, Planning, Executing, Controlling, and Closing process. Relationship of the five process groups is illustrated in Figure 15 (Caltrans, 2002). Note that project risk management components appear in two process groups: Planning and Controlling. Project Risk managing activities are highlighted in red.

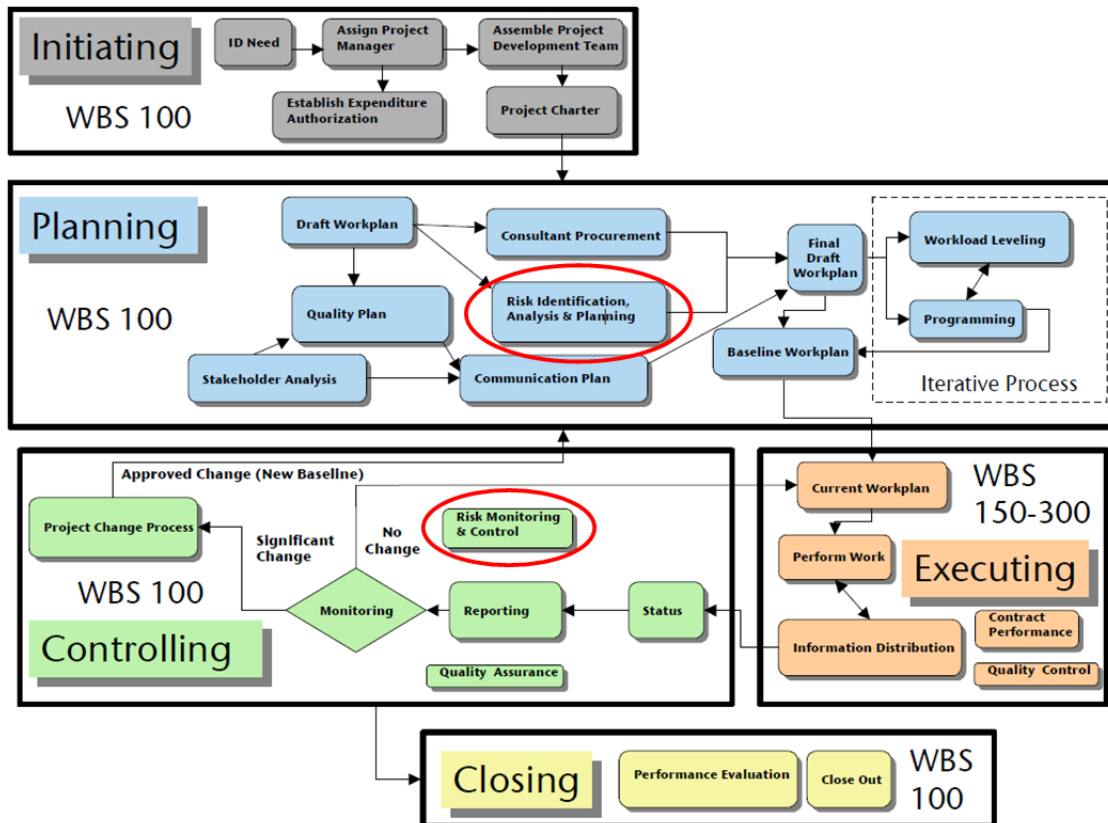


Figure 15 Relationship of Project Management Process Groups in Caltrans

Risk identification is accomplished by creating a risk register for the project. Key members who participate in creating the risk register include project manager, project team members, risk management team (if assigned), subject matter experts both from the project and from outside the project team, customers, end users, other project managers, stakeholders, and risk management experts.

Next, risks are analyzed qualitatively and/or quantitatively. Qualitative analysis assesses the priority of risks using the risk ranking scheme based on risk probability and impact (as described in our first quarterly report submitted in December). Once qualitative analysis is performed for individual risk, quantitative analysis estimates the probability distribution that a project will meet its cost and time objectives. It is noteworthy that the quantitative analysis is not required for projects, but can be implemented if it is necessary due to high complexity and costs of a project. After project risks are identified and analyzed as above, PDT conducts risk response planning that evaluates alternatives to cope with each risk and selects a suitable strategy from one of avoid, transfer, mitigate, exploit, share, enhance, or acceptance. Accordingly, PDT designs specific actions to accomplish the strategy.

Project funding risk is one of the project risks at Caltrans considered in the process as highlighted in Figure 16 (Caltrans, 2007).

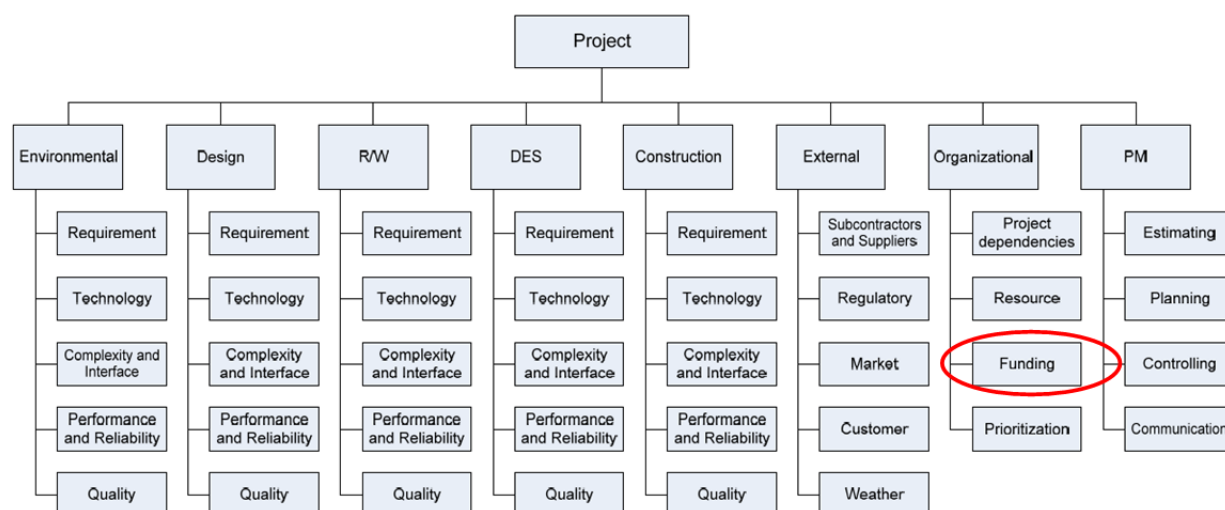


Figure 16 Risk Breakdown Structure of Caltrans

Our notion is that a formal project risk management process has not been installed in NCDOT. Hence, it is impractical to place the funding project risk management tools that will be developed by this research within the project risk management process. Instead, we propose to install the tools within the Funds Administration Section in collaboration with the Prioritization Office for aiding funding-related decision. In the future when the project risk management process is established, the Funds Administration Section can participate in the risk management team by giving inputs regarding the funding risks.

3.4.2 FDOT

In FDOT's project management handbook, it presents risk management plan, different elements of the risk management, and introduced a graded approach to quantify the risk. It deals specifically with the project manager's responsibilities with risk management processes, and it describes three processes: the Risk Based Graded Approach, Caltrans Method for Risk Analysis and the Project Risk Register.

Risk Based Graded Approach is a process to define the overall risk value of the project, which should be used during the initial scoping phase of the project to assess overall project risk. This graded approach is a management tool used to assign resources, define scope, evaluate risk elements and get consensus. It determines requirements for planning and control of the project work effort, maximizes project control effectiveness at the lowest cost, and assists in identification and mitigation of project risks. By list all the risk elements possibly would occur in a project, it divides the risk into low, medium and high by scoring 1, 3 and 5, respectively; also the priorities are ranked as 1, 3 and 5, according to low, medium and high, respectively. Then the total risk score is obtained by multiplying these two, which is "Total Risk Score = Risk Score x Priority Score". An example is shown in Table 2.

The total risk score will be examined. If the total risk score is higher than 10 times of the total numbers of the risk elements, this project is a potentially high risk project; if the score is below 60% of 10 times of the total numbers of the risk elements, it is a low risk project; otherwise it is a medium risk elements. In the example case in Table one, 137 is between 10x15 and 60%x10x15, therefore, it is a medium risk project.

The Project Risk Register is a formal risk analysis involving input from both internal and external stakeholders. The Project Risk Register should typically be used on only the most complicated, riskiest FDOT projects.

Table 2 Example of Graded Approach by FDOT

ITEM	RISK ELEMENT	RISK SCORE	PRIORITY	TOTAL
1	Utility Involvement	1	3	3
2	Project Schedule	5	5	25
3	Interfaces	3	1	3
4	Experience/Capability	3	3	9
5	Right of Way	3	1	3
6	Environmental Impacts/Contamination	3	1	3
7	Regulatory Involvement	1	1	1
8	Contractor Issues	3	3	9
9	Resource Availability	5	3	15
10	Project Funding	1	1	1
11	Political Visibility	3	5	15
12	Public Involvement	3	3	9
13	Safety	3	3	9
14	Construction Complexity	1	1	1
15	Weather Sensitivity	5	5	25
	Total Risk score			137

3.4.3 IowaDOT

IowaDOT created a formal risk management model to be utilized during all stages of the project life cycle of highway projects. It gives a good assessment process for establishing risk models. And it identified different hazards as result, with suggested treatment.

IowaDOT is using the similar process as Caltrans by assign different scores to the risk frequency and severity, obtained the Risk Assessment Matrix, as Figure 17.

FREQUENCY	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
		SEVERITY				

1 to 3	Low Risk Potential
4 to 6	Reduced Risk Potential
8 to 10	Moderate Risk Potential
12 to 15	Elevated Risk Potential
16 to 25	High Risk Potential

Figure 17 IowaDOT Risk Assessment Matrix

3.4.4 MnDOT

Project Management at Minnesota DOT includes the methods and processes used to manage risks and seize opportunities to achieve strategic, program, project and operations objectives. A central goal and challenge is improving the coordination of these risk management efforts and providing a unified picture of risk for stakeholders. The RISK/CONTINGENCY GUIDANCE outlines steps and instructions that will help to use the tools:

RISK REGISTER is a spreadsheet that allows you to document and assess your risks, which will help you in determining a number to assign for contingency of the risk. This spreadsheet also helps you document your risk assessment to share if district management has questions.

RISK CHECKLIST includes a comprehensive list of potential risks to help you in identifying those that may impact your project.

3.4.5 WSDOT

Washington State presented guidance for project risk management with information to project managers and project teams that will help with their risk management to provide a consistent methodology for performing project risk management activities with relevant techniques and tools. WSDOT divided the projects into 4 different levels as shown in Table 3.

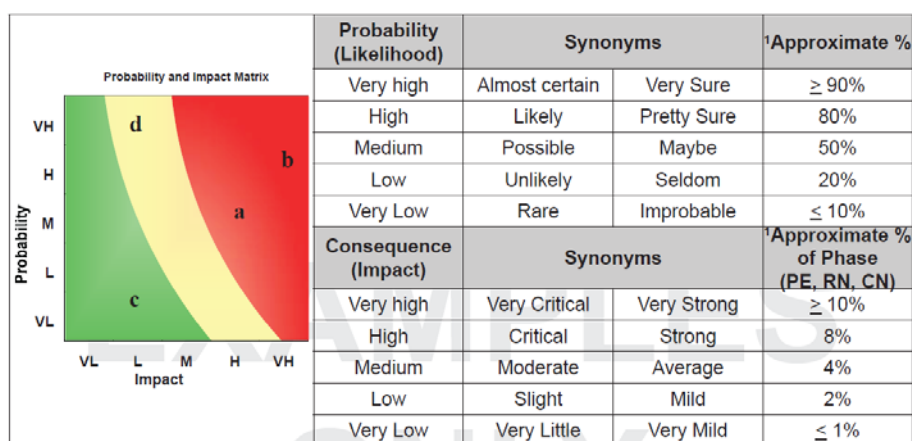
Table 3 WSDOT Project Risk Levels

	Project Size (\$M)	Risk Assessment Level	Notes
Less Formal Risk Assessment	0 to 10	Project Team Risk Assessment Project Management Online Guide (PMOG) Risk Management Plan Qualitative Tool	The Project team assesses each identified risk for its probability of occurrence and its impact on project objectives. Project teams may request assistance from subject matter experts or functional units to assess the risks in their respective fields. The self-modeling spreadsheet can be used for any project.
	10 to 25	Project Team Risk Assessment Self-Modeling Spreadsheet Quantitative Tool	
More Formal Risk Assessment (Workshops)	25 to 100	Cost Risk Assessment (CRA) Workshop Quantitative Tool	The team, working collaboratively with independent subject matter experts, reviews and/or validates cost and schedule estimating and identifies, characterizes and analyzes risks. Accomplished in a structured workshop setting. Modeling can be accomplished with off the shelf software or using the self-modeling spreadsheet.
	Over 100	Cost Estimate Validation Process (CEVP) Workshop Quantitative Tool	

WSDOT uses the Self Modeling Risk Management Plan Spreadsheet, in order to register different types of risks. A simplified self-modeling spreadsheet that project design teams can enter risk into and determine what the quantitative impacts are to the project estimate. WSDOT's risk assessment matrix and associated percentages are shown in Figure 18.

Qualitative Risk List

count	T/O	RBS #	Risk Title	Probability	Impact
a	T	ENV 30.1	Permits and Permit Appeals	Medium	High
b	T	UTL 20.1	Unidentified Utility Conflicts	High	Very High
c	T	STG 20.4	Change to Substructure Assumptions	Very Low	Low
d	T	ROW 40.1	Managed Access challenge	Very High	Low

**Figure 18 Suggested Percentages (project teams may adjust if they desire)**

For larger size of projects, CRA and CEVP are applied to estimate the project cost, which helps to manage the risk.

CEVP® (Cost Estimate Validation Process) is an intense workshop in which a team of top engineers and risk managers from local and national private firms and public agencies examine a transportation project and review project details with WSDOT engineers. The CEVP® workshop team uses systematic project review and risk assessment methods to identify and describe cost and schedule risks. CRA (Cost Risk Assessment) is a term that

describes a workshop process similar but less intense than the CEVP®. CRA is a term used to describe a broad program of risk based assessment being conducted within Washington State Department of Transportation. CRA is also a term that describes a workshop process similar but less intense than a CEVP.

CEVP most frequent cost risks include R/W, structures, environmental, cost, seismic design criteria, design and/or construction related, access, storm water, and traffic control. CRA most frequent cost risks include, environmental, design related, cost, R/W, structures, storm water, and seismic design criteria.

The benefits of risk based estimating, utilizing CEVP/CRA workshops include:

- Increased and improved communication, within the project team, in and among cross-functional groups, stakeholders, management, the legislature, and the public at large
- The risk ranking provided by workshop output helps the project manager know where to focus his/her team's efforts.
- The ability to act pro-actively on risk items and track the risk for which no preemptive action can be taken is helpful.
- It provides a running start into development of the risk management plan component of the project management work plan.
- Project teams receive ideas on potential response strategies for major risks.
- Project managers are better prepared for the unexpected.

3.4.6 Comparison Results

All the DOTs presented previously are following the same process for project risk management, as

1. Risk Management Planning
2. Risk Identification (Threats/Opportunities)
3. Qualitative Risk Analysis
4. Quantitative Risk Analysis
5. Risk Response Planning (Avoid/Exploit, Transfer/Share, Mitgate/Enhance, Accept)
6. Risk Monitoring and Control

Caltrans' PRM procedure is an original model for almost all other DOTs. Other DOTs' PRM is based on what Caltrans has done with some shifts or expansion.

Generally, different DOTs are using different management tools, which are built based on Caltrans' PRM model. The way how they quantify the risk is similar, but with different scoring systems or sequences.

The ranking system with fewer levels, such as GDOT is too general to assign the right score for the risk elements. Especially for large size, or more complicated project, this kind of ranking system may not be able to show the priority of the risks clearly.

For WSDOT, the tools they have been using are an enhanced version of Caltrans' model. It shows more details in the register sheet with more information. Also they divided the project with different levels and treated with different tools. This is an advantage that with smaller size project, the resources would be saved; while with the larger size project, the risk management will be more reliable. Also there are some more benefits from CRA/CEVP workshops for larger size projects, which have already presented in the previous section.

3.5 Review of the Existing NCDOT Construction Cost Forecasting Process

3.5.1 Highway Construction and Material System (HiCAMS)

Construction cost forecasting practice is an essential part of risk management for NCDOT. NCDOT currently utilizes construction cost forecasting within the Highway Construction and Material System (HiCAMS). The HiCAMS forecast model was built on the assumption that the aggregate monthly construction can be explained by the number of current contracts, contracted amounts, age fraction of projects, and monthly seasonal factors.

Large projects aptly named ‘Whales’ tend to make up nearly 80% of the total construction expenditure due to their large amount of contracts (>\$10 million) as displayed in Figure 19 (Bowen, 2013).

SFY	ProjectCount	SFYTotal	ProjectCount>10M	SFYTotal>10M	WhalePercent
2006	59	356,268,468	2	235,427,910	66.08%
2007	77	813,976,114	16	646,805,513	79.46%
2008	146	719,768,970	20	411,380,678	57.15%
2009	200	1,235,642,884	22	787,874,150	63.76%
2010	281	1,246,535,404	24	783,002,018	62.81%
2011	62	964,709,467	21	825,036,105	85.52%
2012	101	1,382,072,359	23	1,171,558,626	84.77%
2013	145	1,380,220,900	31	1,159,376,260	84.00%
2014	132	1,728,362,000	29	1,526,020,000	88.29%
2015	76	1,113,619,000	23	942,299,000	84.62%
2016	89	946,065,000	20	758,100,000	80.13%
2017	76	1,003,485,000	14	854,100,000	85.11%
2018	88	1,001,595,000	18	829,950,000	82.86%
2019	123	1,072,890,000	17	825,800,000	76.97%
2020	112	920,200,000	16	695,350,000	75.57%
2021	119	773,428,000	13	570,849,000	73.81%
2022	118	417,289,000	8	237,000,000	56.80%
2023	132	1,347,137,000	14	1,093,170,000	81.15%
				Average	76.05%

Figure 19 Whale Projects (>\$10 million) in Relation to Other Projects

Note that changing the let schedule of any Whale project can significantly impact on the cash balance. Hence, it is essential to be able to forecast an individual payout curve in order to analyze the impact of changes in the let schedule. An annual flat curve shown in Figure 20 was initially tried in NCDOT for estimating the payout of individual projects. However, it turned out that a rather simple flat curve over the entire projects duration has displayed construction expenditures close to HiCAMS annual forecasts. Hence, the simple flat curve has been in place for aggregate payout estimation in NCDOT. However, we remark that, as will be discussed in Chapter 5, past payout data display a nonlinear curve, and hence, there is a need for developing a more sophisticated forecasting model to accommodate such patterns.

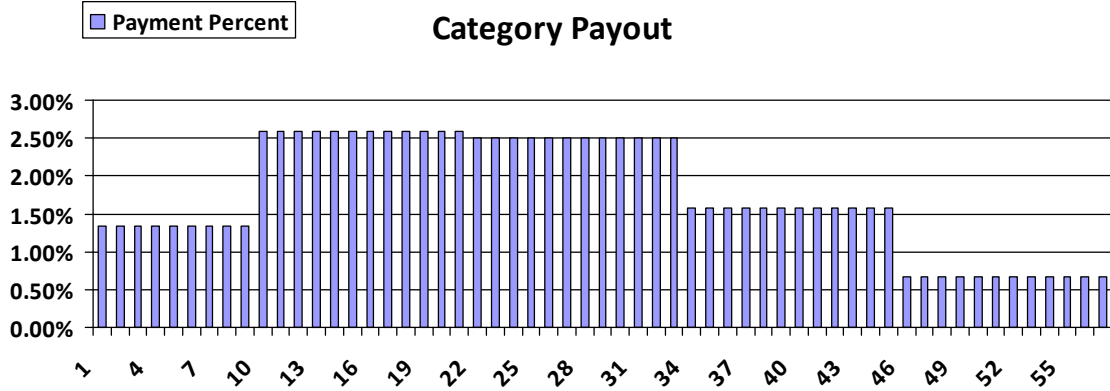


Figure 20 Simple Flat Payout Curve for Whale Projects (>\$10 million)

Construction cost forecasting practice is an essential part of risk management for NCDOT which currently utilizes the construction cost forecasting module within HiCAMS. The HiCAMS forecast model was built on the assumption that the aggregate monthly construction can be explained by the number of current contracts, contracted amounts, age fraction of projects, and monthly seasonal factors (Bowen, 2013). The regression formula is given by

$$Y_t = a + bN_t + c \sum_{i=1}^{N_t} \frac{C_i}{D_i} + dM_t + e \sum_{i=1}^{N_t} \frac{\left(\frac{A_{t,i}}{D_i}\right)}{N_i},$$

where

Y_t = aggregate construction expenditure at month t

N_t = number of active contracts at month t

C_i = amount of contract i

D_i = (expected) duration of contract i

M_t = month of the year at month t (binary variable for seasonal factor)

$A_{t,i}$ = age of contract i at month t .

In Figure 21, parameters to be considered when developing complete forecasting systems are presented as recommendations for forecasting construction expenditures (Bowen, 2013).

- Identify, Develop and Maintain **ONE SOURCE OF DATA** that feeds and supports the models.

Multiple data sources lead to conflicting and confusing forecasts.

Multiple data sources lead to significant, time consuming reconciliation efforts.
- Develop a **BASELINE FORECAST UPDATE SCHEDULE**.

Changes in let dates and construction estimates happen continuously, so the forecast is constantly changing.

Attempting to verify and reconcile forecasts at various times will be time consuming and confusing.
- Develop the ability to create **“WHAT IF” FORECAST SCENARIOS** rapidly, without affecting the baseline.

When cash becomes constrained the ability to test various response scenarios becomes critical.

Creating forecast scenarios SHOULD NOT AFFECT THE BASELINE DATA.
- Bring **STAKEHOLDERS INTO THE DEVELOPMENT PROCESS**.

It is critical that the people who must rely on the forecasts understand the process and have confidence in the results.

Confidence in the models should be established at the outset to avoid defending the forecasts internally when they become crucial.

Figure 21 Recommendations for Developing Forecasting Systems

3.5.2 Other Issue Involving Project Categories:

Currently, project categories vary depending on the project type - whether it is rural, interstate, urban, etc. as well as project cost as shown in Table 4. An emerging issue is that some large-scale projects have much higher construction costs than the highest cost threshold (\$10 million). These projects often have a greater influence on balance sheets. For example, projects costing over \$300 million have a much bigger influence on construction cost balance than a \$10 million dollar project, yet they are within the same category. In addition to the cost balance issue, construction time estimate is the same for both a \$300 million project and a \$10 million project since they are in the same category. This \$10 million cost threshold presents a time estimate issue and a cost balance issue. These issues may need to be further studied to determine the necessity of additional categories that can better characterize those extremely large-scale projects.

Table 4 Cost Categories Given Project Type

Project Type Description	Cost Category Description
A – Rural Special	Less than \$499,999
A – Rural Special	\$500,000 to \$999,999
A – Rural Special	\$1,000,000 to \$2,499,999

A – Rural Special	\$2,500,000 to \$4,999,999
A – Rural Special	\$5,000,000 to \$9,999,999
A – Rural Special	Greater Than \$10,000,000
B – Bridge Replacement	Less than \$499,999
B – Bridge Replacement	\$500,000 to \$999,999
B – Bridge Replacement	\$1,000,000 to \$2,499,999
B – Bridge Replacement	\$2,500,000 to \$4,999,999
B – Bridge Replacement	\$5,000,000 to \$9,999,999
B – Bridge Replacement	Greater Than \$10,000,000
E – Enhancement	Less than \$499,999
E – Enhancement	\$500,000 to \$999,999
E – Enhancement	\$1,000,000 to \$2,499,999
E – Enhancement	\$2,500,000 to \$4,999,999
E – Enhancement	\$5,000,000 to \$9,999,999
E – Enhancement	Greater Than \$10,000,000
F – Ferry	Less than \$499,999
F – Ferry	\$500,000 to \$999,999
F – Ferry	\$1,000,000 to \$2,499,999
F – Ferry	\$2,500,000 to \$4,999,999
F – Ferry	\$5,000,000 to \$9,999,999
F – Ferry	Greater Than \$10,000,000
I – Interstate	Less than \$499,999
I – Interstate	\$500,000 to \$999,999
I – Interstate	\$1,000,000 to \$2,499,999
I – Interstate	\$2,500,000 to \$4,999,999
I – Interstate	\$5,000,000 to \$9,999,999
I – Interstate	Greater Than \$10,000,000
K – Rest Areas	Less than \$499,999
K – Rest Areas	\$500,000 to \$999,999
K – Rest Areas	\$1,000,000 to \$2,499,999
K – Rest Areas	\$2,500,000 to \$4,999,999
K – Rest Areas	\$5,000,000 to \$9,999,999
K – Rest Areas	Greater Than \$10,000,000
R – Rural	Less than \$499,999
R – Rural	\$500,000 to \$999,999
R – Rural	\$1,000,000 to \$2,499,999
R – Rural	\$2,500,000 to \$4,999,999
R – Rural	\$5,000,000 to \$9,999,999
R – Rural	Greater Than \$10,000,000
U – Urban	Less than \$499,999
U – Urban	\$500,000 to \$999,999
U – Urban	\$1,000,000 to \$2,499,999
U – Urban	\$2,500,000 to \$4,999,999
U – Urban	\$5,000,000 to \$9,999,999
U – Urban	Greater Than \$10,000,000
W – Highway Hazard (Highway Safety)	Less than \$499,999
W – Highway Hazard (Highway Safety)	\$500,000 to \$999,999
W – Highway Hazard (Highway Safety)	\$1,000,000 to \$2,499,999
W – Highway Hazard (Highway Safety)	\$2,500,000 to \$4,999,999
W – Highway Hazard (Highway Safety)	\$5,000,000 to \$9,999,999
W – Highway Hazard (Highway Safety)	Greater Than \$10,000,000
X – Special	Less than \$499,999
X – Special	\$500,000 to \$999,999

X – Special	\$1,000,000 to \$2,499,999
X – Special	\$2,500,000 to \$4,999,999
X – Special	\$5,000,000 to \$9,999,999
X – Special	Greater Than \$10,000,000
S – Highway Hazard (Highway Safety)	Less than \$499,999
S – Highway Hazard (Highway Safety)	\$500,000 to \$999,999
S – Highway Hazard (Highway Safety)	\$1,000,000 to \$2,499,999
S – Highway Hazard (Highway Safety)	\$2,500,000 to \$4,999,999
S – Highway Hazard (Highway Safety)	\$5,000,000 to \$9,999,999
S – Highway Hazard (Highway Safety)	Greater Than \$10,000,000

CHAPTER 4: STUDY OF BEST PRACTICES WITHIN CALTRANS

The surveys of the other state DOTs revealed that Caltrans has more advanced and efficient risk management practices and tools. On the basis of the documents provided by Caltrans in response to the “requests and questions” and documents derived from Caltrans official website, a study of the risk management strategies and tools at Caltrans was conducted by the research team.

4.1 In-Depth Evaluation on the Funding Risk Management Practices and Tools at Caltrans

Caltrans has a well-defined fund estimate process to project the available resources for the upcoming five years. Caltrans also has a special funding risk management process for its Intelligent Transportation System (ITS) projects. A revised version of the project risk management handbook includes multi-level risk register with new risk parameters. This section serves to establish a good practice example for NCDOT to use while implementing funding risk management practices.

4.1.1 Revised Version of the Project Risk Management Handbook

A revised version of the project risk management handbook called the “Caltrans Project Risk Management Handbook: A Scalable Approach” was released in June 2012. The new addition to this handbook is a multi-level Risk Register, ranging from a scale of Level 1 to Level 3 corresponding to the project priority. Level 1 includes projects funding less than \$5 million, Level 2 projects funding ranges from \$5 million to \$100 million and Level 3 projects funding is worth more than \$100 million. With the increase in project level, the risk parameters and their reasoning also increase accordingly. The risk parameters used for each level are listed in Tables 5-9.

Table 5 Risk Identification

Risk Identification	Levels Used	Discussion, Options for Selection, or Table Reference
Status	1, 2, 3	Active, Retired
ID#	1, 2, 3	Unique identifier for this risk assigned by the team for tracking purposes. Usually a number.
Type	1, 2	Threat, Opportunity
Category	1, 2, 3	Environmental, Design, ROW, DES, Organizational, Construction, PM
Title	1 2 3	Short title for the risk
Risk Statement	1, 2, 3	Risk statement in the form: “As a result of <definite cause>, <uncertain event> may occur, which would lead to <effect on objective(s)>.”
Current Status / Assumptions	1, 2, 3	Lists Current Status or Assumptions

Table 6 Risk Rating

Risk Rating	Levels Used	Discussion or Table Reference
Priority Rating	1	Low, Medium, or High
Rationale for Rating	1	A rationale for the priority rating by the Project Risk Management Team

Table 7 Risk Assessment

Risk Assessment	Levels Used	Discussion or Table Reference
Probability	2	Very Low, Low, Moderate, High, Very High
Probability - Low	3	Number between 1 and 100
Probability - High	3	Number between 1 and 100
Cost Impact	2	Very Low, Low, Moderate, High, Very High
Cost Impact - Low	3	Dollar value of cost impact
Cost Impact - Most Likely	3	Dollar value of cost impact
Cost Impact - High	3	Dollar value of cost impact
Cost Impact - Probable	3	Dollar value of cost impact
Cost Score	2	Number for cost score
Time Impact	2	Very Low, Low, Moderate, High, Very High
Time Impact - Low	3	Number, in days
Time Impact - Most Likely	3	Number, in days
Time Impact - High	3	Number, in days
Time Impact - Probable	3	Number, in days
Time Score	2	Number for time score
Rationale	2, 3	A rationale for the rating

Table 8 Risk Response

Risk Response	Levels Used	Discussion or Table Reference
Strategy	1, 2, 3	Response strategy: For Threats: Avoid, Transfer, Mitigate or Accept For Opportunities: Exploit, Share, Enhance or Accept
Response Actions	1, 2, 3	The detailed response action to be taken.

Table 9 Risk Miscellaneous

Miscellaneous	Levels Used	Discussion or Table Reference
Risk Owner	1, 2, 3	Owner of the risk
Updated	1, 2, 3	Date last updated

4.1.2 Sources and Allocation of Funds at Caltrans

A detailed study of the sources of funds and their distribution path at Caltrans displayed that Caltrans is responsible for the transportation operations of the State Highway System and the intercity rail. Other transportation facilities such as buses, metro link, etc., are managed by local and regional agencies. Comparing the ideal cash flow of funds with the actual fund allocation, it was observed that the funding allocation is flexible and does not strictly adhere to the distribution model specified in the document named, "Transportation Funding in California (TFC)". The flow chart of sources and distribution of funds is provided in Figure 22.

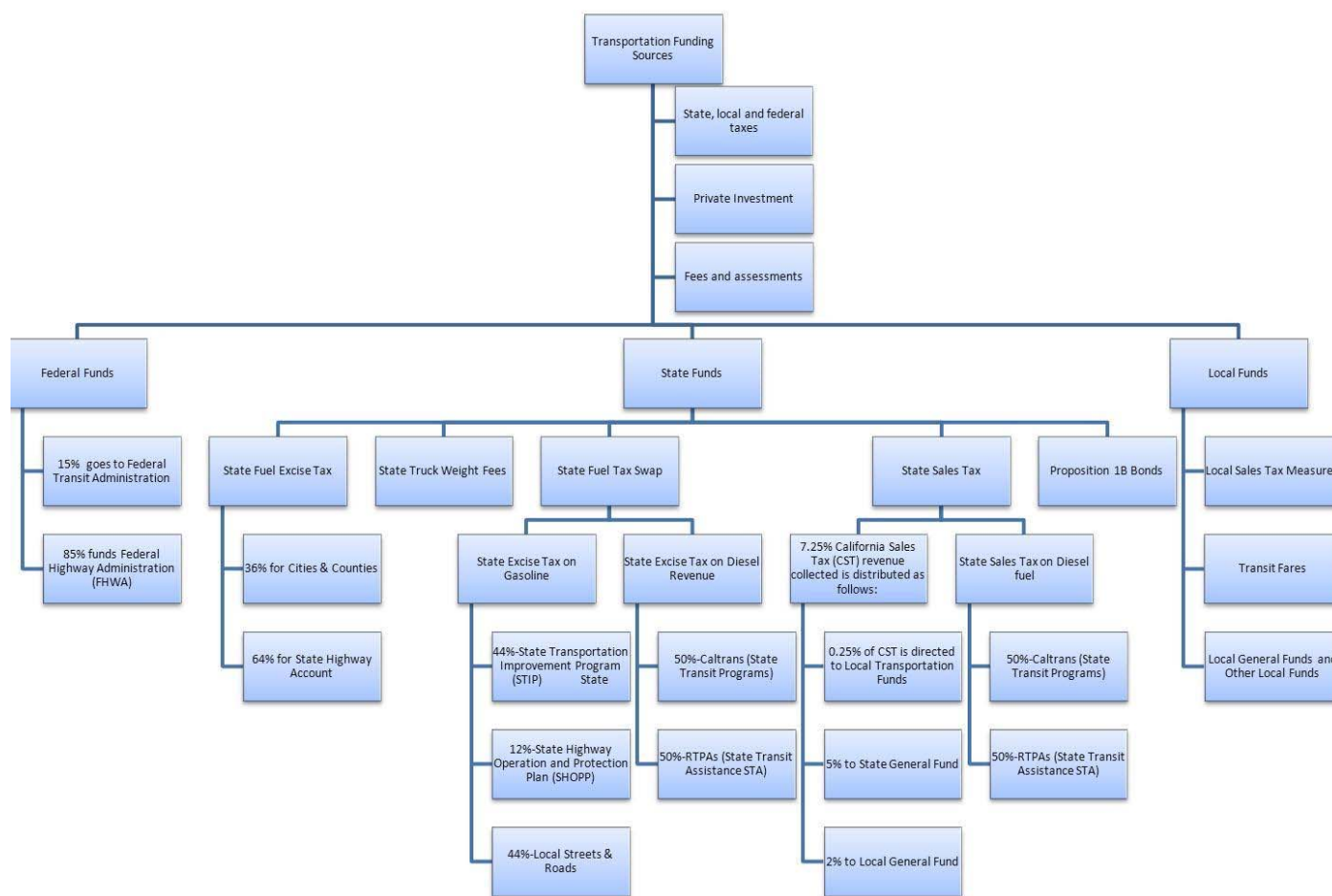


Figure 22 Sources and Allocation of Funds at Caltrans

An example of Real Fund Allocation versus Ideal Fund Allocation is seen in Figure 23 and Figure 24. According to the TFC document, ideally the Public Transportation Account (PTA) revenues are to be divided equally between Caltrans and State Transit Assistance (STA). However, on calculating the actual percentage transfer for the fiscal year 2012-2013 from Chart D of the California Transportation Financing Package (CTFP) document, the research team has found that approximately 65% of the PTA revenues were allocated to Caltrans and 34% to STA. The factors concerning this transition in fund allocation are not specified. This issue is addressed in the questionnaire for Caltrans in Section 3.3.2.

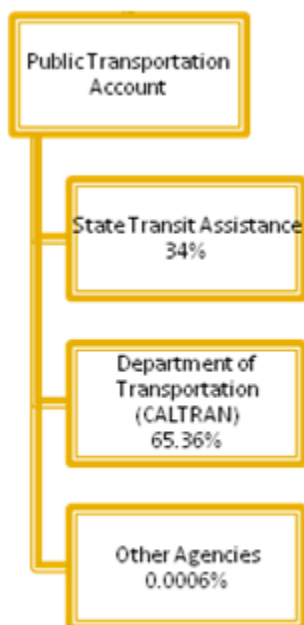


Figure 23 Real Fund Allocation (CTFP)

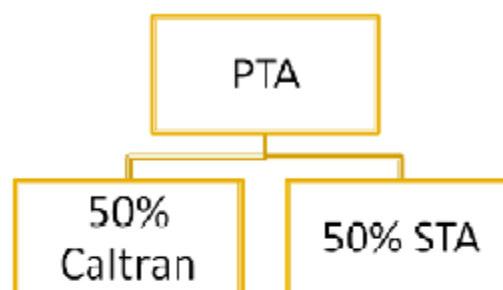


Figure 24 Ideal Fund Allocation (TFC)

4.1.3 Fund Estimate Process

Fund Estimate (FE) is a five year projection of available resources, required by statute, prepared biennially by California Transportation Commission (CTC) and estimates STIP & SHOPP capacity. In the development of FE, there are a number of assumptions made that affect the projections of the various categories of revenue and expenditures for each account. These assumptions are based on the prior fiscal year ending cash balance for the various accounts. FE has a two tier approach with certain assumptions as follows:

Tier 1: Conservative estimate

- Identifies a minimum level of programming, or deprogramming, i.e. a minimum value of funds allocated to a particular department on the basis of prior years is estimated.
- This method ensures no Transportation Congestion Relief Fund (TCRF) loan repayment.

Tier 2: Existing Law

- Identifies a higher level of programming, i.e. if there is a shortage of funds, the difference amount is met by taking a loan from TCRF.
- Additional Programming Capacity is introduced in the FE process for the loan repayment from TCRF, Transportation Investment Fund (TIF), and Transportation Deferred Investment Firm (TDIF).

The FE Methodology is listed through the following steps.

Step 1: Assumptions

Assumptions* are made for the following departments in the various categories on the prior year's operating data and numbers:

a) State Highway Account (SHA)

- Operating Cash Balance
- Revenues and Transfers
- Federal Revenues
- Advanced Construction (AC)
- Advanced Project Development Construction (APDC)
- State Expenditures
- Prior STIP Commitments
- Grant Anticipation Revenue Vehicle(s) (GARVEE)
- SHOPP

b) Public Transportation Account (PTA)

- Operating Cash Balance
- Revenues
- Transfers
- State Operations

c) Transportation Investment Fund (TIF)

d) Bonds

- Proposition 1A
- Proposition 1B

*Actual values are allocated to these assumptions.

Step 2: Cash Model

The cash flow model used to determine the available funds for the next 5 years is shown in Figure 25. The beginning balance is the amount in the account till the last year end. Anticipated Revenues are estimated values from Step 1.

Non-STIP Commitments are Non-STIP funds from previous year. Existing STIP Commitments are STIP funds for the present fiscal year. Available for Programming are funds available for that particular year used in the two tier FE process.

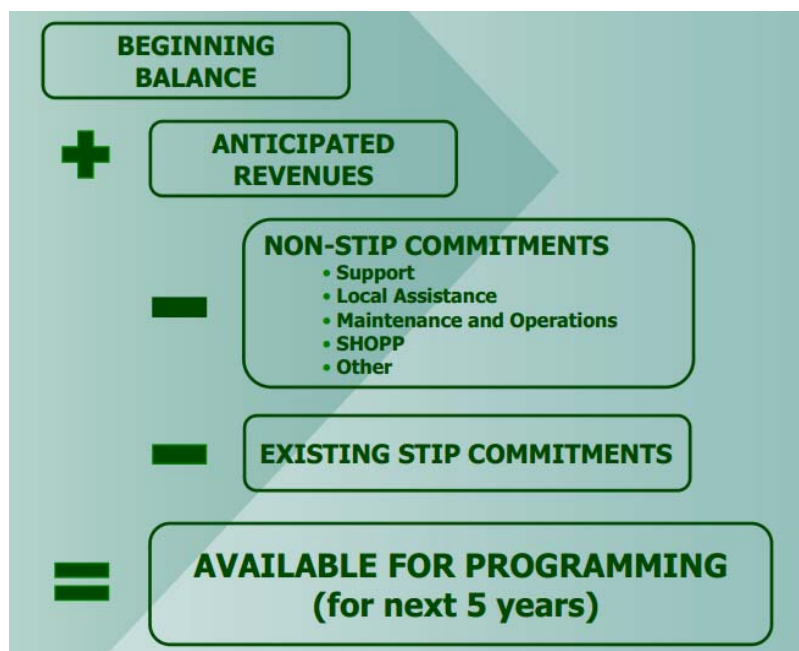


Figure 25 Caltrans Cash Flow Model

Step 3: Program Capacity

Program Capacity is calculated for each fiscal year by taking the net difference and cumulative difference between the Target Capacity, derived from the assumptions and the actual STIP/SHOPP commitments. The estimated capital allocation capacity is calculated using the cash model for each fiscal year. The total of the net difference is the five or six year projection of the available funds. FE is updated biennially. The STIP and SHOPP program capacity process is represented in Figure 26.

2012 STIP FE STIP Program Capacity (\$ in millions)								
	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	5-Year Total	6-Year Total
2012 STIP FE Target Capacity	\$925	\$761	\$633	\$683	\$733	\$733	\$3,544	\$4,468
2010 STIP Program	925	931	506	625	0	0	2,061	2,986
Net Difference	\$0	(\$170)	\$127	\$59	\$733	\$733	\$1,483	\$1,483
Cumulative Difference	\$0	(\$170)	(\$42)	\$17	\$750	\$1,483		
Estimated Capital Allocation Capacity	\$770	\$505	\$435	\$460	\$485	\$485		

Note: Numbers may not add due to rounding.

2012 STIP FE SHOPP Program Capacity (\$ in millions)								
	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	5-Year Total	6-Year Total
2012 STIP FE SHOPP Target Capacity	\$2,050	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000	\$10,000	\$12,050
2010 SHOPP Program	2,045	1,950	2,005	0	0	0	3,955	6,000
Net Difference	\$5	\$50	(\$5)	\$2,000	\$2,000	\$2,000	\$6,045	\$6,050
Cumulative Difference	\$5	\$55	\$50	\$2,050	\$4,050	\$6,050		
Estimated Capital Allocation Capacity	\$1,435	\$1,405	\$1,405	\$1,405	\$1,405	\$1,405		

Note: Numbers may not add due to rounding.

Figure 26 Program Capacity for STIP and SHOPP

4.1.4 Funding Risk Process for Intelligent Transportation System (ITS) Projects

Caltrans has developed a stepwise funding risk process for ITS projects. The ITS projects are federally aided; any funding mishap in ITS, has immediate negative consequences.

Step 1: Risk Assessment by Project Manager (PM)

PM must fill out a Systems Engineering Review Form (SERF), which consists of seven questions, each having a Low-Risk and High-Risk project attributes to classify the projects. Based on the answers, the project is classified as Exempt or Low-Risk or High-Risk for further procedure. The seven Low-Risk and High-Risk Project Attributes with Risk Factors are listed in Table 10.

Table 10 Risk Assessment Attributes and Factors.

	Low-Risk Project Attributes	High-Risk Project Attributes	Risk Factors
1	Single jurisdiction and single transportation mode (highway, transit or rail)	Multi-Jurisdictional or Multi-modal	With multiple agencies, departments, and disciplines, disagreements can arise about roles, responsibilities, cost sharing, data sharing, schedules, changing priorities, etc. Detailed written agreements are crucial!

2	No software creation; uses commercial-off-the-shelf (COTS) or proven software	Custom software development is required	Custom software requires additional development, testing, training, documentation, maintenance, and product update procedures -- all unique to <u>one</u> installation. This is very expensive, so hidden short-cuts are often taken to keep costs low. Additionally, integration with existing software can be challenging, especially because documentation is often not complete and out-of-date.
3	Proven COTS hardware and communications technology	Hardware or communications technology are “cutting edge” or not in common use.	New technologies are not “proven” until they have been installed and operated in a substantial number of different environments. New environments often uncover unforeseen problems. New technologies or new businesses can sometimes fail completely. Multiple proven technologies combined in the same project would be high risk if there are new interfaces between them.
4	No new interfaces	New interfaces to other systems are required.	New interfaces require that documentation for the “other” system be complete and up-to-date . If not (and often they are not), building a new interface can become difficult or impossible. Duplication of existing interfaces reduces the risk. “Open Standard” interfaces are usually well-documented and low risk.
5	System requirements fully-detailed in writing	System Requirements not detailed or not fully documented	System Requirements are critical for an RFP. They must describe in detail about all the functions the system must perform, performance expected, plus the operating environment. Good requirements can be a dozen or more pages for a small system, and hundreds of pages for a large system. When existing systems are upgraded with new capabilities, requirements must be revised and rewritten.
6	Operating procedures fully-detailed in writing	Operating procedures not detailed or not fully documented	Standard Operating Procedures are required for training, operations, and maintenance. For existing systems, they are often out-of-date.
7	None of the technologies used are near end of service life	Some technologies included are near end of service life	Computer technology changes rapidly (e.g. PC’s and cell phones become obsolete in 2-4 years). Local area networks using internet standards have had a long life, but in contrast some mobile phones that use proprietary communications became obsolete quickly. Similarly, the useful life of ITS technology (hardware, software, and communications) is short. Whether your project is a new system or expanding an existing one, look carefully at all the technology elements to assess remaining cost- effective service life.

Step 2a: Process and Funding Steps for Low Risk ITS Projects

For Exempt and Low-Risk ITS projects, the traditional single-phase Preliminary Engineering (PE) obligation and authorization process is followed. The project development life-cycle includes processes from project initialization leading up to construction with maintenance operations and upgrades till the retirement of the project as shown in Figure 27.

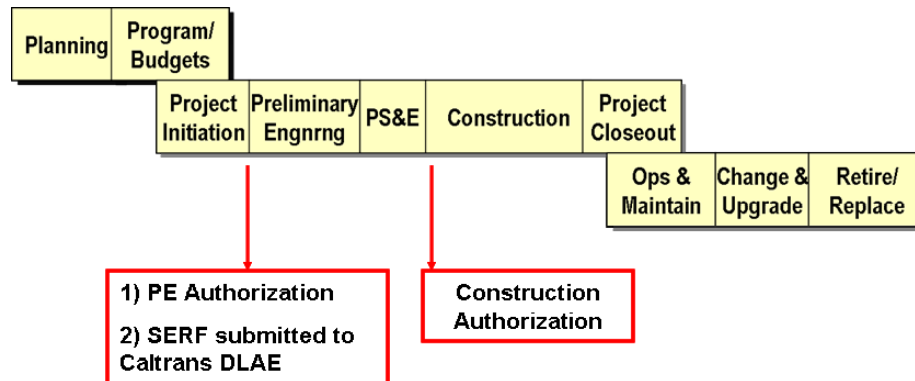


Figure 27 Funding and Process Steps for Low-Risk ITS Projects

Step 2b: Funding Process for High Risk ITS projects:

More complex ITS projects often lead to higher risk of failure (termination, time delays or cost increases). Additional elements are needed in the process of development to mitigate the higher risks. These additional elements are extensions to the traditional road building process used in Step 2a. The systems engineering approach is graphically depicted in Figure 28.

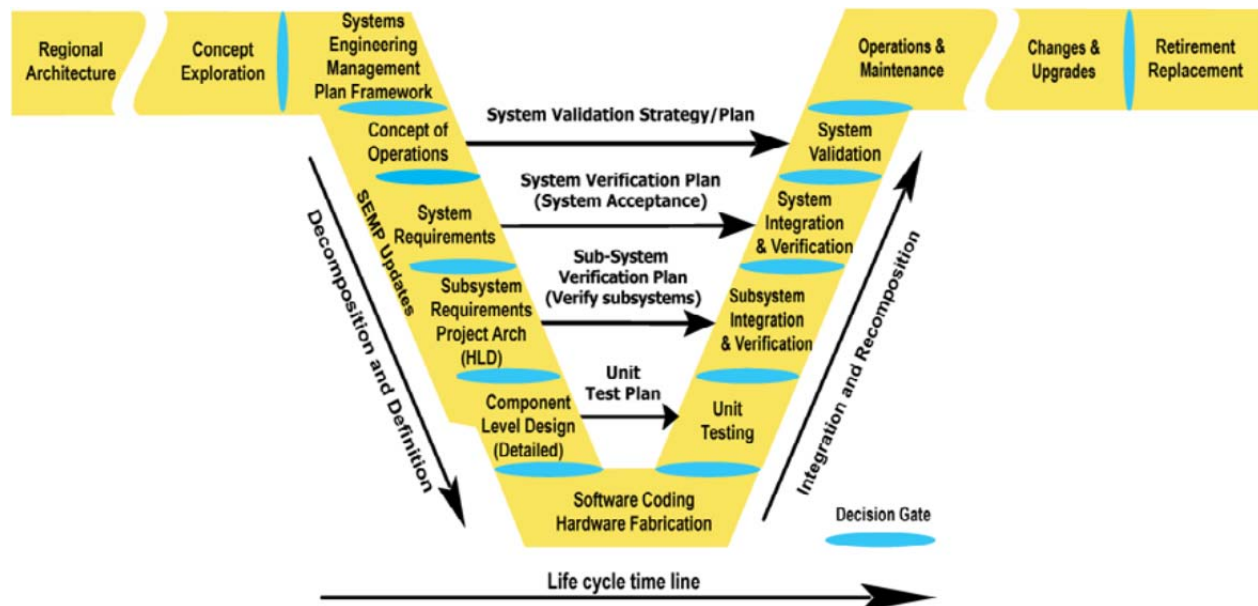


Figure 28 Systems Engineering Vee Life Cycle Process. (Caltrans, 2010)

For High-Risk ITS projects, PE obligation and authorization is followed by two approval actions for project development to proceed. Figure 28 pinpoints the authorization and approval stages in the funding steps for Systems Engineering process. The left side of the Vee Life Cycle represents the funding process, whereas the right side of the Vee Life Cycle represents the implementation of Systems Engineering operation to mitigate the higher risks involved in the projects. The same PE contractor links Systems Engineering activities on both sides of the Vee Life Cycle Process supporting testing, verification and validation.

Early determination of risk leads to early determination of type of ITS project, which leads to an early determination of budgeting approach. The Systems Engineering Vee process concentrates more time and cost on the up-front engineering activities as compared to the traditional road building process (Step 2a).

4.1.5 Funding Allocation Form for Partnership Projects

Caltrans has a precautionary funding allocation approval forms for partnership projects such as State-Local Partnership Program-Competitive (SLPP-C) projects. The form requires both the partners to give detailed data and numbers before any funding is allocated to the project. This ensures to avoid any conflict in the future with a smooth flow of project operations.

4.1.6 Further Clarifications and Questions

The literature survey and study revealed certain doubts in the risk management process at Caltrans as follows:

The Transportation Funding in California (TRF) document and the California Transportation Financing Package (CTFP) provides a description of the sources and distribution of funding in the state of California with the help of graphs and charts. A comparative study of both documents reveals that there is a difference between the percentage distributions of funds in the TRF document as to the actual amounts distributed in the CTFP. For example, in the TRF it is shown in Chart 7 that the Public Transportation Account (PTA) funds are distributed in half (50-50) to Caltrans and State Transit Assistance (STA). However, in Chart D of the CTFP, calculating the percentage from the actual amount transferred, it is inferred that approximately 65% of the PTA funds were allocated to Caltrans and 35% to STA. This is opposed to the 50-50 split specified in the TRF. This discrepancy generates the following questions:

- Is there a range of flexibility of funds for allocation?
- What factors are considered for the actual allocation of funds

As per a press release in September 23, 2010, Caltrans faced a severe problem of delay in the state budget. Funding for transportation projects that were contingent on the approval of the state budget were either deferred or delayed, freezing \$3.9 billion in transportation funding in a two month period.

- What was Caltrans approach to this delay in funding issue?
- Was this sort of uncertainty anticipated or predicted earlier? If yes, what was the feasible solution for such unforeseen problem?
- What was the cumulative effect of this delay on the respective projects?
- How much was the coping period to get things back to normal?

These doubts are compiled into the in-depth survey questionnaire in Section 3.3.2.

4.2 Potential Application of Caltrans Funding Risk Management Practices and Tools

Funding practices and procedures at Caltrans can offer useful application. Caltrans has Transportation Loan Programs which targeted certain priority projects. A loan program provides funds to construction projects, which demands more funds than the awarded amount. . Another major change implemented at Caltrans is the new California Transportation Infrastructure Funding System (CTIFS), which is an integrated system that encompasses programming, project implementation, and funds management. It is replacing the existing systems to consolidate the Funding architecture into one system.

4.2.1 Caltrans Transportation Loan Programs

Caltrans has a Transportation Loan Program to provide funds for certain high priority projects, whose awarded amount has been exhausted. Only high priority projects with the capacity to repay the loan with the interest amount are considered for a loan. The cash for the loan comes from the spillover revenue from other departments. A thorough record at the end of each Fiscal Year is maintained of all the transactions between different departments. One such program at Caltrans is called the Traffic Congestion Relief Fund (TCRF).

4.2.2 TCRF

The Traffic Congestion Relief Act of 2000 created the TCRF; and committed \$4.909 billion to 141 specific projects designated in law. The \$4.909 billion in revenues for the TCRF included:

- \$1.595 billion to the TCRF in 2000-01 from a General Fund transfer and directly from gasoline sales tax revenues.
- \$3.314 billion in transfers to the TCRF from the Transportation Investment Fund (TIF) over five years, the transfers were to be \$678 million per year for the first four years and the balance of \$602 million in the fifth year.

Figure 29 shows the latest status of Caltrans outstanding transportation loans, as of December 31, 2012.

Status of Outstanding Transportation Loans, as of December 31, 2012 (S in millions)			
FUND	Original Loan	Loans / Interest Paid-to- Date	Remaining Balance
Pre-Proposition 42 (Tribal Gaming Revenue):			
State Highway Account (SHA) ¹	\$473	\$341	\$132
Public Transportation Account (PTA)	275	10	265
Traffic Congestion Relief Fund (TCRF)	482	0	482
Subtotal Pre-Proposition 42 Tribal Gaming Loans:	\$1,230	\$351	\$879
Proposition 42:			
Public Transportation Account (PTA) ⁷	\$220	\$218	\$2
Transportation Investment Fund (TIF) ⁷	440	440	0
Transportation Congestion Relief Fund (TCRF) ²	1,066	817	249
Locals ⁵	440	440	0
Subtotal Proposition 42 Loans:	\$2,167	\$1,916	\$251
General Fund Loan:			
State Highway Account (SHA) ³	\$335	\$50	\$285
State Highway Account - Weight Fee Revenues ⁴	\$227	\$0	\$227
State Highway Account - Weight Fee Revenues ^{4a}	\$249	\$0	\$249
Highway User Tax Account (HUTA) ⁵	\$328	\$0	\$328
Public Transportation Account ⁶	\$29	\$0	\$29
Other transportation accounts	\$31	\$1	30
Subtotal General Fund Loan:	\$1,199	\$51	\$1,148
Totals:	\$4,596	\$2,318	\$2,278

Note: Numbers may not add due to rounding.

Figure 29 Status of Caltrans Outstanding Transportation Loans (December 31, 2012)

The benefits of having a Relief Fund account include:

- Can efficiently manage emergency funding short-falls,
- Easy to monitor the flow of cash to the related projects,
- Helps in decision-making for the Let-schedule of the projects depending on the available cash balance, and
- Proper distribution facilitated by classifying the accounts as per their sources.

4.2.3 Caltrans High Level Transportation Infrastructure Funding System

Figure 30 presents tools used by various departments at Caltrans.

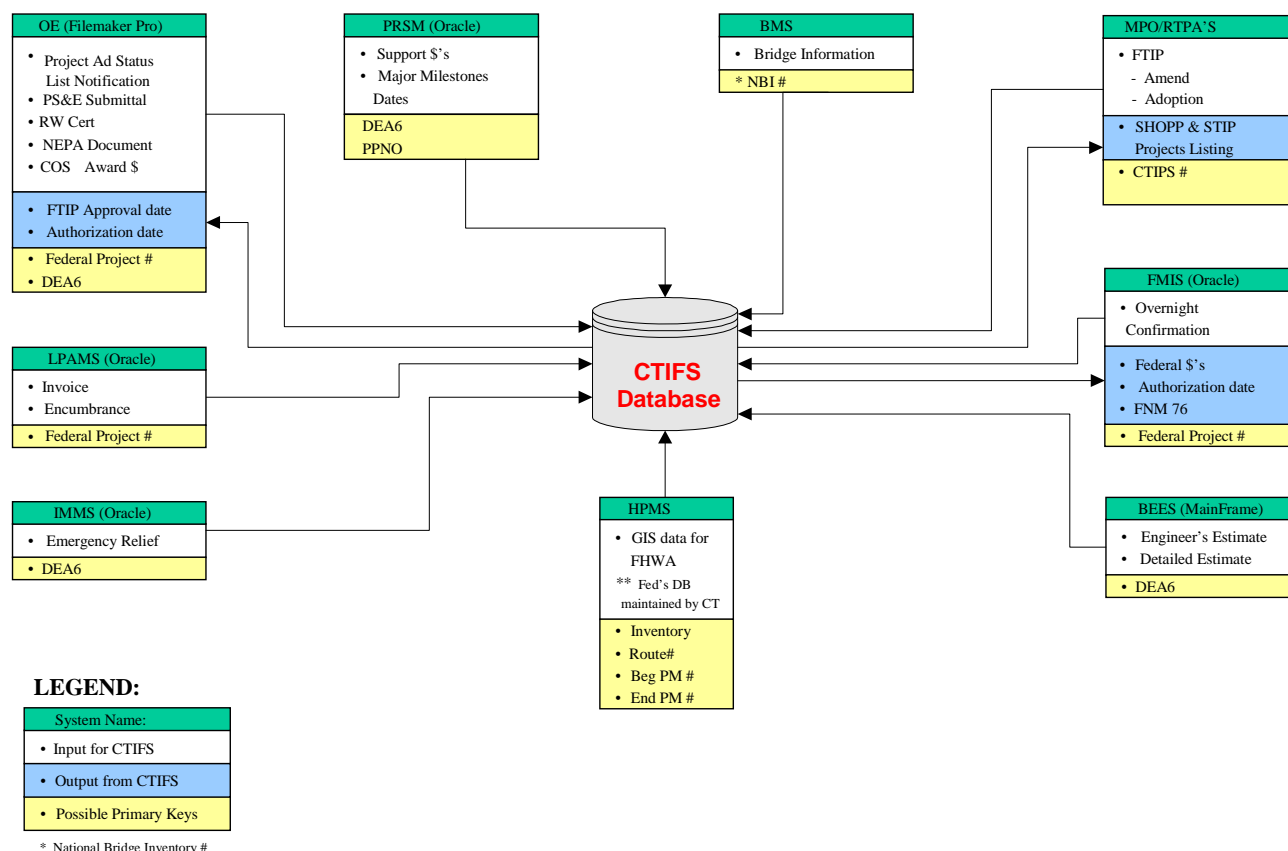


Figure 30 California Transportation Infrastructure Funding System

System Description

The California Transportation Infrastructure Funding System (CTIFS) is a proposed integrated system that encompasses programming, project implementation, and funds management. It is supposed to replace the existing systems at Caltrans such as: California Transportation Improvement Program System (CTIPS), Local Programs 2000 (LP2000), and the Federal Aid Data System (FADS). The system supports the following processes:

1. Management of California's statewide use of Federal appropriations and allocations, both annually and through the life of the appropriations used by the State and local governments.
2. Management of Local Assistance authority for use by local agencies in administering projects.
3. Administration of project documents through compilation of State and Federal Transportation Programs.
4. Selection and funding of categorical Local Assistance programs.
5. Project documentation for Federal or State funded projects administered by local agencies.
6. Project documentation for federally funded projects administered by Caltrans.

Functions: Budgeting Funds & Resources

1. Programming of Funds
 - Support all programming activities and capture STIP, SHOPP, and Federal Programming related data for the FTIP and FSTIP at the source (one time data entry as opposed to duplicate/redundant data entry) via Internet access
 - Record and track CTC adoption (programming), amendment, allocation and award decisions.

- Track Caltrans' official year-of-delivery commitment to the CTC, the fiscal year in which each phase of the project is expected to begin, and the project's programmed capital costs.
 - Track all potential projects and allow Districts to use the database to prepare their 10-Year Plans (a central repository of projects as opposed to multiple lists manually created and updated)
 - Process scope, cost, or schedule changes (amendments) to State and/or Federal programming documents, requests for allocations for State funding, and requests for Federal authorization to proceed with the project.
2. Monitor Utilization of Federal Appropriations and Allocations
- Track Federal appropriations and allocations by Federal Program Code and how they are to be divided between the State and the Division of Local Assistance.
 - Track the following types of information: initial allocation data; adjustment data, including transfers, exchanges, and advanced construction projects; authorizations data; obligation data; apportionment data; and expenditures data.
 - Provide the ability to monitor the obligation of Federal funds and thereby track the State's balance of obligation authority.
3. Develop and Establish the Local Assistance Budget
- Support process of estimating the needed budget authority and developing the subvention budget, also known as "Local Assistance Funds"
 - Provide a comprehensive forecasting model to calculate expected workload for Local Assistance to provide support for local agency projects.

The Benefits of having a consolidated Funding Infrastructure include:

- Better visualization of the programming, project implementation, and funds management system in one sheet,
- Easy to interpret Influence Diagram,
- Knowledge of all the functions clearly stated to all the departments and teams to keep everyone on the same page,
- Facilitates good co-ordination among the departments and teams involved,
- Reduces misinterpretation and misunderstanding of data, and
- Clearly states the technical tools used at each stage of Inbound and Outbound activities

CHAPTER 5: MODELS FOR FUNDING PROJECT RISK MANAGEMENT TOOL

5.1 Background of Modeling Strategy

Funding project risk is originated from the uncertainty of future cash flows, which consists of revenue and expenditure. When all the future cash revenues do not deviate from the forecasted ones, there would be no funding project risk factors as the funds are not the cause of any changes in completing State Transportation Improvement Programs (STIPs). Due to the uncertainty in the future event, however, NCDOT needs to consider and simulate funding change scenarios that make rescheduling STIPs inevitable. One of main function of the funding project risk tool that we develop in this research project is to provide the user a list of projects that are vulnerable to funding changes.

In the tool that we develop, it is assumed that the user is interested in the cash balance at the end of three-year (or 36 months) monitoring window. While we simulate various funding scenarios during the monitoring window, the construction expenditure, which is the other element of the aforementioned cash flows, also plays an important role to ascertain the impact of a funding change. That is, one must know the forecast of construction costs for each individual project in order to adequately estimate the cash balance at the end of the monitoring window for a given funding scenario.

HiCAMS of NCDOT is equipped with useful forecasting modules for the aggregate construction expenditure and the post-let construction costs of individual projects as reviewed in Chapter 2. However, HiCAMS does not provide the forecast of the monthly construction costs of individual projects that have not been let. Therefore, it is necessary to develop a forecasting module as part of the development of the funding project risk management tool.

When a funding change occurs, one needs to find an alternative let schedule, which can accommodate the change in order to avoid overdraft and maintain a healthy cash balance. At the same time, it is desired to have a new let schedule that minimizes the (negative) impact on the entire NCDOT STIP programming. This requires a solution of an optimization problem that minimizes the disruption in the programming, while the cash balance is constrained by a given funding scenario.

Based on the background as described above, we present a suitable forecasting model for construction costs of individual projects in Section 5.2, and the optimization model in Section 5.3. Then, a brief description of scenario generation for simulation is provided in Section 5.3.

5.2 Description of Forecasting Model for Individual Construction Costs

During a discussion about the forecasting model with Mr. Frank Bowen from Funds Administration Section at NCDOT, it was brought to our attention that large-scale projects, so-called Whales, dominantly influence the cash flow balance. Furthermore, NCDOT currently categorizes projects by their scales and types when determining the duration of the individual project (see Table 11). Note that these durations are nominal, and the actual contract period may be different from these values. In the funding project risk management tool, we are focused on the last category of the project scale, which has the award more than \$10 million. In addition, we consider four major project types, bridge (B), interstate (I), rural (R), and urban (U).

Mr. Bowen provided the research team a historical data set of monthly payments, contract periods, and contract amounts. This monthly data set includes 2,781 TIPs, the let dates of which range from March 1998 to March 2013. After a series of data filtering, Whales for types B, I, R, and U are extracted as summarized in Table 12. In this filtered data set, there are total 218 Whales that were already awarded as of March 2013, among which 172 projects were completed. The average contract amount of 218 awarded projects is \$28,140,697 per project. Furthermore, the

lead time that is defined as the time duration between the let date and the beginning of construction is about 44.6 days on average.

Table 11 Durations of Projects Specified by HiCAMS Depending on the Project Type and Scale (months)

Project Type	Project Award Category					
	Less than \$499,999	\$500,000 - \$999,999	\$1,000,000 - \$2,499,999	\$2,500,000 - \$4,999,999	\$5,000,000 - \$9,999,999	Larger than \$10,000,000
A	6	8	12	20	30	40
B	9	13	19	24	29	36
E	7	7	12	12	13	-
F	7	9	11	13	15	20
I	6	9	9	10	21	34
K	7	9	17	26	33	36
R	6	8	12	20	30	40
U	7	9	15	21	29	33
W	6	8	9	9	13	-
X	6	8	12	20	30	40
S	6	8	9	9	13	-

Table 12 Overview of Historic Data for Whales of Four Major Types

Type	No. of Projects	No. of Completed Projects	Average Award	Average Lead Time
B	15	9	\$17,682,436	41.4
I	23	21	\$39,568,564	45.1
R	125	106	\$28,967,575	42.8
U	55	35	\$21,468,986	49.2
Overall	218	171	\$28,140,697	44.6

As mentioned earlier, although there are nominal durations of construction, actual contract durations are different among projects. Besides, actual construction periods are also different from the contract durations. To handle the variation in the actual construction duration, we standardized all the construction periods and corresponding cumulative expenditures into the 0-1 scale. For illustration, consider a project (B-0682) that has the contract duration of 930 days and the total award of \$30,989,261. Suppose that the cumulative payment for its construction expenditure after 703 days into the construction was \$20,272,273. Then, the *standardized age* becomes $\frac{703}{930} = 0.756$, and the corresponding standardized cumulative construction cost becomes $\frac{\$20,272,273}{\$30,989,261} = 0.654$.

This standardization enables us to estimate the cumulative construction costs regardless of the varying contract durations. After examining the pattern of standardized data sets, we concluded that the construction expenditures typically follow an S-curve (see a sample plot for bridge projects in Figure 31), and hence, a logistic function is an

adequate candidate for fitting the standardized data. When selecting a logistic function, one constraint is that the function needs to be forced to cross two points (0, 0) and (1, 1). This is because we assume that no construction cost is incurred at the beginning of the construction, and all the entire award is expected to be spent at the end of the nominal duration of the construction. In conclusion, we derived the following model:

$$[\text{Standardized Cumulative Construction Cost}] = \frac{1 - \exp(-\theta_1 [\text{standardized age}]^{\theta_2})}{\theta_3}.$$

When the standardized age is zero, then the standardized cumulative construction cost becomes zero since the numerator of the right-hand-side is zero. On the other hand, if the standardized age is one, then the standardized cumulative construction cost becomes one under the following constraint:

$$\frac{1 - \exp(-\theta_1)}{\theta_3} = 1.$$

For each project type, we identified the parameters using the Excel solver, and the result is presented in Table 13.

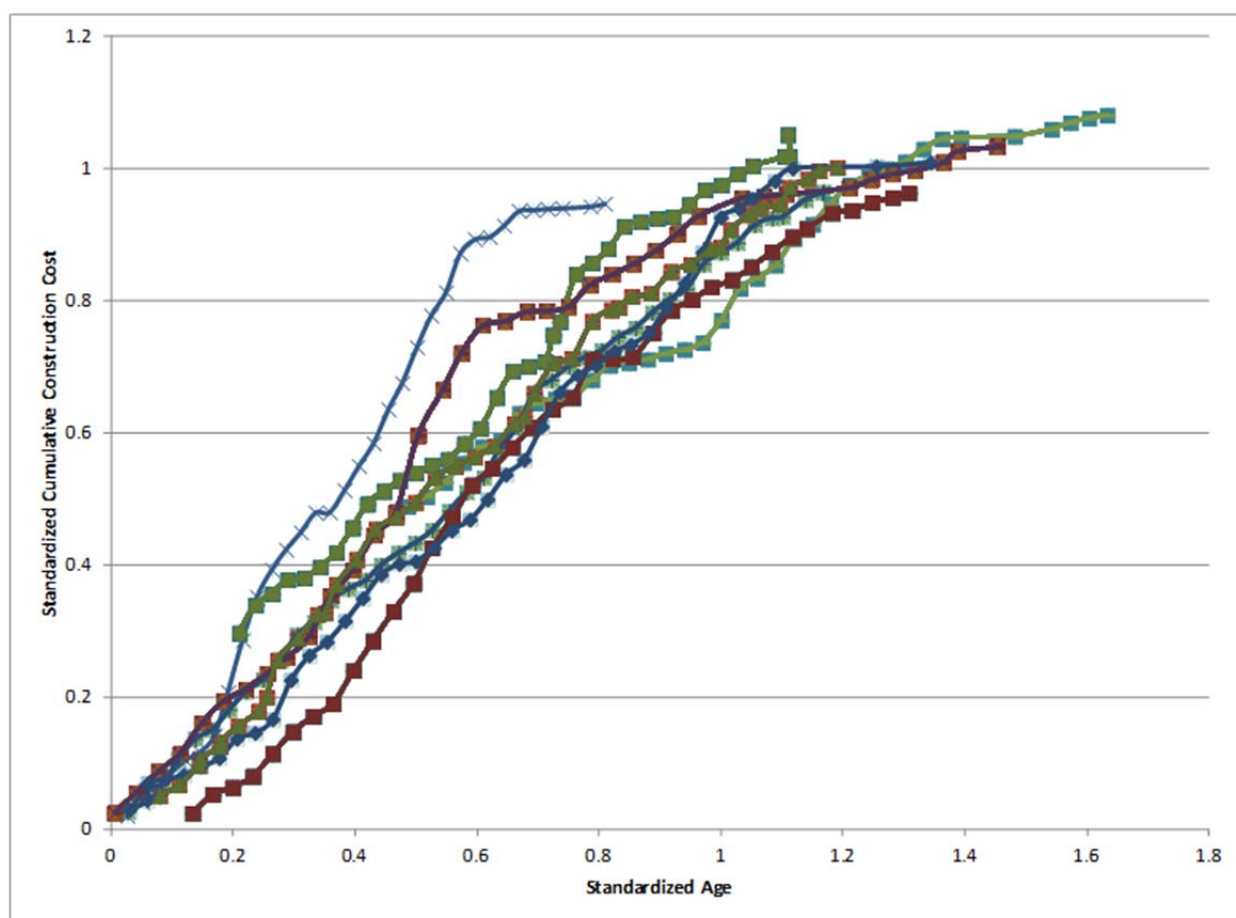


Figure 31 Sample Plots of Standardized Construction Ages vs. Standardized Construction Expenditures for Bridge Projects

Table 13 Parameter Estimation Results for Standardized Cumulative Construction Costs

Parameter	Project Type			
	B	I	R	U
θ_1	1.98	1.75	1.52	1.57
θ_2	1.48	1.84	1.45	1.43
θ_3	0.86	0.83	0.78	0.79

Finally, the forecasting formula is used to calculate the monthly cumulative construction costs for each project type, which is displayed in Table 14.

Table 14 Fraction of Monthly Cumulative Construction Costs (%) to Contract Award

Age in Month	Project Type			
	B	I	R	U
1	1.1	0.3	0.9	1.3
2	3.1	1.2	2.5	3.6
3	5.6	2.4	4.5	6.3
4	8.5	4.1	6.7	9.4
5	11.7	6.1	9.2	12.7
6	15.0	8.4	11.8	16.2
7	18.6	11.1	14.6	19.9
8	22.2	14.0	17.5	23.7
9	26.0	17.1	20.5	27.5
10	29.7	20.4	23.6	31.3
11	33.5	23.9	26.7	35.2
12	37.3	27.6	29.8	39.1
13	41.1	31.3	33.0	42.9
14	44.8	35.1	36.1	46.7
15	48.4	39.0	39.3	50.4
16	52.0	43.0	42.4	54.0
17	55.5	46.9	45.5	57.6
18	58.9	50.8	48.6	61.0
19	62.2	54.7	51.6	64.4
20	65.3	58.5	54.6	67.7

Age in Month	Project Type			
	B	I	R	U
21	68.4	62.3	57.6	70.8
22	71.3	65.9	60.4	73.9
23	74.1	69.5	63.3	76.8
24	76.8	73.0	66.0	79.6
25	79.4	76.3	68.7	82.3
26	81.8	79.5	71.3	84.9
27	84.2	82.6	73.8	87.4
28	86.4	85.5	76.3	89.8
29	88.4	88.3	78.7	92.0
30	90.4	90.9	81.0	94.2
31	92.3	93.4	83.2	96.2
32	94.0	95.7	85.4	98.2
33	95.7	97.9	87.5	100
34	97.2	100	89.5	
35	98.6		91.4	
36	100		93.3	
37			95.1	
38			96.8	
39			98.4	
40			100	

5.3 Description of Let Scheduling Problem

Once a project is let, NCDOT is committed to fund the project to its completion. Hence, one feasible solution for NCDOT to cope with funding changes is to revise the future let schedule of TIPs. Funding for transportation projects is often accompanied by restrictions on how the funds are used, complicating the process of project

selection. NCDOT is currently developing a new priority scoring method that makes it possible for all the projects to have priority scores. Note that the priority score of a project represents its (relative) importance. Therefore, it is rational to take the priority score into consideration when the let schedule is revised. To this end, the project team developed a 0-1 integer programming model that finds the best new let schedule minimizing the extent of disruption according to the priority scores as described below.

We consider a three-year time window for the let scheduling problem. That is, the let schedules of all Whales having types of B, I, R, and U scheduled during the next three-year period are subject to change to satisfy the cash balance constraint at the end of the time window. The time window always begins from the following month of the current month, where the current month is the time when the optimization problem is solved to assess funding risks. We assume that the let date of a project can be either advanced up to 12 months or delayed up to 24 months.

Note that, when a funding shortage occurs, it is inevitable to delay the let dates of some projects. Also, by its nature of discrete time periods, let dates of some projects could be advanced to take advantage of savings due to the delayed projects, still satisfying the overall cash balance constraint. When determining the change of the schedule, we need to consider two factors to make a decision. First, since the priority score provides the importance of the project, if two projects are under exactly same circumstances except for their priority scores, the project having a lower priority score should be delayed first than the other. Second, delaying a project to the next (or more) fiscal year (FY) should be avoided if possible. (Note that the Federal FY begins in October, while the State FY begins in July.) A similar principle applies when we advance the let date of a project, except that the project having a higher score should be advanced first. With this consideration, we make the formula that measures the extent of disruption as in Table 15. For example, suppose that a project has a priority score of 50, and a 7-month delay is considered. If the 7-month delay results in a shift to the next FY, then the extent of disruption is measured as $\left(5 + \frac{6}{24}\right) \times 50 = 262.5$. It is noteworthy that the priority of advancement should not be higher than that of delay. In this way, we can guarantee that advancement is a byproduct from inevitably delaying other project(s). This is the reason that we assign a small weight of 0.001 to the score when advancing the schedule to the previous FY.

Table 15 Quantification Formula for Assessing the Extent of Schedule Disruption

Case	Quantified Disruption
No schedule change	0
Let date is advanced within the same FY	0
Let date is advanced to the previous FY	$-0.001 \times score$
Let date is delayed within the same FY	$\frac{delayed\ period}{24} \times score$
Let date is delayed to the next FY	$\left(5 + \frac{delayed\ period}{24}\right) \times score$
Let date is delayed to the second FY	$\left(10 + \frac{delayed\ period}{24}\right) \times score$

To describe the 0-1 programming problem, suppose that there are N projects, i.e., the number of Whales of B, I, R, and U types that are scheduled in the next three-year period. Let d_{ij} denote the quantified disruption of project i when it is let in month j . Also, let x_{ij} be a binary variable such that $x_{ij} = 1$ if project i is scheduled in month j and $x_{ij} = 0$ otherwise. Then, the objective function in the optimization model can be written as follows.

Objective Function: Minimize $\sum_{i=1}^N \sum_{j \in C_i} d_{ij} x_{ij}$,

where C_i denotes the feasible set of months in which project i can be let. Since d_{ij} is the extent of disruption as defined specified by Table 15, the objective function represents the overall disruption from changing the let schedule.

The let scheduling problem needs to consider two constraint sets. First, only one month should be selected for letting project i . Hence, the problem is subject to

$$\text{Single Let Month Constraints:} \quad \sum_{j \in C_i} x_{ij} = 1 \quad \text{for } i = 1, 2, \dots, N.$$

Second, the cash balance at the end of the time window cannot exceed the available fund. Let c_{ij} denote the cumulative construction expenditure at the end of the time window if project i is let in month j . Also, let F denote the funding amount that can be expended by the projects scheduled during the time window. Then, the second constraint becomes

$$\text{Funding Limit Constraint:} \quad \sum_{i=1}^N \sum_{j \in C_i} c_{ij} x_{ij} \leq F.$$

In summary, the solution of the above optimization problem provides a let schedule of N projects that minimizes the overall disruption while satisfying the funding change.

Remark: While undertaking this research project, we have also incorporated additional constraint sets that reflect the Equity Formula, which was a funding distribution formula among the seven different regions in the North Carolina state. The Equity Formula is no longer considered in NCDOT as part of re-evaluation of priorities. However, we provide a detailed description of this constraint set in Appendix B, where the history of developing the funding risk management tool is presented.

5.4 Scenario Generation for Simulation

The let scheduling problem presented in the previous section will be solved for different funding scenarios to simulate funding changes. If there is no uncertainty, we assume that there is no need for adjusting the let schedule, and all the projects are let as scheduled. Let F_0 denote the total 3-year construction expenditure of those projects that will be let during the next three years as scheduled. Then, F_0 can be considered as the basis of funding. For simulating funding scenarios, we generate 15 scenarios of funding deviation from the basis, F_0 , which are 1%, 2%, ..., 5% surpluses, and 1%, 2%, ..., 10% deficits from F_0 .

CHAPTER 6: FUNDING RISK REGISTER - USER'S GUIDE

6.1 Introduction and Placement of Funding Risk Register Version 2

This chapter provides a user's manual for using the final version of the funding risk register (Register). The Register can be used to assess the vulnerability of projects to funding changes, and to find an alternative let schedule when fund amount changes. By its nature of handling cash flows for construction expenditures, it is recommended that the Register is maintained and operated within the Funds Administration Section in NCDOT. Once the risk analysis module is successfully run, the output of the Register can be referred to by members in other units who need the information about the funding project risk for transportation improvement programs (TIPs). The Register also provides an insightful summary of schedule changes under prescribed 15 funding change scenarios, which can be referred by program managers to inspect the impact of funding changes.

The Register considers TIPs that are programmed in the next three years. Furthermore, it analyzes those that have construction costs of \$10 million or more, which have the greatest influence on the cash flows among TIPs. In order to use the Register, the research team provides a data processing tool that converts a raw data file to a formatted input data file. After describing how to prepare to use the tool and what are included in the package, detailed instructions along with figures are demonstrated in the subsequent sections.

6.2 Tool Package

The Register package is ready to be used by copying all the files to a single folder in a computer that is run on the Windows operating system and equipped with Microsoft Excel spreadsheet software. Particularly, the package was developed and tested on Windows 7 with Microsoft Excel 2010. The package consists of eight files: two macro enhanced Excel files (funding risk analysis v2.xlsm, input_prep.xlsm), one Excel example file (example_raw.xlsx), three GLPK optimization files (glpsol.exe, glpk_4_47.dll, glpk_4_47_java.dll), and two batch run files (riskopt.bat, whatif.bat).

Table 16 Description of Files in the Tool Package

File Name	Description
Funding risk analysis v2.xlsm	Analyzes funding project risks for an input file prepared by 'input_prep.xlsm'.
input_prep.xlsm	Converts a raw data file to a formatted input file for the Register.
example_raw.xlsx	Example of the raw data file.
glpsol.exe	Execution file of the open source mixed-integer linear programming solver, GLPK
glpk_4_47.dll	Dynamic link library file as part of GLPK
glpk_4_47_java.dll	Dynamic link library file as part of GLPK
riskopt.bat	Batch execution for solving 15 mixed-integer programming problems
whatif.bat	Batch execution for solving a mixed-integer programming problems for what-if analysis

6.3 Instructions for Using the Register

6.3.1 How to Prepare Input Data File

The input file for the Register needs to be properly prepared using the provided tool, input_prep.xlsm. The raw data file can be readily obtained from the existing database at the Funds Administration Section in NCDOT. The raw data file is an Excel spreadsheet that contains seven columns with headings of TIPNo, LATEST_LET_DATE, ACTUAL_BID_LET_DATE, LATEST_COST, ACTUAL_BID_AMT, BID_FUNDS, and SCORE as specified below.

- TIPNo: the TIP number of each project.
- LATEST_LET_DATE: the scheduled let date of the project.
- ACTUAL_BID_LET_DATE: the actual let date. Note that actual let dates are not available for those that are scheduled to be let in the future.
- LATEST_COST: the estimate of the construction cost.
- ACTUAL_BID_AMT: the actual contract amount after the project is let.
- BID_FUNDS: the indication of funding source. Federally funded projects are indicated by 'F' or blank, whereas projects funded by the state are indicated as 'S'.
- SCORE: a priority score that is assigned to the project.

Figure 32 displays an example of the raw data file (example_raw.xlsx). In this example file (Figure 32), first six columns are provided by Mr. Frank Bowen and Ms. Laurie Smith from the Funds Administration Section in NCDOT. It should be noted that the Prioritization Office of NCDOT is currently assessing priority scores of all the planned projects based on newly developed formula. Once all the scores are available, the last column of the raw data is expected to be provided by Mr. Alpesh Patel at the Prioritization Office.

	A	B	C	D	E	F	G
1	TIPNo	LATEST_LET_DATE	ACTUAL_BID_LET_DATE	LATEST_COST	ACTUAL_BID_AMT	BID_FUNDS	SCORE
2	R-4745B	12/1/2022		62500000			95
3	A-0009B	7/1/2017		38000000		F	84
4	A-0009CA	6/1/2018		73000000			100
5	A-0009CB	6/1/2018		165000000			92
6	A-0009CC	7/1/2021		17000000			95
7	A-0010AA	1/1/2020		86000000			100
8	A-0011BB	10/1/2008	10/21/2008	14400000	12489954	F	96
9	B-0682	9/1/2007	9/18/2007	31700000	30989260.52	F	96
10	B-2500	7/1/2011	7/19/2011	236000000	215777000	F	100
11	B-2500A	9/1/2013		98000000			100
12	B-2500B	4/1/2014		119000000			92
13	B-2532	2/1/2007	2/20/2007	33654000	39283846	F	100
14	B-2965	4/1/2009	4/21/2009	10500000	7556017.07	F	78
15	B-3159	4/1/2015		20900000			65
16	B-3611	5/1/2010	5/18/2010	22100000	14786170.8	F	100
17	B-3637	9/1/2007	9/18/2007	13500000	10190525.23	F	100
18	B-3684	2/1/2009	2/17/2009	16400000	12431817.04	F	100
19	B-3835	9/1/2007	9/20/2007	24000000	14998300	F	87
20	B-4028	8/1/2012	8/21/2012	19200000	14897884.14	F	81

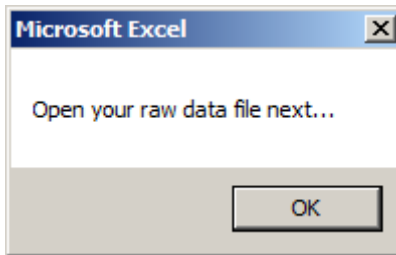
Figure 32 Screenshot of the Example Raw Data File (example_raw.xlsx)

It is important to use the same names of headings as in the example file because those names will be used to recognize each column in the preparation tool. However, the name of the raw data file can be arbitrarily chosen. Once the raw data file is available, the user can run 'input_prep.xlsm' following the steps below. (Since the figures

are confined within the presented steps, we will have a caption only for the first figure, which is followed by figure labels in the subsequent figures.)

Steps to Prepare Input File

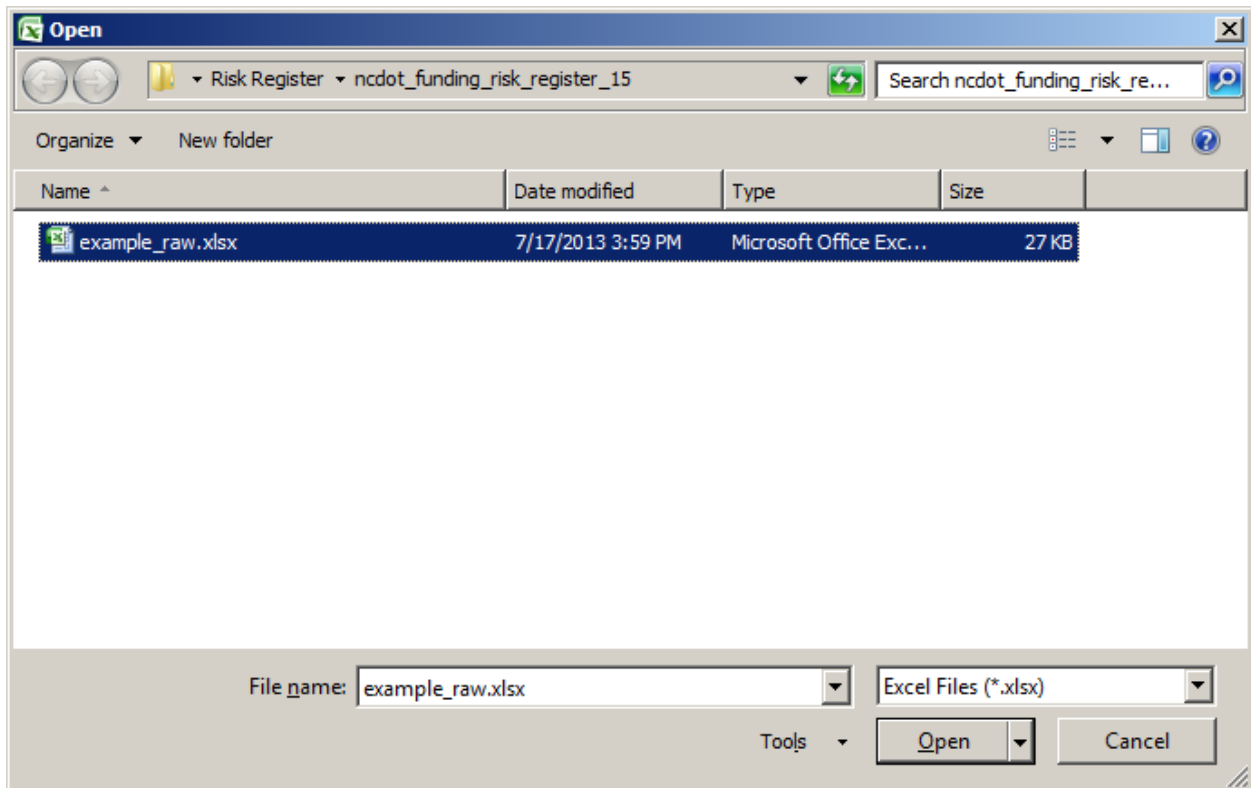
1. Run 'input_prep.xlsm'.
2. Click 'OK' when the tool displays a message box "Open your raw data file next..."



Prep-(a)

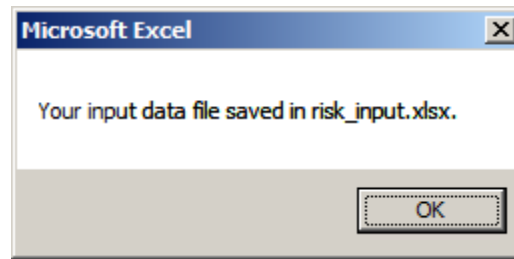
Figure 33 Images for Steps to Prepare Input File

3. In the Open file box, select the raw data file and click 'Open'.



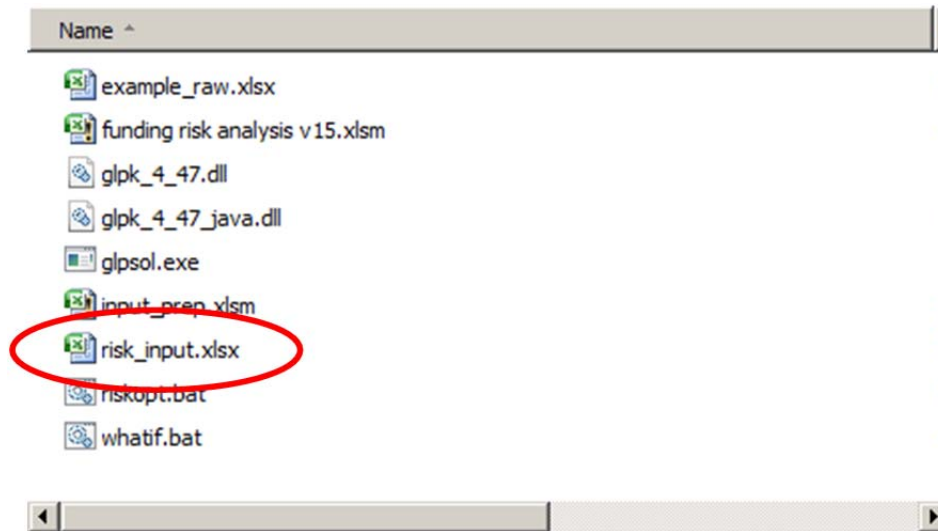
Prep-(b)

4. If the raw data file has a valid format as mentioned earlier, the tool runs a series of preparation tasks, and displays a message box "Your input data file saved in risk_input.xlsx." Click 'OK'.



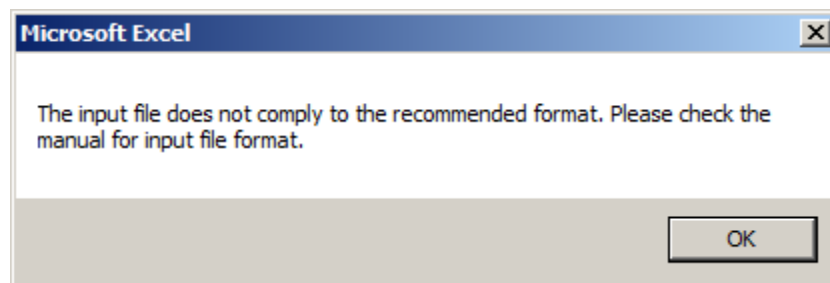
Prep-(c)

5. The input file named 'risk_input.xlsx' is now available in the same folder.

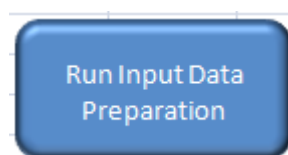


Prep-(d)

Remark: If the user selects an incorrectly formatted raw data file, the tool displays the following message. Click 'OK' and restart the preparation steps by clicking the button named 'Run Input Data Preparation'.



Prep-(e)



Prep-(f)

6.3.2 How to Run Funding Risk Register

When the preparation tool is successfully run, the input file named 'risk_inpu.xlsx' is available and the user is ready to run the Register. (Similar to the figures in the previous section, we will provide a single caption, which is followed by figure labels.)

Steps to Run Register

1. Run 'funding risk analysis v2.xlsm'.

NCDOT STIP Project Funding Risk Register v.2

Project Information	
Project ID	
State or Federal	
Construction Cost	
Priority Score	
Let Date	
Duration (month)	

Search Project

Clear All

No.	Funding Risk	Delay Period (month)	Impact (1-10)	Likelihood	Funding Risk Rating	At Risk	Remark
1	Delay	1					
2		2					
3		3					
4		4					
5		5					
6		6					
7		7					
8		8					
9		9					
10		10					
11		11					
12		12					
13		13					
14		14					
15		15					
16		16					
17		17					
18		18					
19		19					
20		20					
21		21					

Register-(a)

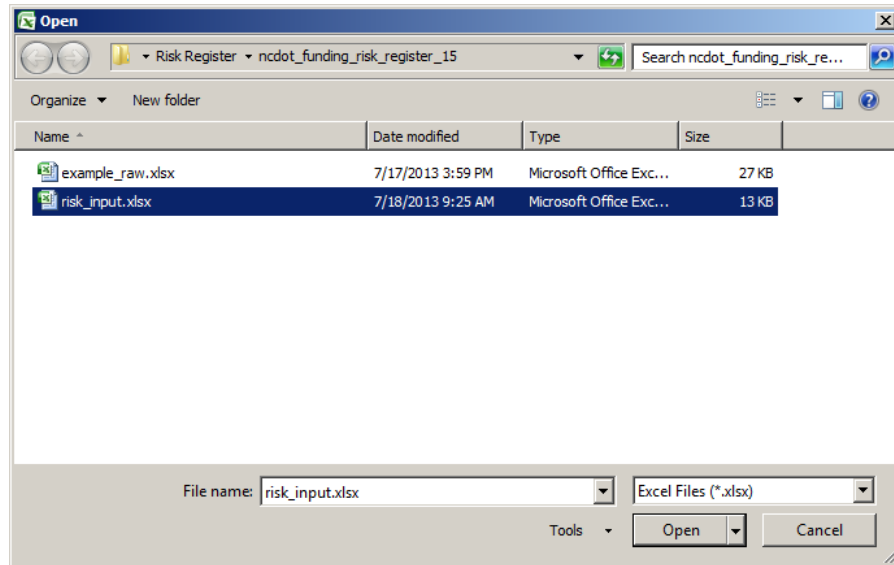
Figure 34 Images for Steps to Run the Register

2. Click the button named 'Import Project Data'.



Register- (b)

3. From the Open file box, select the file named 'risk_input.xlsx', which was created by the preparation tool above. Click 'Open'. Upon opening the file, the Register undertakes a series of tasks to assess impacts of delays, to assign initial likelihoods, and to compute cumulative cash flows over next 36 months under the current let schedule.



Register-(c)

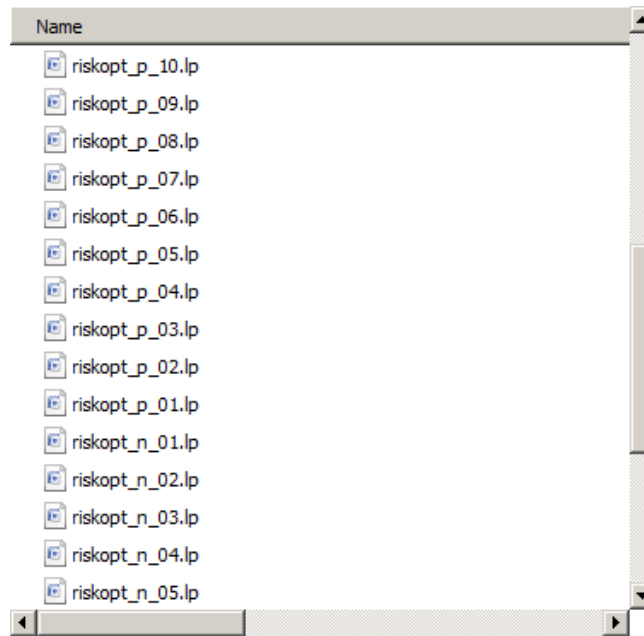
4. Next, click the button named 'Run Risk Analysis'.



Register-(d)

5. The Run Risk Analysis procedure undertakes two tasks as follows.
- Writing 15 mixed-integer programming (MIP) problems in the same folder. Each of these 15 problems correspond to 15 scenarios of requirements for changing three-year cumulative construction costs, ranged from 5%, 4%, ..., 1%, -1%, -2%, ..., -10% of the currently scheduled cumulative construction costs.

MIP Problem File Name	Scenario
riskopt_n_xx.lp	Three-year cumulative construction cost can be increased at most xx percent.
riskopt_p_yy.lp	Three-year cumulative construction cost must be decreased at least yy percent.



Register-(e)

- b. Solving 15 MIP problems using the GLPK solver. Note that time taken by writing and solving problems can be long depending on the computer performance, and the user needs to wait until all the tasks are completed. The user can refer to the status bar at the bottom of the main screen for the current progress of the tasks.

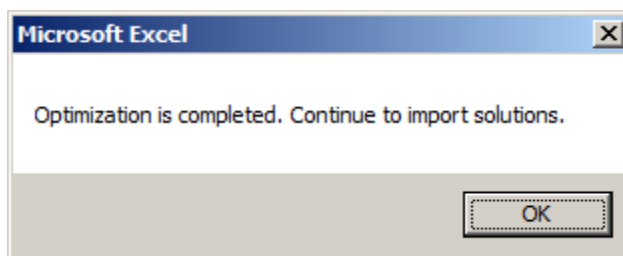
```

C:\Windows\system32\cmd.exe
98 rows, 2603 columns, 5151 non-zeros
2602 integer variables, all of which are binary
Preprocessing...
97 rows, 2602 columns, 5149 non-zeros
2602 integer variables, all of which are binary
Scaling...
A: min|aij| = 1.000e+000 max|aij| = 5.085e+008 ratio = 5.085e+008
GM: min|aij| = 2.341e-001 max|aij| = 4.272e+000 ratio = 1.825e+001
EQ: min|aij| = 5.544e-002 max|aij| = 1.000e+000 ratio = 1.804e+001
2N: min|aij| = 4.002e-002 max|aij| = 1.280e+000 ratio = 3.197e+001
Constructing initial basis...
Size of triangular part = 97
Solving LP relaxation...
GLPK Simplex Optimizer, v4.47
97 rows, 2602 columns, 5149 non-zeros
* 0: obj = 6.934225000e+004 infeas = 0.000e+000 (0)
* 453: obj = -5.378297865e+001 infeas = 4.776e-028 (0)
OPTIMAL SOLUTION FOUND
Integer optimization begins...
+ 453: mip = not found yet >= -inf (1; 0)
+ 801: >>>> 4.480000000e+000 >= -5.378026725e+001 (133; 0)
+ 1465: >>>> 3.380000000e+000 >= -5.376563575e+001 (320; 38)
+ 1801: >>>> -4.807000000e+001 >= -5.376563575e+001 11.8% (440; 101)
+ 2211: >>>> -5.086000000e+001 >= -5.371829003e+001 5.6% (446; 253)

```

Register-(f)

6. When the optimization problems are solved, the Register displays a message box “Optimization is completed. Continue to import solutions.”



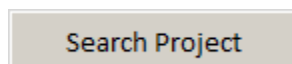
Register-(g)

7. Click 'OK'. Then, the Register reads and processes solution files to extract useful information. The results are summarized in the worksheet named 'Changes of Let Schedule'. The figure below is a partial screenshot of the worksheet. The table displays the let schedule change under 15 scenarios. For example, the let schedule of B-3159 can be advanced by seven months when the construction expenditure budget is increased by 5% or 4%.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1		Let Schedule Changes under Funding Deviation in 3-Year Construction Costs (Currently, \$3,891,215,884)														
2	TIP Number	5%	4%	3%	2%	1%	-1%	-2%	-3%	-4%	-5%	-6%	-7%	-8%	-9%	-10%
3	B-3159	-7	-7													
4	B-4490	-3	-3	-3	-3	-3										
5	B-4565	-7	-7	-7	-7											
6	B-4722B	-7	-7	-7	-7	-7										
7	B-5136	-7	-7	-7	-7											
8	I-0906	-3	-3	-3	-3	-3	-3	-3	-3		-3					
9	I-3311E	-11	-11	-11												
10	I-33188B	-9	-9	-9												
11	I-4927	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1				-1
12	I-4928	-6	-6	-5	-5	-5										
13	I-5000	-1	-1	-1	-1	-1	-1	-1	-1		-1	-1				-1
14	I-5110	-3	-3	-3	-3											
15	I-5405A	-1	-1	-1	-1	-1		-1								
16	I-5508	-4	-4	-4	-4											
17	I-5606	-6	-6	-6	-6	-6	-6	-6	-6							
18	R-0204D	-5	-5	-5												
19	R-0623	-5	-5													
20	R-2501C	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1					
21	R-2514D	-3														
22	R-2603	-8	-8													
23	R-2612B	-9	-9	-9	-9											
24	R-2707AB	-7	-7	-7	-7											
25	R-2707B	-7	-7													
26	R-3100A	-11														
27	R-3100B	-4	-4	-4	-4	-4	-4	-4								
28	R-3307	-4														

Register-(h)

8. Next, to check the funding risk for an individual project, click the button named 'Search Project' in the main screen.



Register-(i)

9. In the Search Project form, enter the TIP number, and click 'Search'.

Register-(j)

10. The Register displays the project information and its funding risk.

Project Information	
Project ID	R-2576
State or Federal	F
Construction Cost	\$556,260,000
Priority Score	87
Let Date	12/1/2013
Duration (month)	40

Register-(k)

No.	Funding Risk	Delay Period (month)	Impact (1-10)	Likelihood	Funding Risk Rating	At Risk	Remark
1	Delay	1	1	1	1		
2		2	1	1	1		
3		3	1	1	1		
4		4	1	10	10		Deficit scenario: 1%
5		5	1	1	1		
6		6	1	1	1		
7		7	1	9	9		Deficit scenario: 2%
8		8	1	1	1		
9		9	1	8	8		Deficit scenario: 3%, 4%, 5%, 6%, 7%, 8%, 9%, 10%
10		10	9	1	9	Shift 1 Year	
11		11	9	1	9	Shift 1 Year	
12		12	9	1	9	Shift 1 Year	
13		13	9	1	9	Shift 1 Year	
14		14	9	1	9	Shift 1 Year	
15		15	9	1	9	Shift 1 Year	
16		16	9	1	9	Shift 1 Year	
17		17	9	1	9	Shift 1 Year	
18		18	9	1	9	Shift 1 Year	
19		19	9	1	9	Shift 1 Year	
20		20	9	1	9	Shift 1 Year	
21		21	9	1	9	Shift 1 Year	
22		22	10	1	10	Shift 2 Years	
23		23	10	1	10	Shift 2 Years	
24		24	10	1	10	Shift 2 Years	

Register-(i)

The table displayed as a result of 'Search Project' provides the funding risk information about the project. The 'Likelihood' indicates whether and how much it will be likely to be delayed. In specific, the likelihood corresponds to each of 10 fund deficit scenarios. That is, the likelihood of 10 corresponds to the 1% fund deficit, 9 corresponds to 2% deficit, and so on, except that the likelihood of 2 corresponds to both 9% and 10% fund deficit scenarios. The likelihood of 1 represents the project does not experience any delay under all 10 fund deficit scenarios. If a project experienced a delay under any fund deficit scenarios, it is important to monitor it. Hence, the likelihood of 2 or

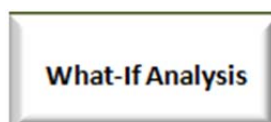
higher is highlighted. Furthermore, it is also important to monitor a project that has a large funding risk rating. Therefore, the register will highlight those values larger than 10 as well. In the last column, the user can see the scenario(s) under which the project is delayed. In the above example with R-2576, observe that the project is delayed by 8 months under eight deficit scenarios (3%, 4%, ..., 10%).

Remark: We recommend monitoring all the projects that display any highlighted likelihood or funding risk rating.

6.3.3 How to Run What-If Analysis

Besides the primary funding project risk run in the previous subsection, the Register also provide a What-If analysis module to cover scenarios other than predetermined 15 scenarios. The What-If analysis can be run as follows:

1. Click the button named 'What-If Analysis'.



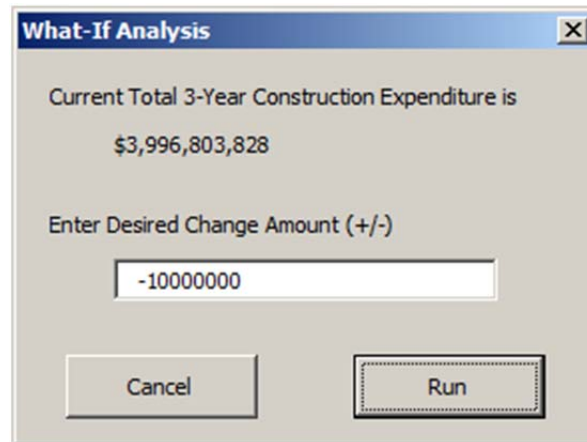
WhatIf-(a)

Figure 35 Images for Steps to Run the What-If Analysis

2. From the 'What-If Analysis' user form, the user can see the 3-year construction expenditure for those projects considered in the Register (i.e., projects that will be let during the next 36 months). The example below displays the expenditure of \$3,891,215,884.

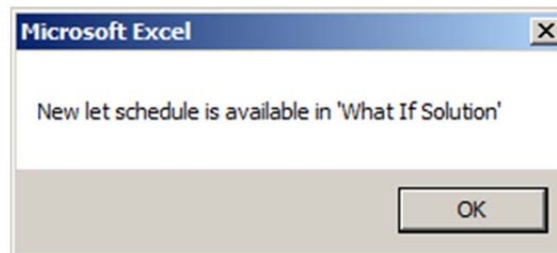
WhatIf-(b)

3. In the text box, enter the change amount of the fund for which the user wants to know the best let schedule. If the scenario considers a surplus of the fund, the sign of the amount becomes positive, and it should be negative otherwise. For example, the following figure indicates a deficit of \$10 million.



WhatIf-(c)

4. Click 'Run'. This module will create a problem file named 'whatif.lp' and a solution file named 'whatif_sol.txt' in the same folder. After the optimal schedule is found, the following message will be displayed.



WhatIf-(d)

5. Click 'OK'. Then, the resulting let schedule is available from the worksheet named 'What If Solution'.

NCDOT - Funding Risk Register					
	A	B	C	D	E
1	Project ID	Current Let	New Let	Month Change	New Costs
2	B-2500A	9/1/2013	9/1/2013	0	\$3,986,622,238
3	B-2500B	4/1/2014	4/1/2014	0	
4	B-3159	4/1/2015	4/1/2015	0	
5	B-4490	12/1/2015	12/1/2015	0	
6	B-4565	4/1/2015	4/1/2015	0	
7	B-4722B	4/1/2015	4/1/2015	0	
8	B-5136	4/1/2015	4/1/2015	0	
9	I-0906	12/1/2015	12/1/2015	0	
10	I-0914BA	9/1/2014	9/1/2014	0	
11	I-0914BB	9/1/2014	9/1/2014	0	
12	I-3311E	8/1/2015	8/1/2015	0	
13	I-3318BB	6/1/2015	6/1/2015	0	
14	I-3802A	9/1/2013	9/1/2013	0	
15	I-4927	10/1/2015	9/1/2015	-1	
16	I-4928	2/1/2014	2/1/2014	0	
17	I-5000	10/1/2015	9/1/2015	-1	
18	I-5110	12/1/2013	12/1/2013	0	
19	I-5405A	10/1/2014	10/1/2014	0	
20	I-5508	1/1/2015	1/1/2015	0	
21	I-5606	2/1/2014	2/1/2014	0	
22	R-0204D	11/1/2015	11/1/2015	0	
23	R-0623	11/1/2014	11/1/2014	0	
24	R-2303C	9/1/2013	9/1/2013	0	
25	R-2303D	9/1/2013	9/1/2013	0	
26	R-2413A	12/1/2013	12/1/2013	0	
27	R-2413B	12/1/2013	12/1/2013	0	
28	R-2501C	7/1/2015	7/1/2015	0	
29	R-2514B	12/1/2015	12/1/2015	0	
30	R-2514C	6/1/2015	6/1/2015	0	
31	R-2514D	9/1/2015	9/1/2015	0	
32	R-2519B	2/1/2014	2/1/2014	0	
33	R-2536AA	8/1/2014	8/1/2014	0	
34	R-2536AB	8/1/2014	8/1/2014	0	
35	R-2536B	8/1/2014	8/1/2014	0	
36	R-2536C	8/1/2014	8/1/2014	0	
37	R-2545B	10/1/2015	10/1/2015	0	
38	R-2576	12/1/2013	1/1/2014	1	
39	R-2582A	2/1/2016	2/1/2016	0	

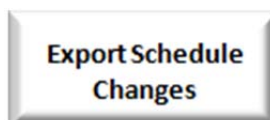
WhatIf-(e)

The columns 'Current Let' and 'New Let' display the original let dates and new let dates, respectively. The column 'Month Change' indicates the difference between the original let month and the new let month. For example, B-4490 is advanced by 3 months, while R-2576 is delayed by 4 months.

6.3.4 How to Export Changes of Let Schedule

The Register is also capable of saving the table in the worksheet 'Changes of Let Schedule', which displays the summary of schedule changes under the prescribed 15 funding scenarios.

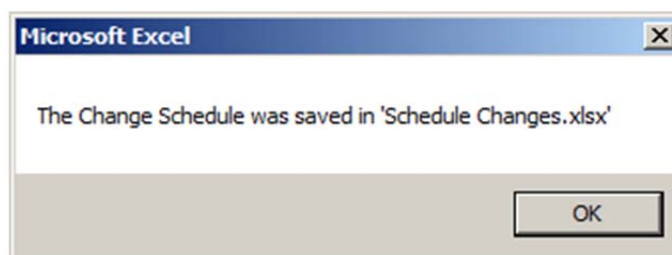
1. Click the button named 'Export Schedule Changes'.



Export-(a)

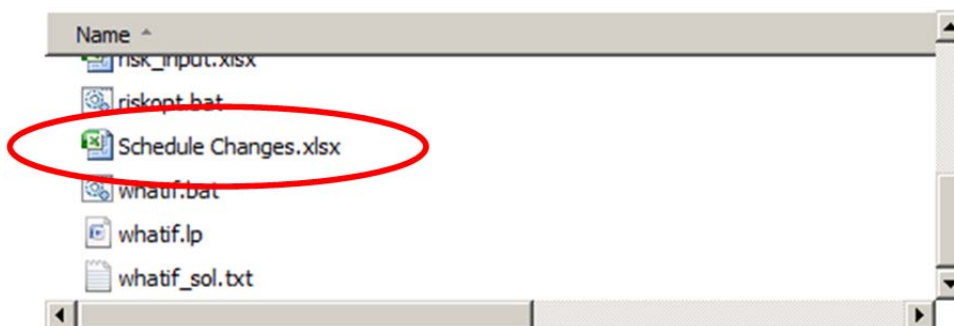
Figure 36 Images for Steps to Export Changes of Let Schedule

2. Then, the register saves the table in the Excel spreadsheet file named 'Schedule Changes.xlsx'.



Export-(b)

3. Click 'OK'. The user can check the newly created file from the same folder.



Export-(c)

6.3.5 Miscellaneous Functions, Unhiding Sheets, Unhiding Menus, and Unprotecting Sheets

Miscellaneous Functions

The following are miscellaneous functions of the Register:

- **Save:** This button saves the current file with solutions. It also creates a backup file with a file name ‘backup yyyy-mm-dd hh-nn.xlsm’, where yyyy is the year, mm is the month, dd is the day, hh is the hour, and nn is the minute when the file is created.
- **Print:** This button enables the user to print the main screen in a single page.
- **Exit:** This button exits the Register.
- **About:** This button displays the basic information about the Register.

Unhiding Sheets

When it is launched, the Register hides worksheets that the user may not need to see. The user can unhide those sheets if the user desires to see them.

Unhiding Menus

When it is launched, the Register hides the Excel menus. If the user wants to see those menus (e.g., to see the source code from ‘Develop’), the user can unhide the menus by pressing ctrl-r.

Unprotecting Sheets

The Register protects all the worksheets when it is launched to avoid accidental changes of parameters and/or other critical values. The user can unprotect worksheets using a password ‘abc’.

6.4 Development History

The version 2 of the Register presented in this chapter is the result of continuous efforts with the help of many members from various units of NCDOT. Hence, it would be beneficial for the reader to know the development history in order to better understand the current version of the Register. Past development includes two prototype tools, the Register version 0.5, the Register version 1.0, and two optimization models for optimal funding portfolio and optimal let scheduling, respectively. Details of development history are provided in Appendix B.

CHAPTER 7: OTHER CONSIDERATION FOR FURTHER ENHANCEMENT

In this chapter, we provide a brief discussion about further research items and issues that can be considered to enhance the reliability of the Register, but are out of the scope of this research project.

7.1 Issues Related to Payout Curves

Note that the Register has been developed on the basis of statistical models for predicting individual payout curves, which provide the expected construction costs of STIPs. By the nature of the uncertainty of the future events, however, it is apparent that predicted values contain forecasting errors, and reducing such errors can benefit the reliability of the Register. While deriving statistical models for individual payout curves, we identified some factors that we cannot arbitrarily change to desired values. For example, the estimates of construction duration are confined to the formula used in HiCAMS as in Table 11, which is referred to by units across NCDOT. According to the formula, the construction durations of Whales of B, I, R, U are 36, 34, 40, 33 months, respectively (see Table 17). These values may serve to predict the contract duration. The past data revealed that the actual duration of construction is significantly longer than that of HiCAMS (see Table 17 and Figure 37).

Table 17 Comparison of Nominal, Contract, and Actual Average Construction Durations for Whales (Programs with Award Amounts more than \$10 million).

Type	Duration (months)		
	HiCAMS	Contract	Actual
B	36	36	42
I	34	33	50
R	40	37	45
U	33	35	42

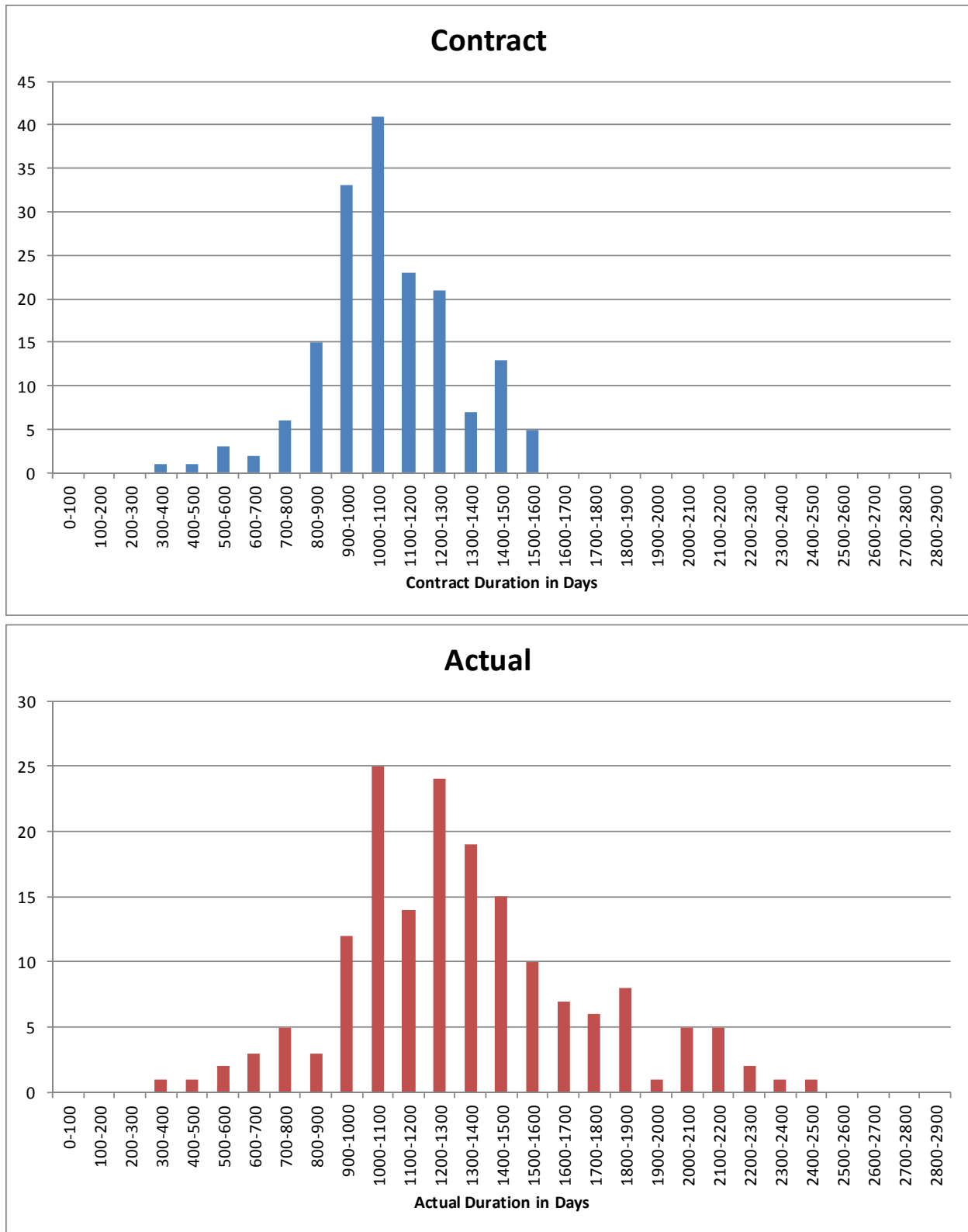


Figure 37 Distributions of Contract Duration and Actual Duration

There can be numerous reasons for this prolonged construction, which can be considered as other project risks. Regardless of the reasons of delayed construction, it should be noted that the cash flow takes place not based on the contract duration, but based on the actual construction duration. Therefore, it is not difficult to conjecture that the predictability of construction cost models could be enhanced by considering the actual duration of construction.

In HiCAMS there are currently six categories of construction costs, among which we are focused on the last category that encompasses construction costs larger than or equal to \$10 million (i.e., Whales). However, the range of construction costs in this last category varies widely as shown in the histogram of 218 Whales (Figure 38), and hence, there is a potential to have significant heterogeneity among those projects belong to the category. This is particularly anticipated as more large-scale projects emerge. Therefore, it could be beneficial to partition this last group into more categories, which require a thorough investigation for meaningful categorization.

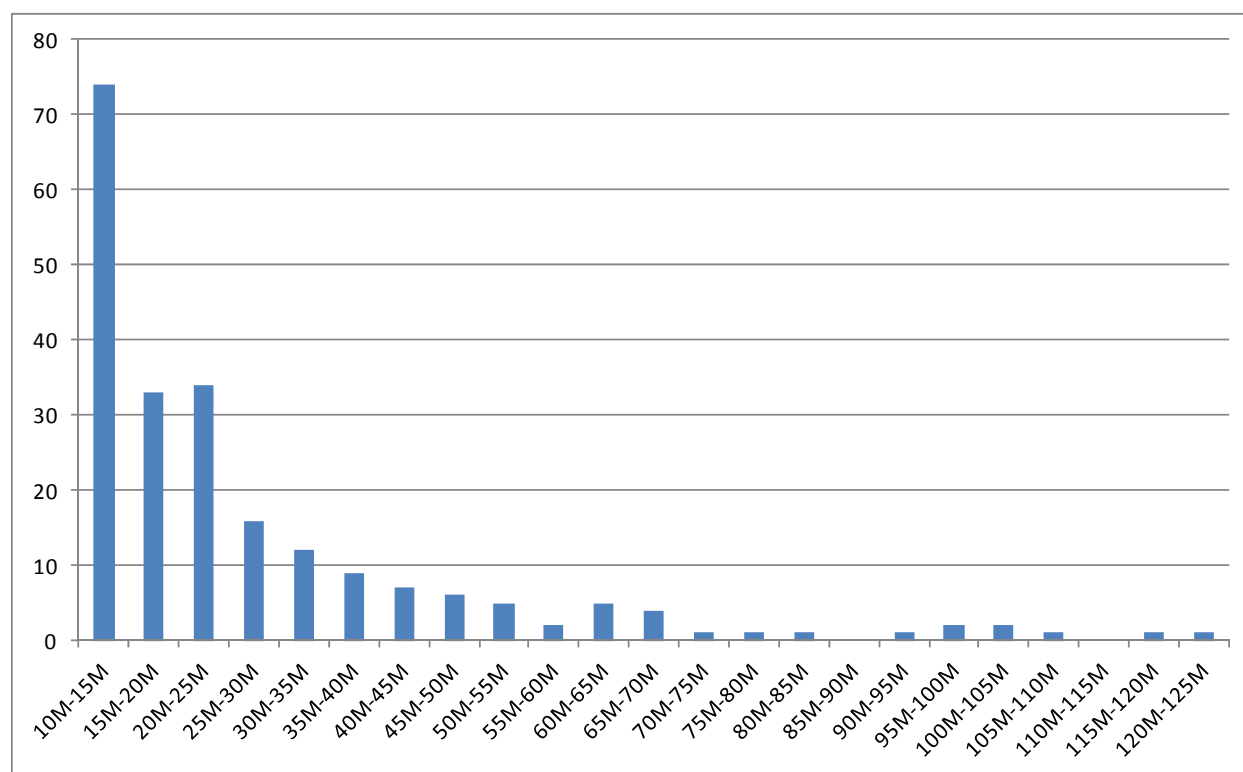


Figure 38 Histogram of Construction Costs for 218 Whale Projects

Being aware of the need for further categorization of Whales, Funds Administration Section of NCDOT proposed partitioning programs having awards of \$10 million or more into three categories:

Category 1: \$10 million - \$50 million

Category 2: \$50 million - \$100 million

Category 3: \$100 million or more.

The categorization is based on the contract durations that are factored by 1.1 to accommodate construction delays. The research team ran a quick statistical analysis to determine the validity of the proposed categorization. A scattered in Figure 39 displays the relationship between the amount of award and the factored contract duration.

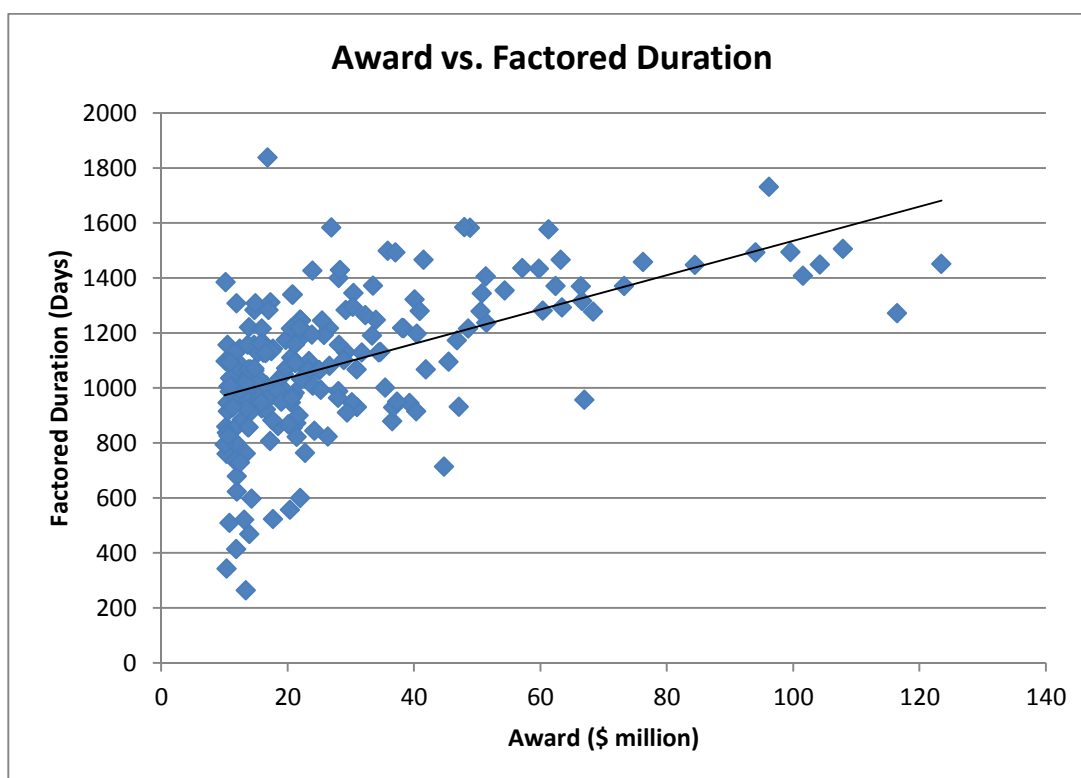


Figure 39 Relationship between Award and Factored Duration.

The linear regression of factored durations on award revealed that the factored durations positively related to the awards with p-value less than 3×10^{-18} . In order to see the statistical validity of the aforementioned additional categories, we ran analysis of variance (ANOVA) as shown in Figure 40. According to the results, these categories display significant differences in factored durations.

SUMMARY						
Groups	Count	Sum	Average	Variance		
10M-50M	191	218406.1	1143.487	62104.76		
50M-100M	22	33422.4	1519.2	26243.28		
100M-Inf	5	7790.2	1558.04	9352.453		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3474497	2	1737249	30.1498	2.87E-12	3.037864
Within Groups	12388424	215	57620.57			
Total	15862921	217				

Figure 40 ANOVA Table for Additional Categorization of Whales.

7.2 Strategic Mobility Formula

NCDOT has recently replaced the Equity Formula with the Strategic Mobility Formula (SMF) to allocate funding for Strategic Transportation Investments. SMF breaks down projects into three categories: statewide, regional, and division level. The statewide level will receive 40% of the available funding, and selection of projects will be based on 100% data-driven scores. The regional level will receive 30% of the available funding, and selection of projects will be based on two weighted factors: 70% by the decision making process and local rankings, and 30% by the NCDOT Transportation Divisions. The division level will receive the remaining 30% of the available funding, and selection of projects will be made based 50% on data and 50% on local rankings. The new formula will be fully implemented by July 1, 2015 (NCDOT, 2013). We remark that the let schedule derived from the optimization module of the current Register can serve as the initial point of discussion for coping with funding changes even after the new formula is in place. Still, incorporating the new formula into the optimization module will further enhance the feasibility of the let schedule that the Register provides.

CHAPTER 8: CONCLUSIONS

8.1 Research Summary

The investigations of current risk management processes in the transportation area revealed a lack of funding project risk management. The research team reviewed handbooks and manuals of other state DOTs, and conducted a short survey to 49 other state DOTs. After reviewing the documents and the survey responses, the research was focused on the practices in California Department of Transportation (Caltrans) and other DOTs that use the variants of Caltrans' process. Based on the review, the research team found no indication that Caltrans and other DOTs are explicitly implementing funding project risk management tools. Instead, funding risks are managed as part of the project risk management, which is typically undertaken and documented by the project manager with help from project team members.

The research team performed an in-depth study on Caltrans' practices through another survey, a document search, and reviews. This determined that, in Caltrans, risk is acknowledged at the project level, not at the funding stage. Caltrans has a well-defined fund estimate process to project the available resources for the upcoming five years. Caltrans also has a special funding risk management process for its Intelligent Transportation System projects. The evaluation results of Caltrans' funding risk management related processes are thoroughly elaborated and a good practice example for implementing funding risk management process has been discussed in the section describing funding risk process for Caltrans' ITS projects. Some of Caltrans' practices have been embedded into the implementation plan discussed below. The establishment of a subcommittee for discussing Let Schedule changes is similar to Caltrans' practice in reviewing and revising its Fund Estimate through California Transportation Commission meetings. NCDOT can follow Caltrans' three step risk management approach for ITS projects to the funding risk management process and project management process. Embracing systems engineering process and investigating potential use of Systems Engineering Management Plan in NCDOT project management processes can enhance risk management performances in NCDOT operations.

In this research, several versions of funding risk register have been progressively developed over the research period. The final version of the funding risk register incorporates the features that include forecasting individual payout curve, accepting only high-impact large-scale projects, incorporating the project delivery rate as a part of the performance measure, extending the time window for monitoring cash flows to 36 months, and employing a data-driven estimate of lead time. The funding risk register is capable of assessing funding risks on individual construction projects, and providing a potential adjustment of the project let schedule under 15 funding change scenarios as well as for a user-specified funding change scenario. A recommended implementation plan for the Register is provided in the next subsection.

In summary, the research team has investigated current risk management and funding risk management processes and evaluated the best practices among DOTs in the US. An in-depth study was performed to appraise the potentials for possible implementation of the best practices. A funding project risk management tool, funding risk register, is developed with optimization and simulation capability. This register can produce the potential adjustment of project let schedule for 15 funding change situations. This can assist DOT staff members in making better decisions regarding budget management, cash management, and project management. The research results and the developed funding risk register will provide NCDOT staff members great help in dealing with funding changes and better decision-making under funding change environment.

8.2 Implementation Plan

The goal of implementation of the research results is for NCDOT staff members to utilize the funding risk register in their decision-making process. The Register involves cash flows under funding scenarios, and hence, it is recommended for the tool to be installed, operated, and maintained within the Funds Administration Section. The outcome of the Register needs to be entered into the central database, so that relevant Units of NCDOT can refer to the funding risk of individual programs. Furthermore, when a subcommittee is convened for discussing Let Schedule changes, it is recommended to utilize the Register to ascertain the impact of funding changes via What-If analysis. The recommended implementation plan can be itemized as follows:

- Funding Risk Database
 - Create a Funding Risk field in the SAP database.
- Monthly Update
 - At each month, Funds Administration Section staff runs the Register with a new 3-year Let Schedule.
 - Enter the funding risk scores to the SAP database.
- Reference to Funding Risk Score
 - Staff members who monitor project risks refer to the Funding Risk field of the SAP database.
- Utilization of What-If Analysis
 - A staff member of the Funds Administration Section is a member of the subcommittee that discusses about changes in the Let Schedule.
 - When convened, the Funds Administration Section staff member shares the results of the What-If Analysis function to facilitate the Let Schedule change process.
 - Besides the Funds Administration Section staff member, it is recommended that a staff member of Prioritization Office be one of core members in the subcommittee since the Register utilizes the priority scores.

The Register was developed to be run in a straightforward way in order to increase its usability. Therefore, formal training is unnecessary. Instead, demonstration and one-to-one communication with the Funds Administration Section staff member(s) will suffice for training purposes.

8.3 Scope for Further Research

The funding project risk management tool developed in this research simultaneously provides funding risk assessment and adequate decision-making under various funding scenarios. The underlying mathematical decision-making framework in the tool employs statistical models that are derived from the historical data of highway construction projects along with the guidelines in the Highway Construction and Material System (HiCAMS) of NCDOT. However, while the research team analyzes the historical construction data, it has been observed that there are significant inconsistencies between the statistics obtained from the data set and the current practice used in HiCAMS. For example, the construction duration specified by HiCAMS underestimates actual construction periods. Furthermore, there is a potential need for adding more categories when classifying construction projects with respect to the estimated construction costs since more extremely expensive projects are expected to emerge in the future. It will soon become difficult to justify applying a single category to widely varying construction costs. Adding more categories or even re-classification requires a meticulous investigation of characteristics of such mega-scale projects and identification of the purpose of such characterization (i.e., who needs to use the categorized information and why?).

Note that an initial step has been made by Funds Administration Section to incorporate additional categories based on duration estimates. However, there is a plenty of leeway to enhance the categorization and estimate durations via

an in-depth review of duration data, especially an investigation of the gap between the contract duration and the actual payment duration. Noting that the payout curve estimation is bound by the durations, a quality model for duration estimation is a necessary condition to have an accurate model for estimating individual payout curves.

It is also noteworthy that only traditional construction projects are considered for estimating payout curves, partially because Design-Build (DB) projects have different processes to follow. However, since more and more DB projects have been awarded and such a trend is expected to continue, estimation of payout curves for DB projects will be necessary.

Note that these are only part of potential problems that could be observed in HiCAMS. It is recommended to conduct a thorough review of modules in HiCAMS and establish an adaptive process to adjust its parameters. If necessary, this includes creating models to accommodate changing environments.

Another scope of the further research is that there is a need for integrating various sources of information within NCDOT. Note that different units of NCDOT handle and update different information pieces with respective purposes. However, not all databases are updated with the same latest information thus there can be discrepancies among the information pieces of different units, which can lead to inefficient organizational communication and incorrect decision-making. The integration of databases requires a significant investment in infrastructure. However, infrastructure alone does not guarantee successful integration. In order to accomplish an effective integration, it is important to understand how and why information is handled across various units and parties within and outside NCDOT. It is recommended to conduct a thorough investigation on sources of information, flows of information, and uses of information in NCDOT.

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APPENDIX A

The appendix contains the survey sent to Caltrans as discussed in Section 3.3.2.

TRANSPORTATION FUNDING RISK MANAGEMENT

RESEARCH PROJECT: DEVELOP TOOLS FOR MANAGING RISK TO FUNDS

Research Project No. RP 2012-06

Executive Summary

The purpose of this document is to request certain information about the practices and procedures used by Caltrans to manage risk to project funds. Managing risk to the schedule, budget, and quality are familiar to anyone working in project or program management in the transportation infrastructure field. However, recent economic conditions have demonstrated that promised funds coming from a variety of fund sources do not always materialize. This presents a risk to the entire project portfolio. The North Carolina Department of Transportation (NCDOT) is studying methods to classify the risk of various funding sources, to investigate how funding risk applies to project prioritization, and to develop tools for project portfolio managers and financial managers to use in assessing and controlling risks.

A preliminary survey sent to all 50 state transportation agencies in June 2012 revealed that Caltrans is one of several states that actively consider funding risk management during project planning. The research team believes that a thorough understanding of the risk management practices and procedures in use by Caltrans is beneficial to our study. This document first presents a brief summary of our understanding about the project risk management process in Caltrans. The research team hopes that this summary sets the stage for the questions that follow by allowing the reader to assess the team's current understanding of Caltrans' framework for project risk management.

Current Understanding of Caltrans' Risk Management Framework

Risk management is an integrated part of the overall project management process. Projects are programmed through a series of steps into a combined *Federal and State Transportation Improvement Program* (FSTIP). A diagram of this process is shown Figure 41.

FEDERAL/STATE PLANNING & PROGRAMMING PROCESS

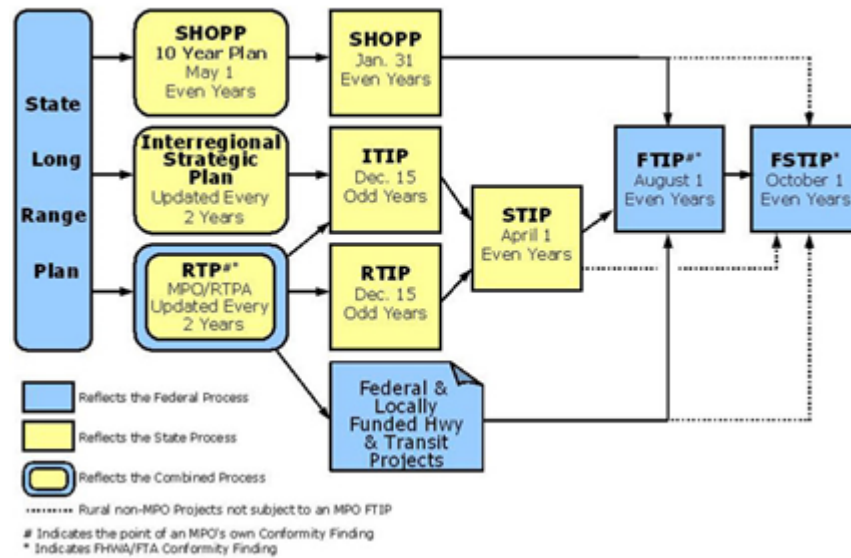


Figure 41 Diagram of Federal and State Transportation Improvement Program

Unfortunately the research team has not been able to identify the process by which projects are funded in any given year, or if any inherent risks in funding sources are considered during programming. Funding risk appears to be considered primarily at the project management level rather than the program management level. *Caltrans Project Management Handbook* shows the project phases that include risk management processes (Figure 42).

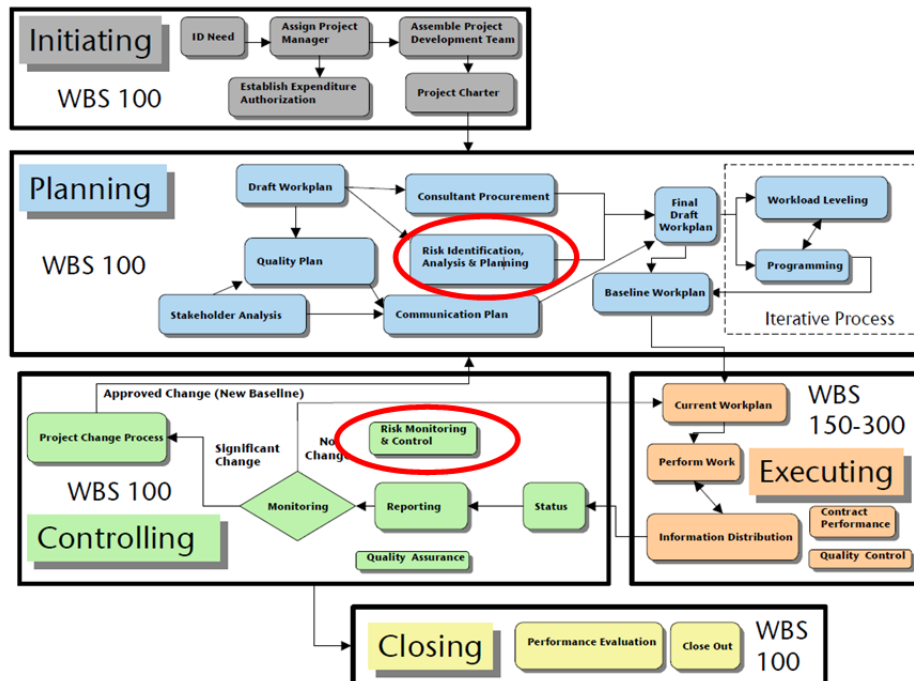


Figure 42 Project Phases Implementing Project Risk Management Process

The risks are broken down into eight broad categories containing several elements of the *Caltrans Project Risk Management Handbook*. Funding falls under the organizational category. There are two examples of funding risks: funding changes for fiscal year and capital funding unavailable for right of way or construction (Figure 43).

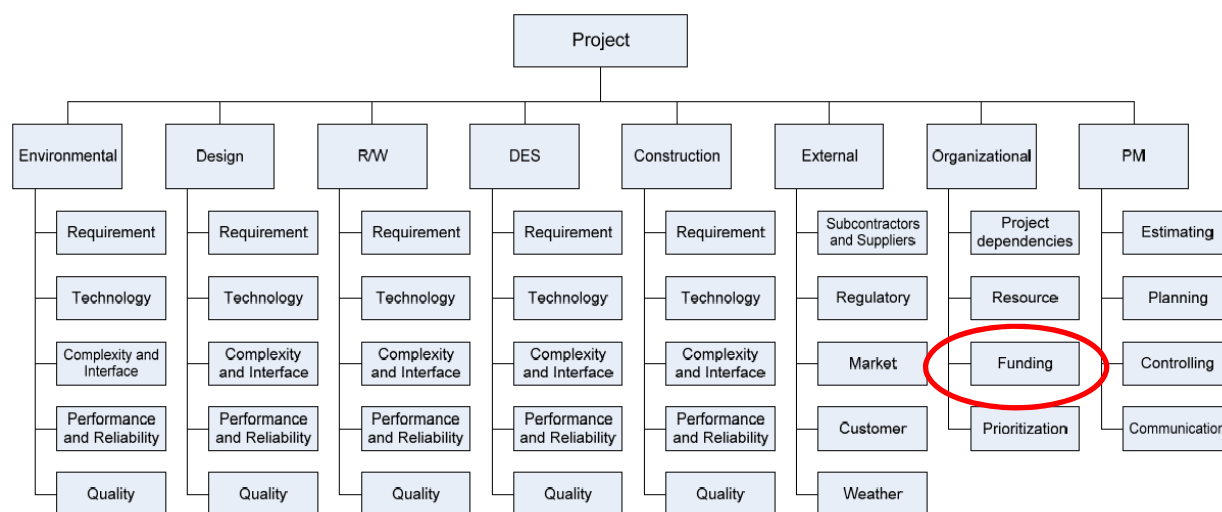


Figure 43 Hierarchical Structure of Project Risks

Brief summary of Documents Reviewed

The project team reviewed a number of publicly available Caltrans documents related to the research topic. A short summary of a few key documents follow.

Project Development Procedures Manual (PDPM) – The PDPM is a comprehensive manual defining the project development process from initiation through the assembly of the final project records after project construction. Chapter 4 addresses programming. It contains definitions of funding sources and defines criteria for funds distribution. Appendix B presents an overview of the project development process. It tangentially addresses project risk and references the Project Risk Management Handbook.

Project Risk Management Handbook – This document appears to be based on the risk management methodology captured in the Project Management Body of Knowledge (PMBOK) published by the Project Management Institute. It has guidance on risk identification, qualitative and quantitative risk analysis, and risk response planning. It does not address funding risk or address prioritization of projects. Risk is captured at the project level, not at the program level.

Project Management Handbook – This handbook also appears to be adopted from the PMBOK, summarizing its key concepts as applied to Caltrans projects. It contains definitions of key terms, acronyms, and systems useful for someone unfamiliar with Caltrans.

State Highway Operation and Protection Program (SHOPP) – The SHOPP is a 10 year plan containing summaries and cost estimates for projects to maintain the state highway system.

State Transportation Improvement Program (STIP) – The STIP is a 5 year plan, produced every 2 years, for allocation of funds to state highway improvements, intercity rail, and regional highway and transit improvements.

Requests and Questions for Caltrans

1. Please provide any funding risk documentation such as handbooks, manuals, and/or articles. Links or electronic documents are preferred.
2. Is funding risk a consideration when prioritizing projects?
3. When considering funding risk, are risk categorized? If so, what are the categories and their definitions?
4. Do you use qualitative method(s) to assess and analyze funding risk? If yes, please provide the method(s) you implement and any applicable documentation.
5. Do you use quantitative method(s) to assess and analyze funding risk? If yes, please provide the method(s) you implement and any applicable documentation.
6. What models (e.g., probability distribution or forecasting model) do you use to describe funding risks?
7. How do you measure the impact of funding risks?

APPENDIX B

HISTORY OF FUNDING RISK REGISTER DEVELOPMENT

The final version of the Register presented in Chapter 6 is the result of continuous efforts with the help of many members from various units of NCDOT. During the development process, several versions of the funding project risk tool were explored and tested. For thorough understanding the final version of the tool, it is important for readers to learn how the development process has been forged over time. In this appendix, therefore, we present the history of the development process for the funding project risk management tools. Past development includes two prototype tools, the Register version 0.5, the Register version 1.0, and two optimization models for optimal funding portfolio and optimal let scheduling, respectively.

B.1 First Prototype: The Initial Effort

We began developing a prototype framework of a funding risk register within an Excel spreadsheet with various modules that were written in VBA codes. We remark that, in this initial prototype risk register tool, only a skeleton of the modules have been developed. That is, no analysis modules were included. The initial funding risk register consists of three modules: 1) user risk register, 2) risk database management, and 3) risk database.

Note that this initial prototype is focused on the user interface of the register, and also intended to have a stand-alone database, unlike the final version that takes a data set from the NCDOT database as presented in Chapter 5. The overall structure of this initial prototype version is described below.

Main Screen: A welcome page shown below helps the user to choose from its three functions: User Risk Register, Risk Database Management, and Risk Database (Figure 44).

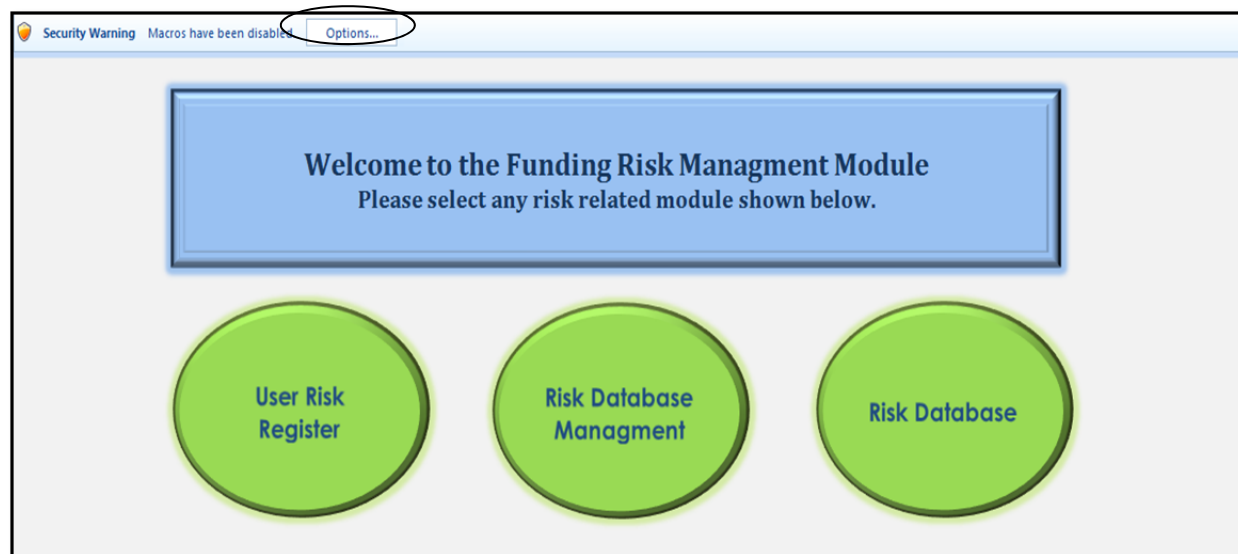


Figure 44 Main Screen of the First Prototype of the Register

User Risk Register Module: This module opens the risk register shown in Figure 45. In this screen, the user can input the project information by 'Enter Input'. The project information includes the project number, project type, project duration, funding source, project cost, etc. Once all information is entered, it was intended to provide various risks based on the project details entered by the user. Hence, using this risk register, a user would be able to identify both risks for any project. Furthermore, it was intended for the user to manually edit the risk register. Using

the “Clear the Screen” button, the user can re-start the input process. Besides the risk register function, this tool makes the user easily navigate to other modules.

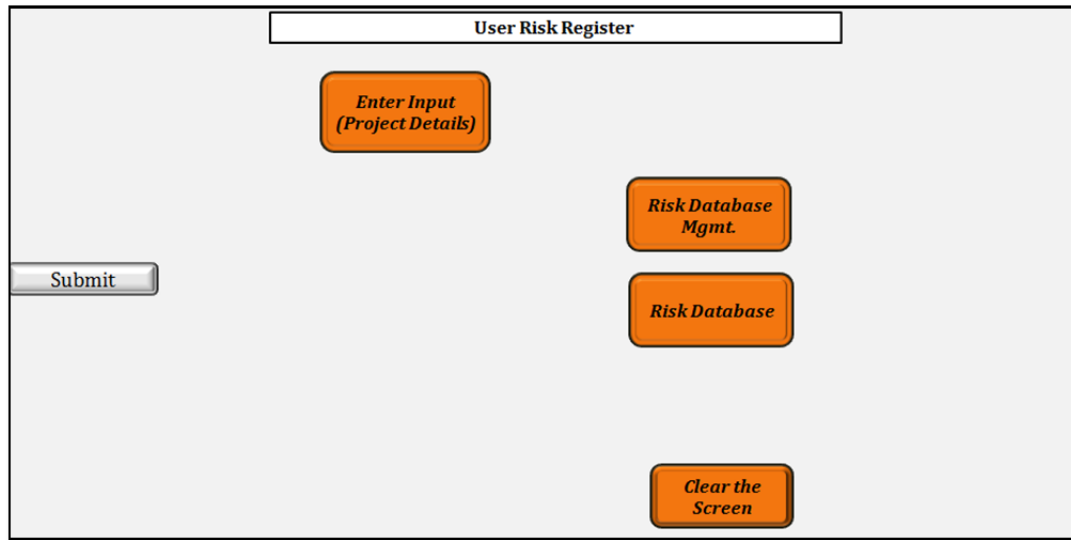


Figure 45 User Risk Register Module of the First Prototype of the Register

Risk Database Management Module: When the user enters this module as shown in Figure 46, all the projects can be displayed and managed along with their identified risks, probability, and impact of those risks. There are drop down boxes in the risk database management sheet which allows the user to select from the available options. The risk database management sheet and the database sheet were protected by a password. Thus, only those users having the password can access the database sheet to keep it from potential alteration. The user can again navigate to either the User Risk Register module or Risk Database module. (This security feature has been conveyed to the final version of the Register.)

[illegible]

Figure 46 Risk Data Management Page of the First Prototype

Risk Database Module: The database page shown in Figure 47 enables the user to observe data for all projects (but the database cannot be directly edited). The database can be edited only via the database management page above.

B.2.1 Databases in Second Prototype

There are three databases in the second prototype: Project Information database, Funding Risk Item database, and Project-Risk database (see Figure 48). The Project Information database stores basic information about projects such as Project ID, budget, funding source, beginning/ending dates, and the number of funding risks associated with the project (see Figure 49 for an example). The Funding Risk Item database contains potential funding risk items that can be identified based on the past project data as well as project managers' expertise. In specific, funding risk items are organized in a hierarchical structure, which has three levels; the primary level, the secondary level, and the tertiary level. In this version of the register, the potential funding risk items are displayed as generic names (see Figure 50 for an example of hierarchically organized funding risk items with generic names). When we developed this prototype, it was our intention to identify actual funding risk items in collaboration with NCDOT, which were practically diverted to let schedule delays later.

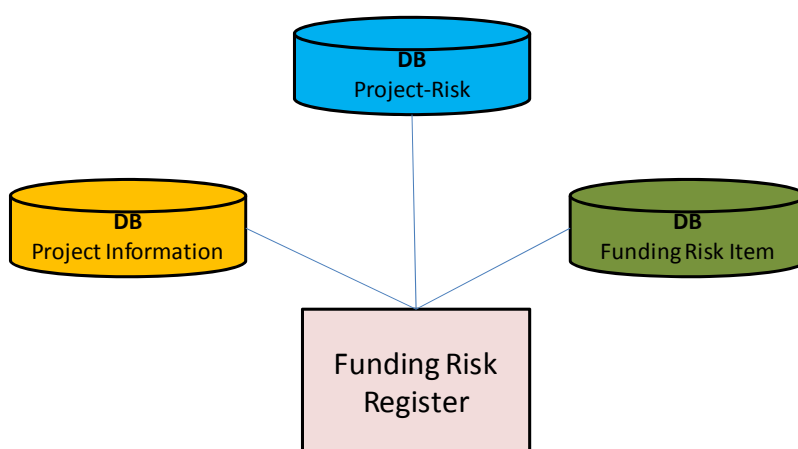


Figure 48 Funding Risk Register and Databases of Second Prototype

Project ID	No. of Risk	Project Budget	Funding Source	Begin	End
B-5312	3	1,500,000	Federal	1/1/2011	12/31/2014
B-4917	1	30,000,000	Federal	2/8/2008	6/30/2016
U-2704B	2	\$1,902,231.00	State	3/6/2012	3/18/2015
U-2222	2	\$34,234,300.00	Federal	3/13/2012	3/18/2016
R-4063	1	\$500,000.00	State	3/1/2012	2/29/2016
B-5526	2	\$1,000,000.00	State/Federal	3/1/2012	3/1/2015
I-4745	1	\$500,000.00	State	1/1/2010	12/31/2013

Figure 49 Sample Data Entries of Project Information Database

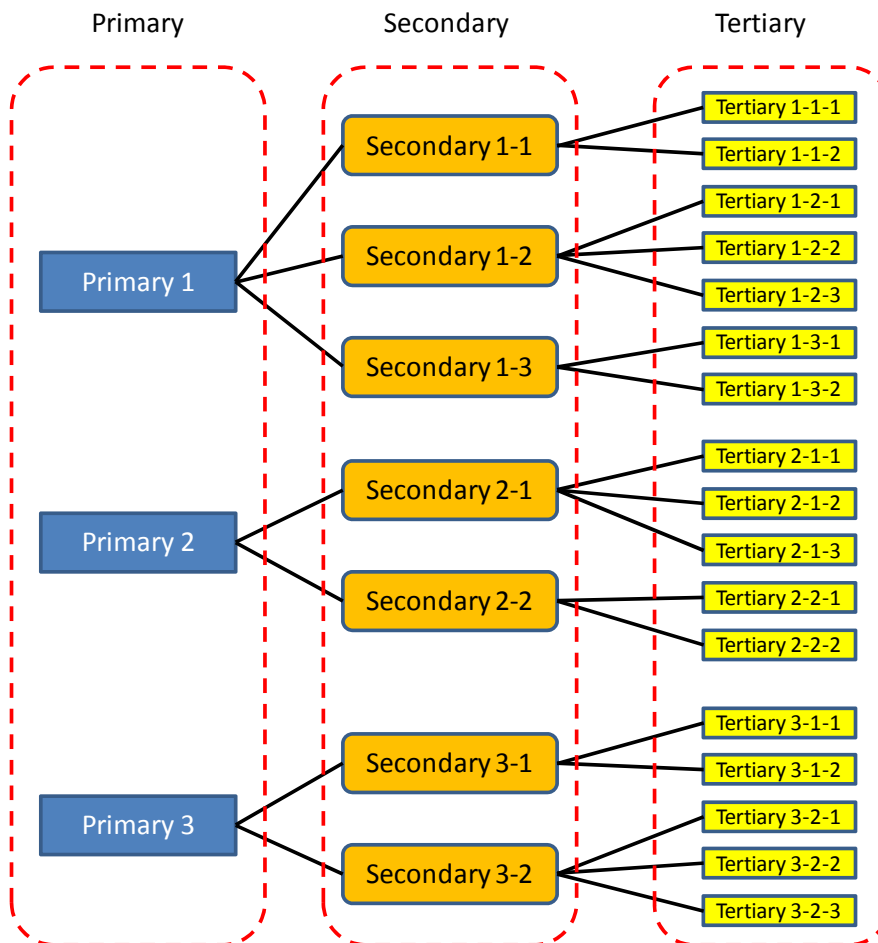


Figure 50 Example of Hierarchically Organized Generic Funding Risk Items

The Project-Risk database records funding risk items that are assigned to each project. It also includes additional information such as likelihood, impact, risk rating, and owner of each funding risk item, along with specific description about the funding risk item in the context of the project. A sample of data entries in the Project-Risk database is displayed in Figure 51. These entries are managed by the main Funding Risk Registry module.

Project ID	Type	Likelihood	Impact	Risk Rating	Owner	Remark
B-5312	1-1-1	8	7	56	Churlzu Lim	Federal to division managed
B-5312	1-2-1	9	3	27	Churlzu Lim	Uncertain federal funding availability
B-5312	2-1-1	4	2	8	Chad Bruton	Revision of contract
B-4917	2-2-2	3	9	27	Yiping Lu	Possible advance of technology
U-2704B	1-1-2	5	5	25	Churlzu Lim	Funding shortage
U-2704B	1-2-2	2	2	4	Gary Teng	ROW issue
R-4063	2-1-2	5	10	50	Chad Bruton	Funding shortage
B-5526	2-2-2	3	5	15	Gary Teng	Possible change of funding allocation
B-5526	3-2-1	4	8	32	Gary Teng	Uncertain federal funding availability
I-4745	1-2-2	3	3	9	Churlzu Lim	Potential cost overrun due to ROW

Figure 51 Sample Data Entries of Project-Risk Database

B.2.2 Functions of Second Prototype

The funding risk register consists of several modules that perform various functions such as inserting a new project, opening an existing project, updating project information, and updating risk items associated with the project. A snapshot of the main screen is displayed in Figure 52.

NCDOT STIP Project Funding Risk Register

Project Information

Project Number	
Project Budget	
Funding Source	
Project Begin (mm/dd/yyyy)	
Project End (mm/dd/yyyy)	

Update Project Info Update Risk Clear All Scenario Analysis (future)

No.	Funding Risk Item	Likelihood (1-10)	Impact (1-10)	Risk Rating (Auto)	Owner	Remark
1						
2						
3						
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Figure 52 Screenshot of Main Page

As shown in Figure 52, main menus are located in the left-hand side of the funding risk register. ‘New Project’ calls a routine by which a project manager can add a new project and associated funding risk items. ‘Open Project’ runs a procedure to search an existing project and populate its funding risk items. ‘Save’ and ‘Print’ render saving the file and printing the screen fit in one page, respectively. ‘Exit’ closes the funding risk register, and ‘About’ displays a brief description of the funding risk register.

In addition to the main menus, there are four in-document menus; ‘Update Project Info’, ‘Update Risk’, ‘Clear All’, and ‘Scenario Analysis (future)’. ‘Update Project Info’ modifies the current project entry of the Project Information database with the latest values as shown in the Project Information (blue colored) area. Similarly, ‘Update Risk’ changes funding risk entries of the current project in the Project-Risk database. ‘Clear All’ initializes the funding risk register form. ‘Scenario Analysis’ is for future development of simulation/decision support routines, which help the project manager make risk-aware decision.

B.2.3 Second Prototype: Creating New Project Entry

To illustrate how a new project entry can be created, consider a (dummy) project that is specified by the following attributes; Project ID: R-1111, budget: \$1,200,000, funding source: State, project duration: 03/01/2012 – 02/28/2015. ‘New Project’ opens a user form that takes a project ID (see Figure 53). In the second prototype, we primarily consider four types of project, B, I, R, and U. However, it can also handle additional types (‘Other’) that are not covered by the primary project types or have irregular ID.

Figure 53 Project ID Entry Form

Once the project ID is entered, the 'Continue' button creates a new entry in the Project Information database with the project ID, and leads the user to the additional input area (Figure 54). (If the project ID exists in the Project Information database, the registry notifies it to the user.) In the Project Information area, funding source entry offers a drop-down list from which the user can select one of State, Federal, and State/Federal.

Project Information	
Project Number	R-1111
Project Budget	\$1,200,000.00
Funding Source	State
Project Begin (mm/dd/yyyy)	03/01/2012
Project End (mm/dd/yyyy)	02/28/2015

Figure 54 Entering Additional Project Information

For date entries, the register also offers a user input form that offers drop-down lists of year, month and day as shown in Figure 55.

Figure 55 Input Date Form

After the project information input is complete, the Project Information database needs to be updated by selecting 'Update Project Info'. As the result of this update, the Project Information database has a new entry with Project ID of R-1111. Notice that 'No. of Risk' is empty as no funding risk items have been added (Figure 56).

Project ID	No. of Risk	Project Budget	Funding Source	Begin	End
B-5312	3	1,500,000	Federal	1/1/2011	12/31/2014
B-4917	1	30,000,000	Federal	2/8/2008	6/30/2016
U-2704B	2	\$1,902,231.00	State	3/6/2012	3/18/2015
U-2222	2	\$34,234,300.00	Federal	3/13/2012	3/18/2016
R-4063	1	\$500,000.00	State	3/1/2012	2/29/2016
B-5526	2	\$1,000,000.00	State/Federal	3/1/2012	3/1/2015
I-4745	1	\$500,000.00	State	1/1/2010	12/31/2013
R-1111		\$1,200,000.00	State	3/1/2012	2/28/2015

Figure 56 New Project Information Added to the Project Information Database

B.2.4 Second Prototype: Adding Funding Risk Items

For illustration purpose, suppose that the aforementioned project R-1111 has two funding risk items, (Primary 2 : Secondary 2-1 : Tertiary 2-1-2) and (Primary 3 : Secondary 3-2 : Tertiary 3-2-1). These funding risk items can be entered via the input risk form (Figure 57), which can be accessed from the cells under *Funding Risk Item*. The form offers drop-down lists of each hierarchy. The list is dynamically assigned so that items in the lower level categories are displayed according to the selection of the higher level category. For example, when the primary category is *Primary 2*, the secondary category displays only *Secondary 2-1* and *Secondary 2-2*.

Figure 57 Input Risk Form for Adding/Modifying Funding Risk Items

After selecting an appropriate risk item, likelihood and impact are selected from respective drop-down lists. Likelihood and impact are assessed using a 10-point scale from 1 – least likely and minimum impact to 10 – highly likely and maximum impact, respectively. Once these two values are entered, the risk rating is automatically calculated as the product of these two values. The Owner and description under ‘Remark’ need to be typed in the next two columns (Figure 58).

No.	Funding Risk Item	Likelihood (1-10)	Impact (1-10)	Risk Rating (Auto)	Owner	Remark
1	Primary 2 : Secondary 2-1 : Tertiary 2-1-2	4	7	28	Gary Teng	Funding source contingent to switch
2	Primary 3 : Secondary 3-2 : Tertiary 3-2-1	8	1	8	Churlzu Lim	Highly uncertain cost estimate

Figure 58 Illustration of Two Funding Risk Items

When all items are entered, these risk items are recorded in the Project-Risk database by the ‘Update Risk’ button. Besides, this adds risk items to the Project-Risk database, it also updates the ‘No. of Risks’ field of the Project Information database (see Figure 59 and Figure 60).

Project ID	Type	Likelihood	Impact	Risk Rating	Owner	Remark
B-5312	1-1-1	8	7	56	Churlzu Lim	Federal to division managed
B-5312	1-2-1	9	3	27	Churlzu Lim	Uncertain federal funding availability
B-5312	2-1-1	4	2	8	Chad Bruton	Revision of contract
B-4917	2-2-2	3	9	27	Yiping Lu	Possible advance of technology
U-27048	1-1-2	5	5	25	Churlzu Lim	Funding shortage
U-27048	1-2-2	2	2	4	Gary Teng	ROW issue
R-4063	2-1-2	5	10	50	Chad Bruton	Funding shortage
B-5526	2-2-2	3	5	15	Gary Teng	Possible change of funding allocation
B-5526	3-2-1	4	8	32	Gary Teng	Uncertain federal funding availability
L-4745	1-2-2	3	3	9	Churlzu Lim	Potential cost overrun due to ROW
R-1111	2-1-2	4	7	28	Gary Teng	Funding source contingent to switch
R-1111	3-2-1	8	1	8	Churlzu Lim	Highly uncertain cost estimate

Figure 59 Updated Project-Risk Database

Project ID	No. of Risk	Project Budget	Funding Source	Begin	End
B-5312	3	1,500,000	Federal	1/1/2011	12/31/2014
B-4917	1	30,000,000	Federal	2/8/2008	6/30/2016
U-2704B	2	\$1,902,231.00	State	3/6/2012	3/18/2015
U-2222	2	\$34,234,300.00	Federal	3/13/2012	3/18/2016
R-4063	1	\$500,000.00	State	3/1/2012	2/29/2016
B-5526	2	\$1,000,000.00	State/Federal	3/1/2012	3/1/2015
I-4745	1	\$500,000.00	State	1/1/2010	12/31/2013
R-1111	2	\$1,200,000.00	State	3/1/2012	2/28/2015

Figure 60 Updated Project Information Database

B.2.5 Second Prototype: Opening Existing Project and Funding Risk Items

Once created, funding risk items can be opened via the 'Open Project' module. The module activates a search project form that is similar to the project ID entry form (Figure 61).

Figure 61 Search Project Form

If the project ID that the user enters does not exist in the Register, a message is displayed to inform the absence. If the project ID exists, the register retrieves relevant data items from three databases. First, the project information is retrieved from the Project Information database and displayed in the project information area. Consider the project, B-5312, which was already in the Register. The 'Open Project' module retrieves budget (\$1,500,000), funding source (Federal), and period (1/1/2011 – 12/31/2014) that are displayed in Figure 62.

Project Information Database

Project ID	No. of Risk	Project Budget	Funding Source	Begin	End
B-5312	3	1,500,000	Federal	1/1/2011	12/31/2014
B-4917	1	30,000,000	Federal	2/8/2008	6/30/2016
U-2704B	2	\$1,902,231.00	State	3/6/2012	3/18/2015
U-2222	2	\$34,234,300.00	Federal	3/13/2012	3/18/2016
R-4063	1	\$500,000.00	State	3/1/2012	2/29/2016
B-5526	2	\$1,000,000.00	State/Federal	3/1/2012	3/1/2015
I-4745	1	\$500,000.00	State	1/1/2010	12/31/2013
R-1111	2	\$1,200,000.00	State	3/1/2012	2/28/2015

Project Information	
Project Number	B-5312
Project Budget	\$1,500,000.00
Funding Source	Federal
Project Begin (mm/dd/yyyy)	01/01/2011
Project End (mm/dd/yyyy)	12/31/2014

Figure 62 Retrieval of Project Information

Subsequently, the module retrieves all funding risk items associated with B-5321, and populates them in the table of the Register (Figure 63).

Project-Risk Database

Project ID	Type	Likelihood	Impact	Risk Rating	Owner	Remark
B-5312	1-1-1	8	7	56	Churlzu Lim	Federal to division managed
B-5312	1-2-1	9	3	27	Churlzu Lim	Uncertain federal funding availability
B-5312	2-1-1	4	2	8	Chad Bruton	Revision of contract
B-4917	2-2-2	3	9	27	Yiping Lu	Possible advance of technology
U-2704B	1-1-2	5	5	25	Churlzu Lim	Funding shortage
U-2704B	1-2-2	2	2	4	Gary Teng	ROW issue

No.	Funding Risk Item	Likelihood (1-10)	Impact (1-10)	Risk Rating (Auto)	Owner	Remark
1	Primary 1 : Secondary 1-1 : Tertiary 1-1-1	8	7	56	Churlzu Lim	Federal to division managed
2	Primary 1 : Secondary 1-2 : Tertiary 1-2-1	9	3	27	Churlzu Lim	Uncertain federal funding availability
3	Primary 2 : Secondary 2-1 : Tertiary 2-1-1	4	2	8	Chad Bruton	Revision of contract

Figure 63 Retrieval of Funding Risk Items

Note that the potential funding risk items are separately managed in the Risk Item database. The names of risk items are retrieved from the Risk Item database and displayed in the table as well (Figure 64).

Risk Item Database

Index	Level 0	Level 1	Level 2	Description
1-1-1	Primary 1	Secondary 1-1	Tertiary 1-1-1	Primary 1 : Secondary 1-1 : Tertiary 1-1-1
1-1-2	Primary 1	Secondary 1-1	Tertiary 1-1-2	Primary 1 : Secondary 1-1 : Tertiary 1-1-2
1-2-1	Primary 1	Secondary 1-2	Tertiary 1-2-1	Primary 1 : Secondary 1-2 : Tertiary 1-2-1
1-2-2	Primary 1	Secondary 1-2	Tertiary 1-2-2	Primary 1 : Secondary 1-2 : Tertiary 1-2-2
1-2-3	Primary 1	Secondary 1-2	Tertiary 1-2-3	Primary 1 : Secondary 1-2 : Tertiary 1-2-3
1-3-1	Primary 1	Secondary 1-3	Tertiary 1-3-1	Primary 1 : Secondary 1-3 : Tertiary 1-3-1
1-3-2	Primary 1	Secondary 1-3	Tertiary 1-3-2	Primary 1 : Secondary 1-3 : Tertiary 1-3-2
2-1-1	Primary 2	Secondary 2-1	Tertiary 2-1-1	Primary 2 : Secondary 2-1 : Tertiary 2-1-1
2-1-2	Primary 2	Secondary 2-1	Tertiary 2-1-2	Primary 2 : Secondary 2-1 : Tertiary 2-1-2
2-1-3	Primary 2	Secondary 2-1	Tertiary 2-1-3	Primary 2 : Secondary 2-1 : Tertiary 2-1-3
2-2-1	Primary 2	Secondary 2-2	Tertiary 2-2-1	Primary 2 : Secondary 2-2 : Tertiary 2-2-1
2-2-2	Primary 2	Secondary 2-2	Tertiary 2-2-2	Primary 2 : Secondary 2-2 : Tertiary 2-2-2
3-1-1	Primary 3	Secondary 3-1	Tertiary 3-1-1	Primary 3 : Secondary 3-1 : Tertiary 3-1-1
3-1-2	Primary 3	Secondary 3-1	Tertiary 3-1-2	Primary 3 : Secondary 3-1 : Tertiary 3-1-2
3-2-1	Primary 3	Secondary 3-2	Tertiary 3-2-1	Primary 3 : Secondary 3-2 : Tertiary 3-2-1
3-2-2	Primary 3	Secondary 3-2	Tertiary 3-2-2	Primary 3 : Secondary 3-2 : Tertiary 3-2-2
3-2-3	Primary 3	Secondary 3-2	Tertiary 3-2-3	Primary 3 : Secondary 3-2 : Tertiary 3-2-3

No.	Funding Risk Item	Likelihood (1-10)	Impact (1-10)	Risk Rating (Auto)	Owner	Remark
1	Primary 1 : Secondary 1-1 : Tertiary 1-1-1	8	7	56	Churlzu Lim	Federal to division managed
2	Primary 1 : Secondary 1-2 : Tertiary 1-2-1	9	3	27	Churlzu Lim	Uncertain federal funding availability
3	Primary 2 : Secondary 2-1 : Tertiary 2-1-1	4	2	8	Chad Bruton	Revision of contract

Figure 64 Risk Items Name Retrieval

B.2.6 Second Prototype: Other Modules

The 'Print' module activates the Excel print window, where the user can select a suitable printer. The Register is set up to print the entire contents of the Register into a single page (see Figure 65 for a preview).

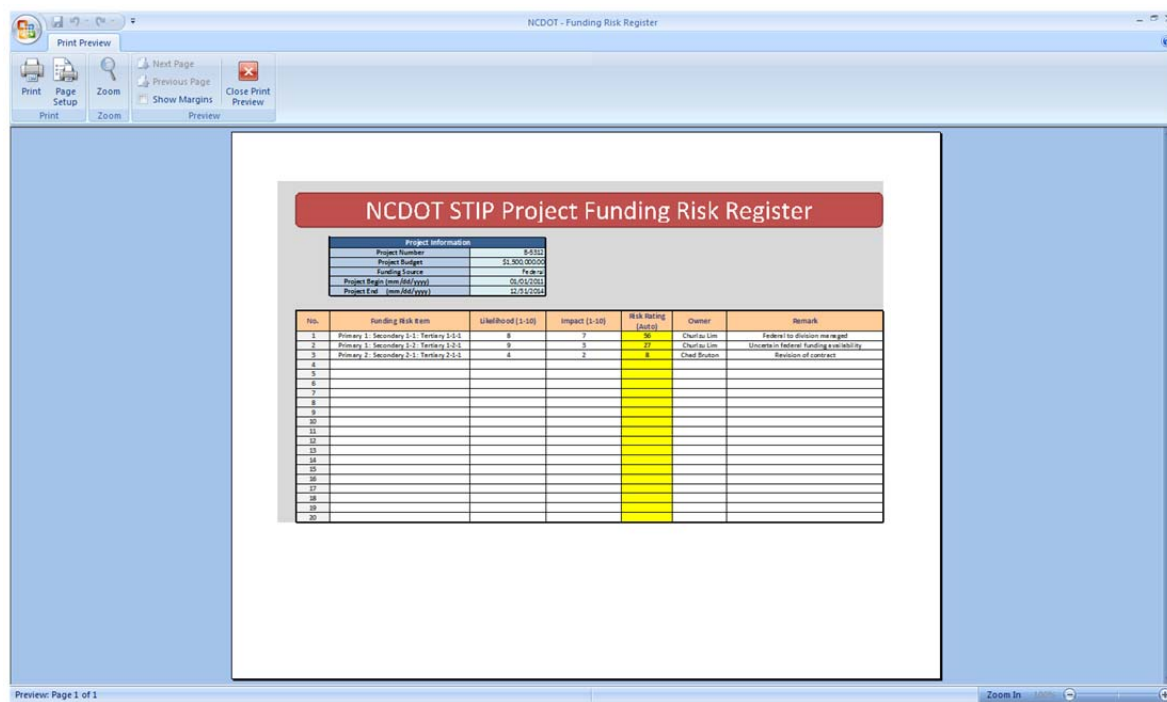


Figure 65 Preview of the Page Setup of the 'Print' Menu

Note that the second prototype has not incorporated an optimization routine. Our next step was to develop a valid optimization model that can provide the user an optimized portfolio of projects to be funded.

B.3 Model 1: Funding Project Portfolio Optimization

Funding for transportation projects comes from two major sources, the federal government and the state government. These funds are made available through the respective legislative bodies with restrictions which create numerous problems for transportation planners. In combination with the effects of smaller tax revenues, it makes the planners even harder to determine how to fund seemingly equal projects. Transportation planners are in need of a mechanism that will allow them to judge and rank projects on objective criteria, and then filter them through the maze of legislative restrictions on the use of funds. Noting this need, our initial effort for modeling an optimization problem was focused on finding the best portfolio of highway projects in North Carolina.

To develop a complete model for the highway project funding portfolio optimization problem, we commenced with a deterministic model that consists of a basic structure of problem parameters. In this base model, we seek a project funding portfolio that maximizes the sum of project utility scores. At the time when we developed the base model, NCDOT used a point allocation process to rank order projects, and this system required the conversion of numerous objective and subjective criteria into a constructed attribute scale. These scores are generated in a similar way to those in (Taplin & Qiu, 1995). We combined this data with the budgetary constraints to formulate the base deterministic model as presented in what follows. Before proceeding, we remark that NCDOT is currently revising the priority scoring method, and new scores will be available for all the future projects soon.

Objective Function

The objective function is the sum of utility scores of selected projects. The utility score of an individual project is determined by the sum of several scores, each of which is evaluated through separate means. In particular, a project utility score is determined by three categories; *quantitative*, *local input*, and *multimodal*. (We remark that the

formula described in this section was being implemented by NCDOT at the time we were developing Model 1, but NCDOT is in process of developing and testing a new scoring and distribution formula when this report is being drafted.)

Quantitative category includes scores for congestion, safety, pavement, benefit-to-cost, economic competitiveness, lane width, and shoulder width. Points are allocated according to formulas specific to each type of score. The following table illustrates some of the basic factors influencing these scores.

Table 18 Factors of the Scoring Method

Congestion	Volume/Capacity Ratio
Safety Score	Critical Crash Rates, Density
Pavement	Pavement Condition Rating
Benefit/Cost	Travel Time Savings / Project Cost
Economic Competitiveness	Value Added in \$
Lane Width	Existing Width vs. Standard Width
Shoulder Width	Existing Width vs. Standard Width

Local input score is determined by local planning organizations known as Municipal Planning Organizations (MPO) and Rural Planning Organizations (RPO). Each organization is given a certain number of points, and allowed to allocate them among projects using any methodology they choose. The North Carolina State also has 14 highway divisions (see Figure 66, Grzymiski, 2010) that also allocate points to projects. MPOs, RPOs, and divisions are allowed to gift points to one another so that they can push certain project scores higher if they have a vested interest in its completion.

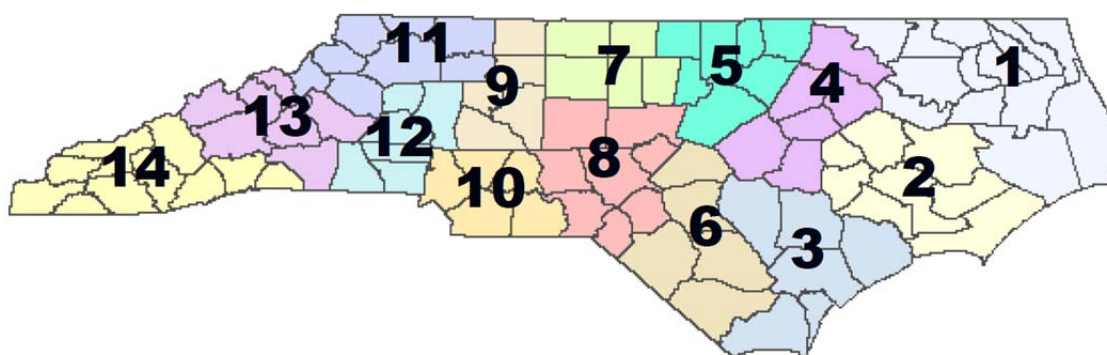


Figure 66 Fourteen Highway Divisions of North Carolina

Multimodal scores are bonus points awarded to projects that meet certain criteria. Projects that include high occupancy vehicle lanes, bus rapid transit lanes, or connect to light rail receive 8 extra points. Projects connecting to an airport, seaport, military base, or a park and ride lot receive 5 extra points. Projects which include bike lanes, sidewalks, bus pullouts, or bus shoulders receive 3 extra points. Bonus points are additive, meaning that a project with high occupancy vehicle (HOV) lanes connecting to an airport would receive 13 points.

The weight assigned to the quantitative scores and local input scores are determined by a set of guidelines developed through a combination of pair-wise comparisons and the Delphi technique. For the projects included in this study, the weights in Table 19 apply.

Table 19 Weights Assigned to Quantitative Scores and Local Input Scores

Score Type	Weight
Congestion	0.2
Benefit/Cost	0.2
Safety	0.1
Pavement Condition	0.1
Economic Competitiveness	0.1
Division Rank	0.2
MPO/RPO Rank	0.1

Mathematical Model

With the objective function defined and the constraint set provided above, we formulate a 0-1 integer programming problem that maximizes the total utility score. For mathematical formulation, we first define the following notation:

n = number of projects under consideration

$N = \{1, 2, \dots, n\}$

$N_k = \{j \in N: \text{project } j \text{ in region } k\}$

u_j = utility score of project $j = 1, 2, \dots, n$

c_j = cost of project $j = 1, 2, \dots, n$

F = total available fund

p_k = population estimate in region $k = 1, 2, \dots, 7$

p = population estimate in the state, i.e., $p = \sum_{k=1}^7 p_k$

r_k = remaining miles of intrastate highways in region $k = 1, 2, \dots, 7$

r = remaining miles of intrastate highways in the state, i.e., $r = \sum_{k=1}^7 r_k$

x_j = binary variable representing $x_j = 1$ if project j is selected; $x_j = 0$ otherwise.

With the notation above, the basic deterministic model is as follows:

$$\begin{array}{lll}
 \text{Minimize} & \sum_{j=1}^n u_j x_j & \text{(objective function)} \\
 \text{subject to} & \sum_{j=1}^n c_j x_j \leq F & \text{(budgetary constraint)} \\
 & \sum_{j \in N_k} c_j x_j \leq \left(\frac{0.5p_k}{p} + \frac{0.25r_k}{r} + \frac{0.25}{7} \right) F \quad \text{for } k = 1, 2, \dots, 7 & \text{(Equity Formula)} \\
 & x_j \in \{0, 1\} \text{ for } j \in N. &
 \end{array}$$

Seven Regions of North Carolina for applying Equity Formula are defined as pairs 14 divisions as depicted in **Error! Reference source not found.**Figure 67.

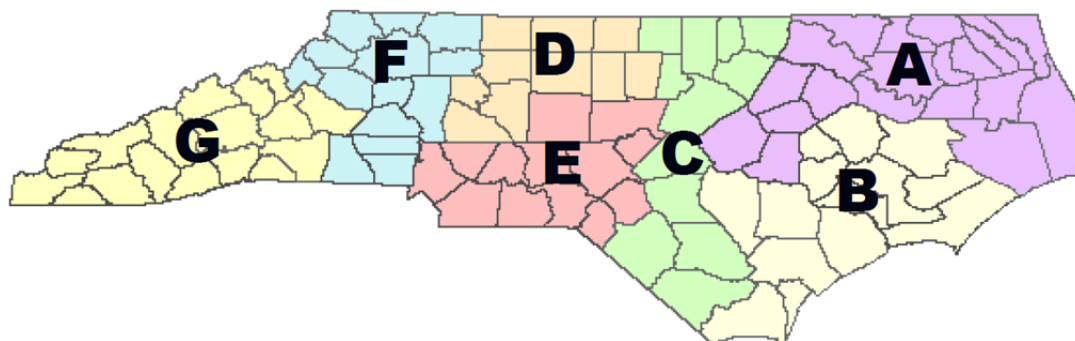


Figure 67 Seven Regions of North Carolina

B.4 Model 2: Initial Model for Let Scheduling

After developing the funding portfolio optimization model which can be applied to a long-term programming, the research team acquired more information about the cash flow management scheme of NCDOT. Being aware of the importance of maintaining healthy cash flow balances over time, our next modeling strategy was to develop an optimization model that finds the best let schedule. Before introducing this second model, we present a brief background first.

B.4.1 Background of Let Scheduling Model

Senate Bill 1005 (Appropriations Act of the General Assembly) passed in 2001 required NCDOT to implement a cash flow based finance management, which freed up large amounts of reserves of Highway Fund and Highway Trust Fund (Mills & Tasaico, 2005). While employing cash flow based finance management allowed NCDOT to utilize funds to the maximum extent for construction projects, this practice also increased the risk of overdraft as it maintains a relatively small amount of cash. As a part of establishing sound cash management, the target balance is set at 12% of estimated annual revenues (State Budget Act, 143C-6-11). Furthermore, NCDOT is required to maintain monthly cash balance at a level of least 5% of the unpaid balance of the total transportation project contract obligations.

Major sources of cash inflows consist of State Highway Fund, State Highway Trust Fund, and Federal Funds, where the first two revenues are supplied mostly from Motor Fuels Tax, Highway Use Tax, and DMV fees. Besides, additional State revenues are generated from toll revenues, annual payments from Highway Trust Fund, and GARVEE (Grant Anticipation Revenue Vehicle). These additional funds are dedicated to certain types of projects such as projects providing relief and increased mobility (Mobility Fund), or North Carolina Turnpike Authority (NCTA) projects. Cash outflows include State Transportation Improvement Program (STIP) projects, highway maintenance, NCTA project construction, bridge preservation, multi-modal programs, and other construction (see Figure 68 [excerpt from NCDOT, 2012]).

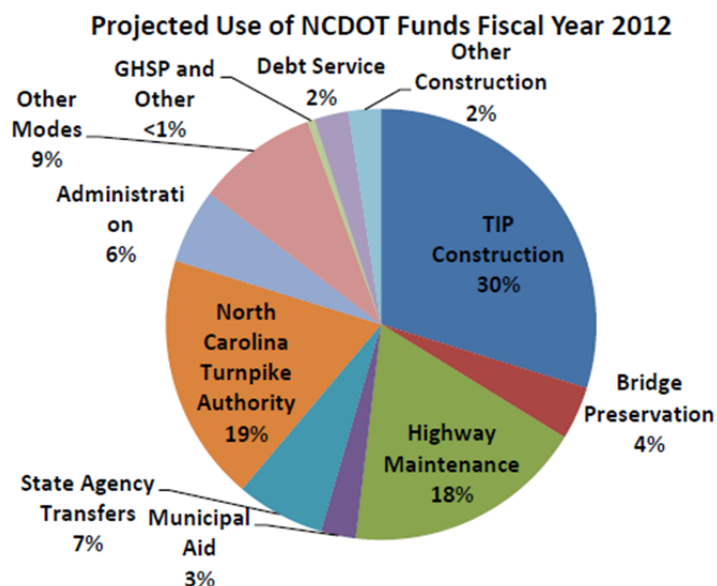


Figure 68 Example of Cash Outflows

The team noticed that it is important for NCDOT to forecast cash inflows and outflows with precision since decisions are made based on the estimated future cash flows. To this end, NCDOT has established and maintained solid forecasting models (Mills & Tasaico, 2005).

When forecasted cash flows indicate that overdraft or excessive cash balance is anticipated, NCDOT needs to take appropriate action to avoid depleting available funds or inefficient usage of funds, respectively. For example, NCDOT can delay lettings of certain construction projects in order to defer cash outflows for several months. Also, the pace of some projects can be accelerated to mitigate excessive cash balance. In what follows, we present the optimization model that we first developed to optimize the letting schedule to control anticipated overdraft.

B.4.2 Deterministic Optimization Model for Let Scheduling

Given forecast of cash inflows and outflows (except for construction expenditures of future lettings), consider a decision-making problem, where the schedule of lettings for the next N months is determined. While N can be any number of months, our intention is to provide a letting schedule for a 12 month period. Nonetheless, we will keep general planning horizon as N in our presentation.

To formulate this optimization model, we introduce the following notation:

Sets and Parameters:

- N = the number of months for lettings to be scheduled, indexed by i .
- K = the set of all possible new projects that can be let during the next N months, indexed by k .
- $p_{k,i}$ = penalty incurred when project k is let in month $i = 1, 2, \dots, N$.
- $p_{k,N+1}$ = penalty incurred when project k is not let within the planning horizon.
- CI_i = estimated cash inflows in month i .
- CO_i = estimated cash outflows except for construction expenditures incurred from future lettings in month i .
- CB_0 = initial cash balance.
- T_i = cash balance target in month i .
- F_i = cash balance floor in month i .
- A_k = expected amount of award for project k .
- ϵ_i = tolerance factor that specifies an acceptable range of cash balance in month i , i.e., $T_i \pm \epsilon_i T_i$.
- $r(a)$ = progress percentage to completion of a project when a project's age is a .
- $j(k)$ = month in which project k is ready to be let. $j(k) \in \{1, 2, \dots, N\}$

Decision Variables:

- $x_{k,i} = 1$ if project k is let in month i , and $x_{k,i} = 0$ otherwise, for $i = 1, 2, \dots, N$.
- $x_{k,N+1} = 1$ if project k is not scheduled within the planning horizon and $x_{k,N+1} = 0$ otherwise.
- $y_{k,i} = 1$ if new project k is active in month i , and $y_{k,i} = 0$ otherwise, for $i = 1, 2, \dots, N$.

Given the notation defined above, we can formulate an integer programming problem as follows. First, the total penalty over the next N months is given by

$$\sum_{k \in K} \sum_{i=j(k)}^{N+1} p_{k,i} x_{k,i},$$

where the inner summation is taken for those months that project k is available to be let, i.e., in or after month $j(k)$. Note that project k cannot be let more than once. Hence, we have the following constraint:

$$\sum_{i=j(k)}^{N+1} x_{k,i} = 1 \quad \text{for } \forall k \in K.$$

$x_{k,N+1} = 1$ implies that project k is not let within the planning horizon.

The cash balance in month $i = 1, 2, \dots, N$, is given by

$$CB_0 + \sum_{n=1}^i (CI_i - CO_i) - (\text{cumulative construction expenditures for new projects that are active in month } i).$$

Note that the cumulative construction expenditure of each project depends on its age and the amount of (expected) award. The age of project k in month i can be written as

$$\sum_{n=j(k)}^i y_{k,n}.$$

Hence, the cumulative construction expenditure of project k in month i becomes

$$A_k r \left(\sum_{n=j(k)}^i y_{k,i} \right).$$

Therefore, the cash balance in month i can be expressed as follows:

$$CB_0 + \sum_{n=1}^i (CI_i - CO_i) - \sum_{\{k \in K: j(k) \leq i\}} A_k r \left(\sum_{n=j(k)}^i y_{k,i} \right),$$

where the last summation over k represents the total cumulative construction expenditures for new projects that are active in month i . Note that the progress percentage to completion (i.e., $r(\cdot)$) in the summation includes a function of decision variables y_{\cdot} . We notice that, as investigated in Mills & Tasaico (2005), this function can be expressed as a nonlinear function, specifically, a quadratic or cubic function.

Since the cash balance is bounded below by cash flow, we have the following constraint:

$$CB_0 + \sum_{n=1}^i (CI_i - CO_i) - \sum_{\{k \in K: j(k) \leq i\}} A_k r \left(\sum_{n=j(k)}^i y_{k,i} \right) \leq F_i \quad \text{for } i = 1, 2, \dots, N.$$

Furthermore, since we desire that the cash balance remains in the acceptable range specified by ϵ_i , we have

$$CB_0 + \sum_{n=1}^i (CI_i - CO_i) - \sum_{\{k \in K: j(k) \leq i\}} A_k r \left(\sum_{n=j(k)}^i y_{k,i} \right) \geq T_i - \epsilon_i T_i \quad \text{for } i = 1, 2, \dots, N,$$

and

$$CB_0 + \sum_{n=1}^i (CI_i - CO_i) - \sum_{\{k \in K: j(k) \leq i\}} A_k r \left(\sum_{n=j(k)}^i y_{k,i} \right) \leq T_i + \epsilon_i T_i \quad \text{for } i = 1, 2, \dots, N.$$

Finally, the relationship between $x_{k,i}$ and $y_{k,i}$ can be prescribed as in the following constraints.

$$y_{k,i} \geq x_{k,i} \quad \text{for } i = j(k), j(k) + 1, \dots, N.$$

In summary, the integer programming model can be written as follows:

$$\begin{aligned} \text{Minimize} \quad & \sum_{k \in K} \sum_{i=j(k)}^{N+1} p_{k,i} x_{k,i} \\ \text{subject to} \quad & \sum_{i=j(k)}^{N+1} x_{k,i} = 1 \quad \text{for } \forall k \in K \\ & CB_0 + \sum_{n=1}^i (CI_i - CO_i) - \sum_{\{k \in K: j(k) \leq i\}} A_k r \left(\sum_{n=j(k)}^i y_{k,i} \right) \leq F_i \quad \text{for } i = 1, 2, \dots, N \\ & CB_0 + \sum_{n=1}^i (CI_i - CO_i) - \sum_{\{k \in K: j(k) \leq i\}} A_k r \left(\sum_{n=j(k)}^i y_{k,i} \right) \geq T_i - \epsilon_i T_i \quad \text{for } i = 1, 2, \dots, N \\ & CB_0 + \sum_{n=1}^i (CI_i - CO_i) - \sum_{\{k \in K: j(k) \leq i\}} A_k r \left(\sum_{n=j(k)}^i y_{k,i} \right) \leq T_i + \epsilon_i T_i \quad \text{for } i = 1, 2, \dots, N \\ & y_{k,i} \geq x_{k,i} \quad \text{for } i = j(k), j(k) + 1, \dots, N \\ & x_{k,i} \text{ is binary} \quad \text{for } i = j(k), j(k) + 1, \dots, N + 1 \\ & y_{k,i} \text{ is binary} \quad \text{for } i = j(k), j(k) + 1, \dots, N. \end{aligned}$$

Before closing this section, we also notice that the tolerance of the acceptable range for cash balances in the proposed formulation is time dependent (i.e., ϵ_i for $i = 1, 2, \dots, N$). The purpose of using a variable tolerance is to accommodate risks involved with the variability in forecasts of revenues and expenditures. For example, if the variability of expenditures in month i is relatively high, we need to impose a relatively strict tolerance when compared to the month in which the variability of cash flow estimates is low (i.e., has a lower chance of overdraft or inefficiency).

B.5 Funding Risk Register Version 0.5: Incorporation of Model 2

The funding risk register had been modified from the second prototype in order to improve the register's input process and to incorporate the let schedule optimization module (Model 2). We replaced the individual manual key-in input process with a module that imports a list of NCDOT projects by a single command. When importing the project data, the register also assigns default impact of delay in construction based on the imported priority scores. Besides the input module for project information, two other input modules have been added to import regional information and cash flow estimates in the planning horizon (12 months). These imported data are used to solve a portfolio optimization problem in letting schedule.

The funding risk register version 0.5 includes two important modules: *Run Optimization* and *Run Risk Analysis*. The former module exports a mixed integer programming formulation in Model 2 and executes an open-source optimization routine, called GLPK. Then, the latter module imports the optimal solution to assign likelihoods and ratings of funding risks in construction delays. In what follows, details of the modules in the funding risk register will be described in a way that a user can follow the steps to obtain solutions and funding risk ratings.

NCDOT STIP Project Funding Risk Register

Project Information	
Project ID	
Region	
Construction Cost	
Funding Source	
Priority Score	
Availability	
Duration (month)	

Buttons: Search Project, Update Risk, Clear All

No.	Funding Risk	Delay Period (month)	Impact (1-10)	Likelihood	Funding Risk Rating	Remark
1	Delay	1				
2		2				
3		3				
4		4				
5		5				
6		6				
7		7				
8		8				
9		9				
10		10				
11		11				
12		12 or more				

Figure 69 Screenshot of the Register Version 0.5

Version 0.5 Package

The funding risk register version 0.5 package consists of the files listed below:

funding risk register.xlsm	(main funding risk register)
glpsol.exe	(optimization execution file)
glpk_4_47_java.dll	(file associated with glpsol.exe)
glpk_4_47.dll	(file associated with glpsol.exe)
ProjectInfo.xlsx	(example file – project information)
RegionInfo.xlsx	(example file – regional information)
CashInfo.xlsx	(example file – cash flow data)
riskopt.bat	(batch file to execute optimization tool)

The funding risk register v.0.5 can be started by opening ‘funding risk register.xlsm’. Functions of the Register v.0.5 are described in what follows.

Import Project Data

The first step of funding risk analysis is to import the project data. The project data needs to be prepared in a separate excel file. (An example file named ‘ProjectInfo.xlsx’ is provided in the package.) This file contains basic information about projects that are considered to be let during the next 12-month period. While the file name can be arbitrarily chosen, the data needs to be input in a specific format as follows (see Figure 70).

- Column A (Project ID) – project id numbers (e.g., U-0001).
- Column B (Region) – region number of the project (1 – 7). This will be used to enforce Equity Formula.
- Column C (Construction Cost) – total estimated construction cost for completing the project. The total cost will be used to compute monthly expenditure using S-curve (logistic function)
- Column D (Funding Source) – SHF (State Highway Fund), SHTF (State Highway Trust Fund), Federal

- Column E (Priority Score) – score determined by the formula (max. 300). This value will be used to compute impact of delay.
- Column F (Availability) – month when the project is available for letting. Availability is indexed from 1 to 12 (e.g., if the user analyzes the 12-month funding risk from July 2012 to June 2013, and a project is available for letting in October 2012, availability is 4).
- Column G (Duration) – estimated construction duration in months (from letting to completion)
- Column H (Must) – value is 1 if the project “must” be let in the month when the project is available. For example, if Availability = 4 and Must = 1, then the project will be let in October 2012. This is to give the user flexibility to incorporate subjective information/decision.

Project ID	Region	Construction Cost	Funding Source	Priority Score	Availability	Duration	Must
B-0001	4	\$2,728,500	Federal	247	10	8	0
B-0002	3	\$5,350,500	Federal	109	6	12	0
B-0003	7	\$4,039,500	Federal	201	1	30	0
B-0004	5	\$2,391,000	SHF	220	2	27	0
B-0005	5	\$5,227,500	SHTF	112	10	18	0
B-0006	3	\$2,995,500	SHF	78	8	20	0
B-0007	4	\$453,000	Federal	188	6	8	0
B-0008	2	\$1,894,500	Federal	167	4	10	0
B-0009	4	\$6,082,500	Federal	228	6	42	0
B-0010	5	\$4,498,500	SHTF	88	1	16	0
I-0001	7	\$4,504,500	SHF	21	2	18	0
I-0002	1	\$6,297,000	SHF	198	9	8	0
I-0003	3	\$1,495,500	Federal	201	7	11	0
I-0004	4	\$6,412,500	Federal	78	2	25	1
I-0005	4	\$2,400,000	SHTF	297	3	12	0
I-0006	4	\$1,140,000	Federal	46	8	34	0
I-0007	2	\$829,500	SHTF	131	10	44	1
I-0008	2	\$6,901,500	SHF	40	7	7	0

Figure 70 Screenshot of the Example File 'ProjectInfo.xlsx'

To import the project data, click the 'Import Project Data' from the left side of the screen. Then, the risk register displays the file open dialogue (see Figure 71). Select the file that has the project information, and click 'Open' or press the Enter key.

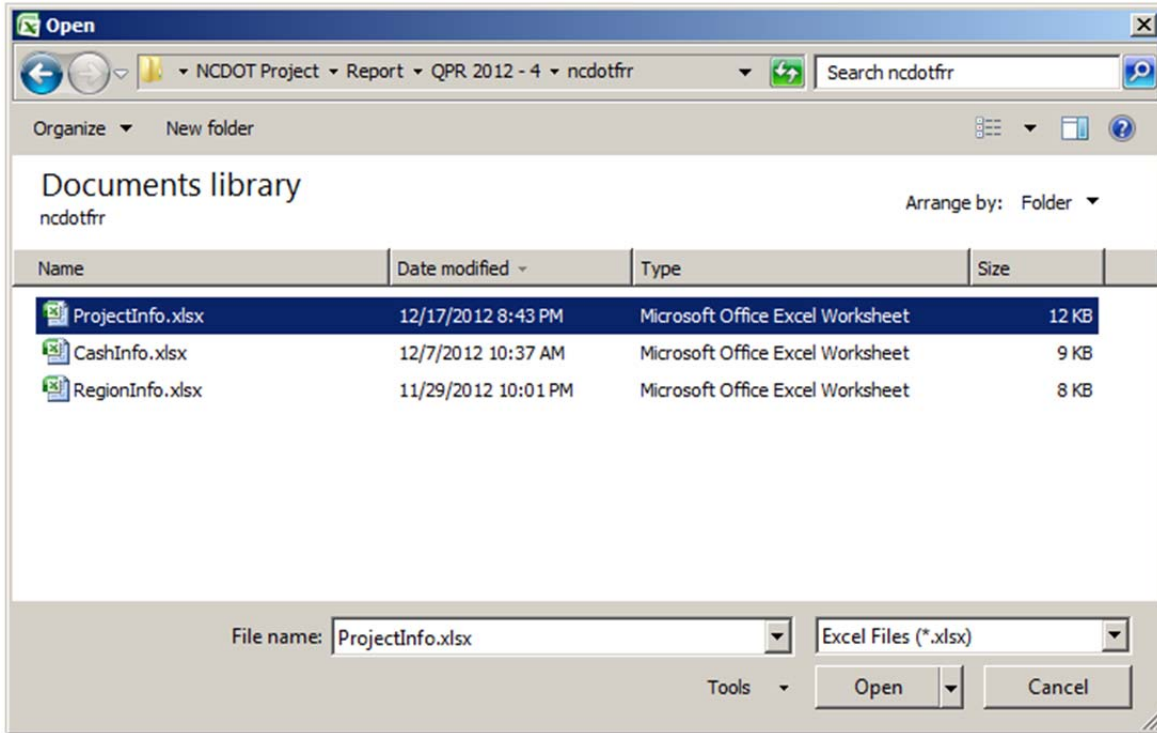


Figure 71 File Open Dialogue

The 'Import Project Data' module will open and copy the data into a worksheet named 'Project Information'. (Except for the main worksheet, all other worksheets in the funding risk register are hidden.) Furthermore, the module also generates initial risk impact and its likelihood, which are stored in a worksheet named 'Project Funding Risk'. The impact of risk is an integer value chosen from the range between 1 and 10. The larger the value is, the higher the impact is. We assume that the impact of delay is determined by the score assigned to the project and the delay period. In specific, the score of the project specifies the maximum impact, which is computed by

$$\left\lceil \frac{\text{score}}{300} \times 10 \times (\text{factor}) \right\rceil,$$

where $\lceil \cdot \rceil$ denotes the round-up operator. Note that, if construction of the project begins on time, then there is no impact. However, as the delay period increases, the impact becomes significant, and hence, the factor in the above equation is determined according to the following S-curve shown in Figure 72.

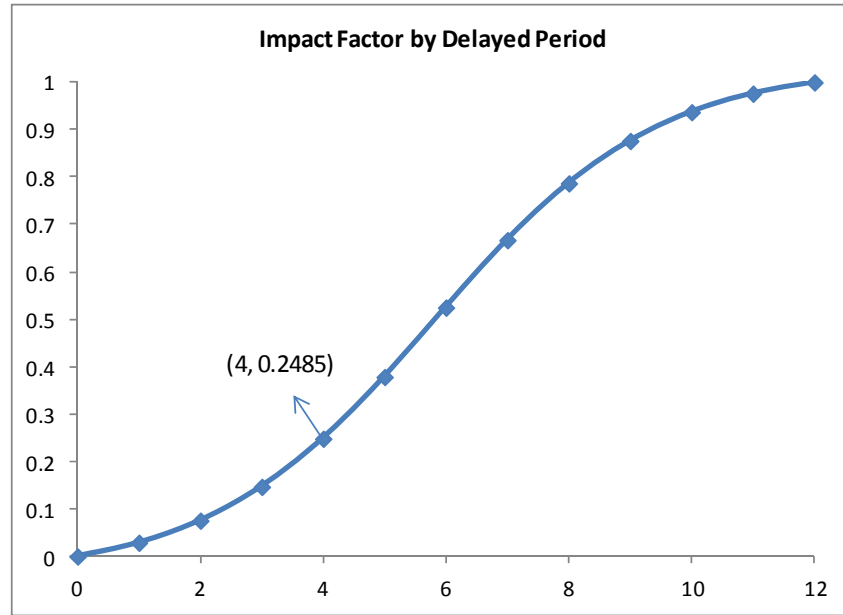


Figure 72 Impact Factor Determined by the Delay Period

For example, if the score of a project is 180 out of 300 and it is delayed by 4 months, then the maximum impact of delay on the project is $\left\lceil \frac{190}{300} \times 10 \times 0.2485 \right\rceil = \lceil 1.491 \rceil = 2$.

Once imported, the project information and initial funding risk can be viewed using the 'Search Project' command.

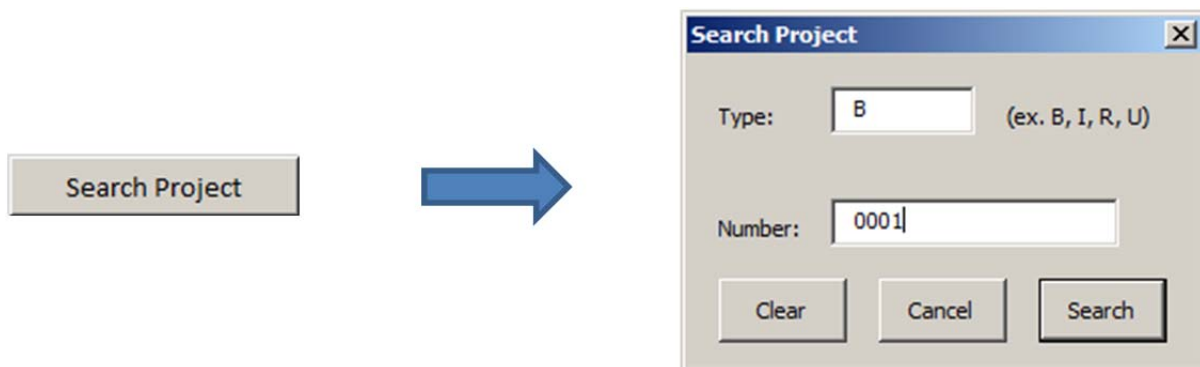


Figure 73 Illustration of Search Project Function

Upon entering a project ID that is composed of Type and Number, project information and initial risk values are displayed in the main screen as shown in Figure 73.

Project Information	
Project ID	B-0001
Region	4
Construction Cost	\$2,728,500
Funding Source	Federal
Priority Score	247
Availability	10
Duration (month)	8

Figure 74 Project Information Display

No.	Funding Risk	Delay Period (month)	Impact (1-10)	Likelihood	Funding Risk Rating	Remark
1	Delay	1	1	1	1	
2		2	1	1	1	
3		3	2	1	2	
4		4	3	1	3	
5		5	4	1	4	
6		6	5	1	5	
7		7	6	1	6	
8		8	7	1	7	
9		9	8	1	8	
10		10	8	1	8	
11		11	9	1	9	
12		12 or more	9	1	9	

Figure 75 Default Risk Impact and Likelihood

Be aware that the likelihood value is initialized as one, but it will be updated/modified to an appropriate value after running Run Risk Analysis module later. At this stage, it is assumed that all projects are commenced on time, hence the likelihood of delay is minimal.

Once the initial impact is generated and displayed as shown above in Figure 75, the user can employ subjective information regarding impact of delays, and modify impact and the likelihood values. Pressing 'Update Risk' button after changing these values, impact and the likelihood values are updated from the database.

Import Other Parameter Data

Similar to 'Import Project Data', two other commands, 'Import Regional Data' and 'Import Cash Flow Data', read information files about region and cash flow, respectively. Regional data consists of population and remaining miles to complete in each region in the following format:

- Column A (Region) – region numbers
- Column B (Population) – population size of the region
- Column C (remaining miles to complete) – remaining intrastate mileage of the region

This set of information is used to enforce Equity Formula, which specifies the distribution of funds to the seven regions.

Region	Population	Remaining Miles to Complete
1	1,000,000	800
2	1,900,000	1200
3	1,800,000	1600
4	1,500,000	700
5	950,000	600
6	1,300,000	1100
7	1,600,000	950

Figure 76 Screenshot of the Example File ‘RegionInfo.xlsx’

The risk register uses cash flow estimates to formulate constraints in the optimization model. Cash flow data contains five data fields for the next 12-month period as specified in the following list.

- Column A (Month) – month index (1, 2, ..., 12)
- Column B (Inflow) – estimated cash inflow of the month
- Column C (outflow) – estimated cash outflow of the month: this value does not include the new construction expenditure. For example, this outflow contains the estimated PE, ROW, and construction expenditures incurred from the “on-going” projects.
- Column D (Target) – target ending balance of the month
- Column E (Floor) – floor value of ending balance of the month (i.e., cash balance cannot be lower than this value)
- Column F (Tolerance) – this value specifies the tolerable difference between the target balance and the actual balance. For example, if the target value is \$11,638,560 and the tolerance of the month is 0.3, then we tolerate the ending balance that can be as low as $\$11,638,560 \times (1 - 0.3) = \$8,146,992$. Typically, for the near future, this can be relatively large because cash flow estimates are relatively close to the actual future flows. On the other hand, this tolerance can be small (i.e., tight to the target) to reflect the fact that cash flow estimates in the further future become more uncertain, and hence, the decision for later months need to be more conservative.

In addition, the current cash balance needs to be written in cell “G2” of the input file. Figure 77 displays an example of the input file.

Month	Inflow	Outflow	Target	Floor	Tolerance	Balance
0						11,000,000
1	6,032,800	4,024,000	11,638,560	4,849,400	0.50	
2	5,938,400	4,661,160	11,638,560	4,849,400	0.50	
3	7,541,600	4,876,080	11,638,560	4,849,400	0.50	
4	5,817,600	2,825,320	11,638,560	4,849,400	0.50	
5	7,336,000	3,778,560	11,638,560	4,849,400	0.30	
6	6,196,800	5,192,000	11,638,560	4,849,400	0.30	
7	6,716,000	2,584,400	11,638,560	4,849,400	0.30	
8	7,724,000	2,866,320	11,638,560	4,849,400	0.30	
9	5,807,200	3,822,560	11,638,560	4,849,400	0.20	
10	5,399,200	1,934,880	11,638,560	4,849,400	0.20	
11	7,584,800	4,068,000	11,638,560	4,849,400	0.20	
12	5,496,000	2,379,560	11,638,560	4,849,400	0.20	

Figure 77 Screenshot of the Example File ‘CashInfo.xlsx’

Run Optimization

After importing all data sets (and updating risk impact values and likelihood values if necessary), a portfolio optimization problem can be formulated and solved via the ‘Run Optimization’ command. When pressed, the Run Optimization module first creates a file named ‘riskopt.lp’ in the same directory, where all other files were extracted. This file is in a standard linear programming (LP) format with binary constraints as shown below:

Minimize	(Objective function)
Subject To	(Each project can be started once)
	(Cash balance equations)
	(Cash balance > Floor)
	(Cash balance > Tolerable Lower Bound)
	(Equity Formula constraints)
	(Hard constraints for projects to be commenced on time)
Binary	(Binary variables)
End	

In the problem, it is assumed that the monthly construction expenditure is computed based on the fraction of construction period and an S-curve (see Figure 78).

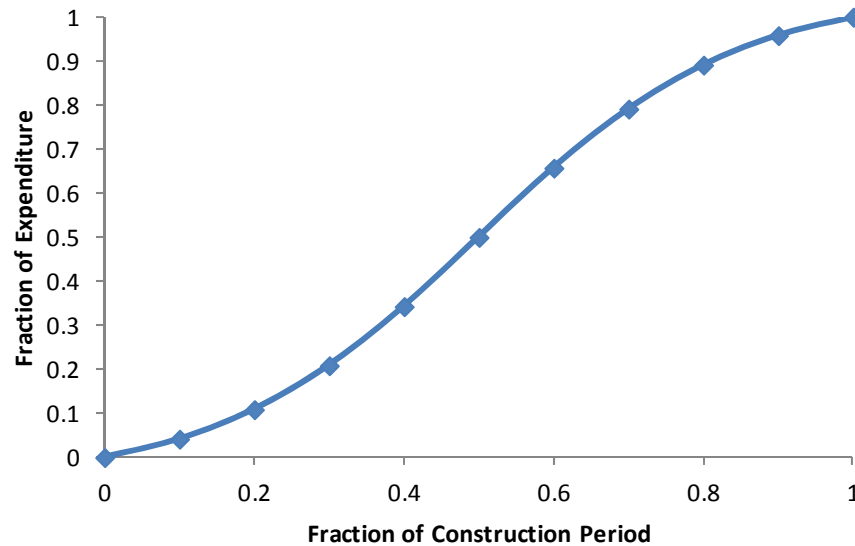


Figure 78 S-curve for Computing Construction Expenditure

Subsequently, the routine executes the open-source optimization tool, called GLPK, via a batch execution file having the following command lines:

```
glpsol.exe --lp riskopt.lp -w risksol.txt
```

PAUSE

'glpsol.exe' is the name of the execution file. '--lp' is a flag that specifies the input file type as the standard LP format. 'riskopt.lp' is the name of the input file, which was created earlier. '-w' is a flag that specifies the output file format. Finally, 'risksol.txt' is the name of the output file, where a solution is written. When successfully executed, the Windows command prompt will display the process of optimization.

Run Risk Analysis

After solving the portfolio optimization problem, the user can import the solution and assign the likelihood of delay by the 'Run Risk Analysis' command. This routine reads 'risksol.txt' and writes the solution into a worksheet named 'Letting Schedule' (again these worksheets are all hidden, but can be 'Unhide' to see contents). See Figure 79 for a partial screenshot of the worksheet, where one can see four constructions are delayed: B-0001 by 2 months, B-0009 by 2 months, B-0010 by 11 months, and I-0002 by 2 months.

Project ID	Availability	Schedule	Month	Ending Balance
B-0001	10	12	1	12840827
B-0002	6	6	2	13700224
B-0003	1	1	3	15852551
B-0004	2	2	4	18129989
B-0005	10	10	5	20794616
B-0006	8	8	6	20320177
B-0007	6	6	7	22378033
B-0008	4	4	8	24115299
B-0009	6	8	9	22167245
B-0010	1	12	10	20400819
I-0001	2	2	11	16931915
I-0002	9	11	12	11315927

Figure 79 Screenshot of “Letting Schedule”

At this stage, observe that the problem is solved with a single cash flow scenario. In the solution, therefore, a project is either delayed or commenced on time. If it is delayed, the likelihood of delay is modified to 10 (highest chance). For example, if the user searches B-0001 using ‘Search Project’, then one can see the likelihood of 2-month delay is now 10 (see Figure 80).

Project Information					
Project ID	B-0001	Search Project			
Region	4	Update Risk			
Construction Cost	\$2,728,500	Clear All			
Funding Source	Federal				
Priority Score	247				
Availability	10				
Duration (month)	8				

No.	Funding Risk	Delay Period (month)	Impact (1-10)	Likelihood	Funding Risk Rating
1	Delay	1	1	1	1
2		2	1	10	10
3		3	2	1	2
4		4	3	1	3
5		5	4	1	4
6		6	5	1	5
7		7	6	1	6
8		8	7	1	7
9		9	8	1	8
10		10	8	1	8
11		11	9	1	9
12		12 or more	9	1	9

Figure 80 Screenshot of risk information of B-0001 in the example

Additional Feature: In addition to the aforementioned functions and routines, the risk register is capable of creating a backup file whenever the file is saved or closed. The back file is named as 'backup on DATE.xlsm'.

B.6 Funding Risk Register Version 0.5: Further Enhancement

In the previous version of the Register, we considered a single cash-flow scenario, which is a most-likely scenario. Accordingly, we have a single let schedule that renders the highest likelihood rating (i.e., 10). The research team has further revised the Register by adding four more scenarios, where the revenue is decreased by 2%, 4%, 6%, and 8%, respectively. We assume that a small change in the cash revenue is more plausible than a large change. Hence, we assign likelihood ratings for these additional scenarios as in Table 20.

Table 20 Assignment of Likelihood Rating for Additional Scenarios

Revenue decreased by	2%	4%	6%	8%
Likelihood Rating	8	6	4	2

A major modification was made in 'Run Optimization' and 'Run Risk Analysis'.

Modification in 'Run Optimization'

If a user selects 'Run Optimization' after importing all three sets of data, the routine first generates five mixed integer programming problem files in LP format, being named as 'riskopt_ k .lp', where k is the percentage of revenue decrease (i.e., 0, 2, 4, 6 and 8). Once problem files are generated, each of five problems is sequentially solved by GLPK as instructed in a batch file 'riskopt.bat'. Then, solutions are recorded in five text files entitled as 'risksol_ k .txt', where k is again the percentage of revenue decrease.

Changes in 'Run Risk Analysis'

Once solution files are created, a user can execute 'Run Risk Analysis'. In this function, the register reads data from the five GLPK solution files, and writes five sets of letting schedules and expected cash balances into the worksheet named 'Letting Schedule' (Figure 81). These five sets of schedules, from left to right, correspond to 0%, 2%, 4%, 6% and 8% decrease in revenue, respectively. Therefore, if a project is delayed by X months in one of the schedules, its X month delay risk is assigned the corresponding likelihood as in Table 20.

Project ID	Availability	Schedule	Month	Ending Balance	Schedule	Month	Ending Balance	Schedule	Month	Ending Balance	Schedule	Month	Ending Balance	Schedule	Month	Ending Balance
B-0001	10	12	1	12840827	12	1	12720171	12	1	12654102	13	1	12478859	13	1	12358203
B-0002	6	6	2	13700224	6	2	13460800	6	2	13338572	6	2	12981952	7	2	12742528
B-0003	1	1	3	15852551	1	3	15462295	1	3	15206242	1	3	14681783	1	3	14291527
B-0004	2	2	4	18129989	2	4	17623381	2	4	17269956	2	4	16689521	2	4	16103557
B-0005	10	10	5	20794616	10	5	20096107	10	5	19662165	10	5	19040901	10	5	18181304
B-0006	8	8	6	20320177	8	6	19578267	8	6	19095105	8	6	18409118	8	6	17522002
B-0007	6	6	7	22378033	9	7	21571111	9	7	21099211	9	7	20283347	9	7	19320248
B-0008	4	4	8	24115299	4	8	23239309	4	8	22693472	7	8	21936859	4	8	20742312
B-0009	6	8	9	22167245	8	9	21244806	8	9	20585932	10	9	19889313	10	9	18694568
B-0010	1	12	10	20400819	8	10	19402573	8	10	18579531	13	10	17832544	8	10	17202162
I-0001	2	2	11	16931915	2	11	15650995	2	11	15047270	2	11	14503657	2	11	14332281
I-0002	9	11	12	11315927	11	12	9795003	11	12	9342293	12	12	9492755	12	12	9381825
I-0003	7	7			7			7			7			7		
I-0004	2	2			2			2			2			2		
I-0005	3	8			8			8			8			8		
I-0006	8	8			8			8			8			8		
I-0007	10	10			10			10			10			10		
I-0008	7	10			10			10			10			11		
I-0009	10	13			13			10			10			10		
I-0010	1	1			1			3			1			1		
R-0001	8	8			8			8			8			8		
R-0002	7	7			7			7			7			7		
R-0003	9	9			9			9			9			11		
R-0004	1	11			11			12			13			12		
R-0005	6	6			6			6			6			6		
R-0006	7	7			7			7			7			7		
R-0007	6	6			6			6			6			6		
R-0008	5	8			11			9			9			12		
R-0009	4	4			4			4			4			4		
R-0010	10	10			10			10			10			10		
U-0001	7	7			7			7			7			7		
U-0002	9	9			9			9			9			9		
U-0003	1	1			1			1			1			1		
U-0004	6	6			7			8			6			8		
U-0005	9	9			9			9			9			9		
U-0006	8	8			8			8			8			8		
U-0007	2	7			5			7			7			7		
U-0008	10	10			10			10			10			10		
U-0009	10	10			10			10			10			10		

Figure 81 Screenshot of the 'Letting Schedule' Worksheet in Version 0.5

For example, consider a project coded as B-0007 (see Figure 82). Under the most-likely scenario, B-0007 can be let without delay since it is available in Month 6 and scheduled in Month 6. However, if the revenue is decreased by 2%, the project is scheduled to be let in Month 9, which renders a 3-month delay. Then, the register assigns B-0007 a likelihood rating of 8 to the 3-month delay funding risk.

	A	B	C	D	E	F	G	H	I
1	Project ID	Availability	Schedule	Month	Ending Balance		Schedule	Month	Ending Balance
2	B-0001	10	12	1	12840827		12	1	12720171
3	B-0002	6	6	2	13700224		6	2	13460800
4	B-0003	1	1	3	15852551		1	3	15462295
5	B-0004	2	2	4	18129989		2	4	17623381
6	B-0005	10	10	5	20794616		10	5	20096107
7	B-0006	8	8	6	20320177		8	6	19578267
8	B-0007	6	6	7	22378033		9	7	21571111
9	B-0008	4	4	8	24115299		4	8	23239309
10	B-0009	6	8	9	22167245		8	9	21244806
11	B-0010	1	12	10	20400819		8	10	19402573
12	I-0001	2	2	11	16931915		2	11	15650995
13	I-0002	9	11	12	11315927		11	12	9795003
14	I-0003	7	7				7		

Figure 82 Example of Schedule Change under Different Revenue Scenarios

This assignment of likelihood can be verified by 'Search Project'. Figure 83 displays the search result for the project B-0007, for which likelihood of 3-month delay is updated to 8.

NCDOT STIP Project Funding Risk Register

Project Information	
Project ID	B-0007
Region	4
Construction Cost	\$453,000
Funding Source	Federal
Priority Score	188
Availability	6
Duration (month)	8

No.	Funding Risk	Delay Period (month)	Impact (1-10)	Likelihood	Funding Risk Rating	Remark
1	Delay	1	1	1	1	
2		2	1	1	1	
3		3	1	8	8	
4		4	2	1	2	
5		5	3	1	3	
6		6	4	1	4	
7		7	5	1	5	
8		8	5	1	5	
9		9	6	1	6	
10		10	6	1	6	
11		11	7	1	7	
12		12 or more	7	1	7	

Figure 83 Screenshot of Search Result for B-0007

Interpretation of Funding Risk Rating

Funding risk rating is the product of impact (1-10 scale) and likelihood (1-10 scale). Hence, its minimum and maximum values are 1 and 100, respectively. Note that the optimization model minimizes the overall impact of delays. Hence, even if the maximum value is 100, it is relatively rare to have a large value of funding risk rating. Among those 40 fictitious projects tested, only two projects (B-0010 and R-0004) display funding risk ratings larger than 10. B-0010 has a funding risk rating of 30 for 11-month delay, and R-0004 has a funding risk rating of 24 for 10-month delay. These two projects need to be monitored and further investigated to find appropriate actions to be taken.

B.7 Funding Risk Register Version 1.0

After circulating the version 0.5 of the Register among the steering committee members, the research team has modified it to ease the usage of the tool as the original version requires a set of comprehensive cash flow data. The newer version does not need forecasts for cash inflows and outflows, which must consider multiple sources of cash flows and forecasting models. Instead, version 1.0 considers construction expenditures that are incurred from projects to be let in the future. Figure 84 displays a screen shot of the main page of the current version.

B.8 Toward the Final Register Version 2

During the progress meeting held on May 14, 2013 at NCDOT, the research team presented the version 1.0 to the steering committee. The steering committee members provided quick helpful feedbacks regarding the shape of the construction payout curve and the impact of a let delay within/beyond the fiscal year. In a subsequent meeting with Mr. Frank Bowen and Ms. Laurie Smith, the research team received additional feedback regarding the time window of monitoring cash flows and the importance of large-scale projects, called ‘Whales’ in relation to their impact on cash flows.

Mr. Bowen, Ms. Smith, Dr. Majed Al-Ghandour, and the research team had a meeting on May 31 at NCDOT to discuss the current practice of forecasting construction expenditures and the need of forecasting the individual payout curve, especially for ‘Whale’ projects. During the meeting, the research team also demonstrated the current version of the funding risk register, and received additional feedback regarding the target cash balance.

After some initial sets of data were provided by Mr. Bowen, he and the research team had another meeting on June 12, 2013 at UNC Charlotte to discuss more in details about the HiCAMS forecasting process and the development of the individual payout curve. Subsequently, Mr. Bowen provided the research team a set of raw data along with the lists of Design Build, GARVEE, and ARRA projects, which were recommended to be excluded from further analysis.

Based on the feedback and discussion, the final version of the Register incorporated the following features.

Forecasting Individual Payout Curve

While HiCAMS is equipped with a forecasting routine for the aggregate monthly construction expenditure, it is essential to forecast the individual payout curve for those that are programmed to be let in the future, so that the funding risk register can identify the impact of an individual schedule change. A simple flat payout curve can be used as an approximation, but the predictability can be improved by a more sophisticated model. The research team developed a statistical model that can provide a robust estimation of the payout curve, which is presented in Chapter 5.

Inclusion of Only Large-Scale Projects

Around 20% of projects can be classified as ‘Whales’, construction costs of which are estimated to be higher than \$10 million. Noting that delaying a single Whale project can make a great impact on the cash balance in the future, the research team was advised to focus on large-scale projects. Hence, the final version of the Register considers only Whales.

Incorporation of Project Delivery Rate as a Performance Measure

During the progress meeting on May 14, it was noted that delaying lets to the next fiscal year is a great concern since it decreases the on-time project delivery rate. In the final version of the Register, we modified the objective function to reflect the penalty on the delay depending on the month when the federal and state fiscal year changes.

Extension of Time Window

It was also noted that the cash balance in the near future is less important than the cash balance in the further future. To accommodate this concern, the time window for monitoring cash flows has been extended from 12 months to 36 months (3 years). Furthermore, it was recommended to use a constraint on cash balance at the end of the time window instead of the cash balance of entire 36 months. This process allows cash balances to deviate from the target balance during the 3-year time window, but enforces the cash balance to come back to the healthy level at the end of the window.

Precise Estimation of Lead Time

In version 1.0, the Register used one-month lead time between let and construction. During the progress meeting, it was recommended to use three-month lead time instead. However, after analyzing the raw data provided by Mr. Bowen, we concluded the one month lead time is adequate as the statistic shows a 45-day lead time on average. Noting that the let dates are schedule on the first day of the month, it is reasonable to assume that the first construction cost is incurred at the end of the following month.