RESEARCH & DEVELOPMENT

Expanding the NCDOT's Current Risk Management Program

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16. Abstract

Enhancing the risk management program within the North Carolina Department of Transportation (NCDOT) is the focus of this collaborative research project with North Carolina State University (NCSU). The objective is to provide valuable insights and best practices to strengthen the NCDOT's Value Management Office (VMO) and implement an effective risk management program. By conducting a thorough literature review of efforts by other pioneering state DOTs and evaluating the existing NCDOT risk management program, areas for improvement have been identified. This project aims to develop tools, guidelines, and procedures to enhance the current risk assessment program, particularly within the Integrated Project Delivery process. Data obtained from the NCDOT's VMO were analyzed to identify major risks across different project types and identify effective risk mitigation strategies. This project involves two separate studies to develop a risk insights tools and risk management playbook to bolster the NCDOT's risk management program. Through the collaboration of NCSU and the NCDOT, this project aims to contribute to the continual improvement of risk management practices in the transportation sector, thereby promoting project success.

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EXECUTIVE SUMMARY

The effective implementation of risk management practices is acknowledged by state departments of transportation (DOTs) to achieve favorable outcomes for transportation projects. Many state DOTs have developed various tools to assist project managers in their risk management efforts. In line with this work, the North Carolina Department of Transportation (NCDOT) has initiated a collaborative effort through its Value Management Office (VMO) with North Carolina State University (NCSU) to identify opportunities for enhancing the NCDOT's existing risk management program. Consequently, NCSU researchers conducted a comprehensive examination of the NCDOT's program and those of other DOTs, which led to identified areas for suggested improvements. This report discusses two separate studies conducted by the NCSU research team that aim to address the identified areas for enhancement within the NCDOT's risk management practices.

Among the various steps in the risk management process, risk identification is clearly one of the most critical steps, if not the most critical. Although utilizing past project data to improve risk identification in future endeavors has potential benefits, comprehensive analyses that use actual project data are currently lacking. To address this gap, the first study, Study I, incorporates the thorough analysis of almost 3,800 past project claims and supplementary agreements obtained from the NCDOT. These data encompass a diverse range of thirteen distinct project types. The primary objective of this analysis is to determine the underlying factors of project problems and significant risks encountered during projects while also assessing the impacts of such problems and risks in terms of cost and schedule. Building upon the findings of the data analysis, Study I culminates in the development of the NCDOT Risk Insights Tool, an Excel-based resource that is tailored to risk insights that are specific to various transportation project types. This tool can serve as a valuable asset for project managers, equipping them with enhanced capabilities to identify and address risks more effectively in future projects. The Risk Insights Tool is designed to enhance the overall effectiveness of risk management practices within the NCDOT, with potential applicability for other state DOTs as well.

The second study, Study II, aims to address another area for improvement in the NCDOT’s current risk management program by creating a new tool that facilitates the identification and mitigation of potential risks associated with transportation projects. This work was accomplished by conducting a thorough literature review, interviewing NCDOT staff, and examining prior project claims and supplementary agreements. This study’s results reveal common risks and effective mitigation strategies for six crucial transportation project areas. The key outcome of Study II is the NCDOT Risk Management Playbook. This comprehensive tool offers project managers a structured approach to identifying and mitigating potential risks, thus leading to better risk management outcomes and, overall, a more effective program.

Further research can explore the efficacy of both the NCDOT Risk Insights Tool and Risk Management Playbook in real-world transportation projects, develop more automated and intuitive risk management tools, and expand the Playbook's categories to encompass additional risks.

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1 INTRODUCTION

The construction industry plays an integral role in infrastructure development and societal progress, making it a primary sector for governments to allocate significant financial resources [1] [2]. As of March 2023, the United States Census Bureau Monthly Construction Report reported a seasonally adjusted value of $399.6 billion for construction in the public construction sector [1]. Yet, construction projects rarely meet their allocated budget and timelines because they are continuously confronted with risks [3]. Given the multitude of challenges that departments of transportation (DOTs) face, implementing a formal approach to risk management is the most effective method to identify numerous potential risk events, systematically analyze those risks, and understand their interrelationships that ultimately highlight the most critical risks [4]. Therefore, the process of risk management entails the identification and analysis of potential risks, followed by the determination of suitable responses [5] [6]. This approach allows the project team to gain control over uncertainties and adopt a proactive stance rather than reacting to problems as they arise. Brainstorming, case-based approaches, and checklists are among the commonly employed tools and techniques for risk management, especially during the risk identification and response steps [7] [8].

This report describes a project that is part of a collaborative effort by the Value Management Office (VMO) of the North Carolina Department of Transportation (NCDOT) and North Carolina State University (NCSU) to enhance the NCDOT's current risk management program. To achieve this goal, NCSU researchers took four main steps: (1) reviewed the current risk management practices employed by the NCDOT, (2) investigated risk management programs implemented by other state DOTs to glean valuable insights and best practices, (3) analyzed generic and specific causes of NCDOT project claims and supplementary agreements, and (4) developed strategies for mitigating the most common risks. By studying the practices of both the NCDOT and other DOTs, the NCSU research team identified areas of improvement and developed a foundation for enhancing the NCDOT's risk management program.

Most transportation agencies, including the NCDOT, adhere to the Project Management Body of Knowledge (PMBOK) guidelines for risk management procedures. Nonetheless, the effectiveness of the risk management programs at different DOTs varies. Although some state DOTs, such as the Washington DOT (WSDOT) and the California State Transportation Agency (Caltrans), have developed robust risk management programs, others, including the NCDOT, have risk management programs that are still maturing and can be enhanced over time. The primary reason for this variation in the level of maturity is two-fold. First, WSDOT and Caltrans already have formal risk management procedures in place and employ various practices that include risk management policies, risk management guidelines, qualitative analysis, quantitative analysis, tools for quantitative analysis, and risk lists [9]. Based on project cost, WSDOT and Caltrans have established different levels of formality for their risk management practices whereby higher estimated project costs necessitate a more formal and thorough risk management approach than projects with lower costs [10] [11]. The second reason for discrepancies in risk management effectiveness is that these two pioneering DOTs, WSDOT and Caltrans, have developed numerous tools for each step of the risk management process [9] whereas the NCDOT's primary tool currently is the Risk Assessment Worksheet (RAW), an Excel file that contains a risk register, a risk list with examples, and a risk matrix for qualitative risk assessment [12]. WSDOT and Caltrans have developed more comprehensive tools for each activity covered by the RAW. For example, WSDOT has a Risk Breakdown Structure (RBS) (see Appendix A) that serves as a detailed risk

list and provides separate tools for qualitative and quantitative analyses [10]. WSDOT's RBS includes predefined Level One and Level Two risks, whereas the NCDOT provides only risk categories and examples that project managers may add or remove. Also, the NCDOT has opted not to use Monte Carlo simulations to quantify the impact of identified risks, except when required on large federally funded projects [9] [13].

To summarize, although the NCDOT has made notable progress in establishing a more formalized risk management program, the program's effectiveness currently relies heavily on the expertise of project managers and team members during the risk management process. More comprehensive checklists and tools need to be designed and in place to ensure the process does not overlook critical factors. Developing a formal framework for the NCDOT's risk management program requires significant expertise, and the NCDOT is currently creating procedures to capitalize on such expertise. Therefore, the work described in this report focuses solely on the creation of tools that can be used to identify both project-related risks and appropriate risk mitigation strategies.

1.1 Research Objectives and Methodology Overview

This report results from a research project conducted by NCSU researchers (the authors of this report) for the NCDOT's VMO to improve and enhance the NCDOT's current risk assessment program. The project's main objective is to assist the VMO in developing a more robust risk management program as part of the NCDOT's new Integrated Project Delivery process. This work involves the development of new tools, guidelines, and procedures for implementing this novel risk management program. The two primary goals of this project are achieved through two separate studies, Study I and Study II.

The first goal of this project, achieved through Study I, is to provide risk management insights that can help project managers identify risks and populate the risk register. Project managers will gain insights into the risk assessment process by having access to information about the impacts of past claims and supplementary agreements. The methodology needed to achieve this first goal is content analysis of claims and supplementary agreement data supplied by the NCDOT. This work resulted in the NCDOT Risk Insights Tool.

The second goal of this project, achieved through Study II, is to address the identified shortcomings in the current risk identification and response processes. To this end, the aim is to provide project managers with a risk list and mitigation strategies that are determined based on a thorough literature review and interviews with subject matter experts at the NCDOT. This work resulted in the NCDOT Risk Playbook, a tool for project managers to use for risk identification and response processes that are inherent of the risk management program.

1.2 Report Format

This report contains an introductory Chapter 1, two studies presented respectively in Chapters 2 and 3, and Chapter 4 that presents conclusions and future research. Chapter 2 discusses Study I that describes the development of the NCDOT Risk Insights Tool and Chapter 3 discusses Study II that describes the development of the NCDOT Risk Management Playbook. These two studies described respectively in Chapter 2 and 3 each present their own set of background information, methodology, results, discussion and future work, and conclusion.

2 STUDY I: DEVELOPMENT OF RISK INSIGHTS TOOL BASED ON PAST PROJECT CLAIMS AND SUPPLEMENTARY AGREEMENTS

The idea that a construction project can be entirely risk-free is a fallacy [14]. The intricate, one-of-a-kind nature of construction projects makes it nearly impossible to predict every possible scenario during the scope development phase [15]. Risk management is widely regarded as a crucial aspect of project delivery [7]. Proper risk management practices can significantly enhance the likelihood of achieving desired project outcomes within the project scope, cost, schedule, and quality constraints [16] [17]. The risk management process involves identifying and analyzing potential risks and determining appropriate responses [18]. Many studies indicate that the identification step of the risk management process is considered the most crucial step [19] [20]. Brainstorming, case-based approaches, and checklists are the most frequently employed tools and techniques to improve risk identification [7] [8]. Previous project data and lessons learned also can serve as a foundation for risk identification [13] [9].

The NCDOT is responsible for planning, constructing, and maintaining transportation projects within the state. Like other state transportation departments and agencies, the NCDOT recognizes the importance of implementing effective risk management practices and is currently developing a more formalized risk management program. As part of a larger project aimed at improving the current risk management practices at the NCDOT, in this Study I, the NCSU research team analyzed past project claims and supplementary agreements to gain insights into the causes and impacts of common transportation risks. The results of this analysis will serve as a valuable risk insights tool for the NCDOT in identifying and analyzing potential risks in future projects.

2.1 Background

According to the U.S. Federal Highway Administration (FHWA), “project risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on at least one project objective” [6]. Transportation projects, given their complexity, are susceptible to a plethora of risks that can result in claims, change orders, and/or supplementary agreements, ultimately leading to cost and schedule overruns [21] [22]. According to a study conducted by Alleman et al. in 2020, the existing literature on highway construction in the United States indicates that transportation agencies across the country encounter change orders that total around $4 billion annually [22]. Many state DOTs implement risk management practices to mitigate these risks.

The first step in the systematic risk management process is risk identification [5] [6]. The output of this step is the project Risk Register in which project managers record the risks that may affect the project's ability to achieve its objectives [12]. Many researchers acknowledge that the identification step of the risk management process is the most critical [19] [20]. To enhance the efficiency of the risk identification process, several state DOTs utilize various techniques in conjunction with the expertise of subject matter specialists. Among the tools and techniques commonly utilized in risk identification are brainstorming, case-based approaches, and checklists [7] [8]. In order to streamline the identification of risks, the FHWA’s risk guide proposes categorizing risks into groups of similar types, thereby minimizing duplication and simplifying their management [6]. Several studies have been conducted to develop categorization schemes for more effective risk identification. Some studies have reviewed construction literature and

identified common risk factors in different categories [23] [24]. Others have focused primarily on risks specific to transportation projects [25] [26]. State DOTs, like other large public organizations, also have developed risk lists or a risk breakdown structure (RBS) to categorize risks.

However, despite the importance of identifying risks, not all state DOTs have developed formalized tools and procedures like WSDOT's RBS and/or formal workshops. The NCDOT, for instance, relies heavily on the expertise of subject matter experts, such as project managers, for risk identification. Recognizing the need for improvement in this area, Jaselskis and Leca sought to identify best practices that the NCDOT could adopt and interviewed personnel from two pioneering DOTs, WSDOT and Caltrans [31]. Among the suggested practices put forth by WSDOT and Caltrans, one was to gather insights from past risk registers, claims, change orders, and other relevant sources such as supplementary agreements [27]. By analyzing past project records, valuable information can be gleaned to enhance the risk identification process.

Dicks and Molenaar [32] focused their analysis on risk statements derived from the risk registers of 51 major WSDOT projects. Their study aimed to better understand the risks encountered by the department by utilizing WSDOT's RBS (see Appendix A) as a framework for analysis. The findings of their study provide valuable insights into the nature of the risks faced by WSDOT [28]. However, the Dicks and Molenaar study had certain limitations. It concentrated solely on the risk statements captured during WSDOT's risk identification workshops, which excluded an in-depth examination of the specific content contained within the claims and supplementary agreements that directly impacted project budgets and schedules. Hence, the Dicks and Molenaar study did not encompass a comprehensive assessment of the actual impacts of the identified risks. Also, not all risk statements captured in the risk register resulted in claims or supplementary agreements, emphasizing the need for more comprehensive analysis.

In summary, previous studies primarily have either reviewed existing literature or utilized survey-based approaches to develop general lists of risks and evaluate their impacts on hypothetical projects. Even when incorporating actual project data, these studies have not assessed the data obtained from claims or supplementary agreements [28]. By contrast, this Study I aims to bridge this gap by comprehensively analyzing more than three decades of data from actual NCDOT projects by examining past claims and supplementary agreements specifically.

2.2 Methodology

This Study I aims to examine the NCDOT's past project data to determine the fundamental causes of claims and supplementary agreements in transportation projects and subsequently create a risk profile for the causes identified while also assessing the impacts of the identified risks or problems. These risk insights will provide valuable assistance to project managers in future risk management endeavors by facilitating a deeper understanding of areas of common risks.

In the construction industry, a claim is a formal assertion made by one party, which is often a contractor or subcontractor, against another party to seek compensation for damages, delays, or other issues. A claim typically arises when there is a perceived breach of contract terms or disagreement regarding the interpretation or fulfillment of contractual obligations. The NCDOT's HiCAMS User Guide outlines specific situations and circumstances in which contractors can submit claims for additional compensation or contract time extensions. Table 2.1, which is taken from the HiCAMS User Guide [29], provides a comprehensive overview of such situations and circumstances.

Table 2.1: Circumstances that Allow Contractors to Submit Claims [29]

Claim Category	Reason
Compensation	Altered Work
Compensation	Suspension or Alleged Suspension
Compensation	Contract Quantities Overrun/Underrun
Compensation	Elimination of Contract Line Item
Compensation	Extra Work
Compensation	Contract Termination
Time Extension	Delays or Supplemental Agreements
Time Extension	Additional Work, Quantities Overrun/Underrun, or Supplemental Agreements

A supplementary agreement, according to the NCDOT website [30], is a contractual arrangement between the Department and the Contractor that is established during the execution phase of a transportation project. The primary objective of a supplementary agreement is to facilitate essential amendments to the existing contract to ensure the satisfactory completion of the proposed project. These modifications encompass a range of adjustments, including alterations to work requirements, unit prices of existing contract items, including new work items, and contract timelines, etc.

This study forms a crucial part of a larger project that aims to enhance the existing risk management program at the NCDOT by exploring alternative approaches. As part of this main project, the NCSU research team analyzed cost data from previous transportation projects, which yielded noteworthy findings, including those presented in Figure 2.1. The bar graphs are categorized by project type and show the proportions of projects that exceeded actual costs by more than 4% of the bid amount [31]. The results from the analysis suggest that project type may play a significant role in cost overruns, which indicates the importance of considering project type as a critical variable in risk management efforts. Building upon this finding, Study I delves deeper by examining the underlying causes of claims and supplementary agreements, focusing on categorizing them by project type [32].

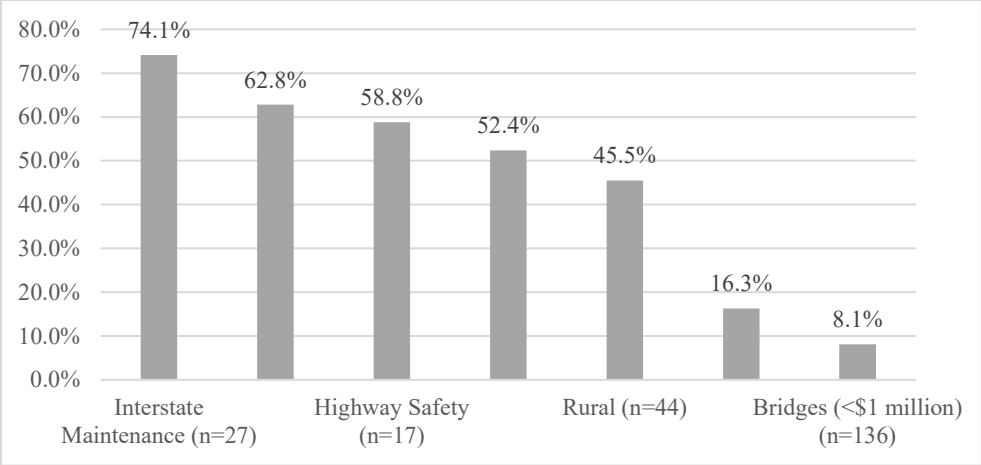

Figure 2.1: Projects that exceed actual costs by more than 4% of bid amount, categorized by project type.

To identify the root causes of problems, the research team performed content analysis using data for past project claims and supplementary agreements obtained from the NCDOT. The analysis was carried out by categorizing the data based on project type, identifying causes of problems, and assessing the impact of each identified cause. Figure 2.2 presents an overview of the steps taken to perform this analysis. This flowchart depicts the methodology used for this study, except for the data preparation stage that involved cleaning the data to ensure its suitability for analysis. Following data cleaning, the subsequent steps involved content analysis to obtain the results and refining the findings by grouping similar causes of identified problems to obtain the final outcomes.

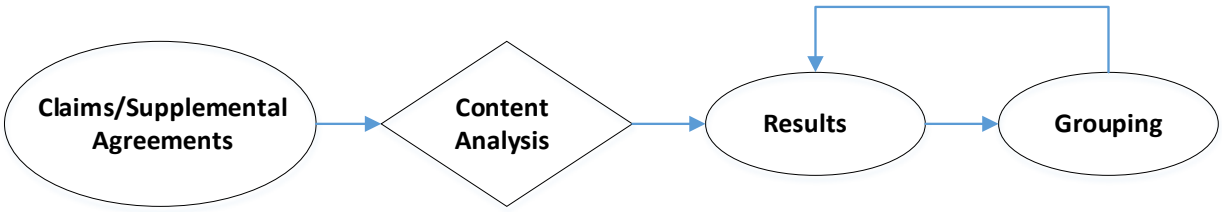

Figure 2.2: Overview of steps taken for analysis of NCDOT claims and supplemental agreement data.

The remainder of Section 2.2 provides a comprehensive overview of the datasets supplied by the NCDOT to the NCSU research team and elaborates on the four steps taken to obtain the final results.

2.2.1 Data Overview

This study employed three datasets supplied by the NCDOT that were extracted from the HiCAMS database. HiCAMS is a comprehensive record-keeping platform for contract administration, materials tracking, and payment disbursement to contractors, as specified in the NCDOT HiCAMS User Guide [33]. The datasets supplied by the NCDOT for the analytical phase

of this study encompassed claims data, supplementary agreement data, and contract data, described briefly as follows. Note that Study I is focused on claims and supplementary agreement data, and the contract data were used only to help identify the project types that were relevant to the claims and supplementary agreement data.

Claims data: The claims data extracted from HiCAMS is accessible in Excel format and encompasses 13,085 claims associated with NCDOT past projects that date from 1993 and extend to 2021. The dataset comprises 40 columns, providing diverse information about each claim, including contract numbers, claim descriptions, and requested and granted time and compensation amounts. The compensation granted for the claims ranges from $50 to $36.1 million, and the granted time ranges from 1 to 999 days.

Supplementary agreements data: The supplementary agreements data extracted from HiCAMS is accessible in Excel format and comprises 228,829 past project supplementary agreements, extending from 1998 to 2022. This dataset comprises 14 columns that offer diverse information associated with each agreement, including contract numbers, descriptions, and compensation amounts. In contrast to the claims data, details regarding the number of days granted for supplementary agreements were unavailable. The only information about granted time is presented in a column that provides a Yes/No response but does not include the specific number of days. The granted compensation for supplementary agreements ranges from -$8.8 million to $186.3 million. To clarify, a negative sign in the supplementary agreement compensation column indicates that the NCDOT received credit rather than making a payment to the contractor.

Contract data: This dataset contains various information related to NCDOT projects, including contract numbers, Transportation Improvement Program (TIP) numbers, and contract bid amounts, covering the period from 1975 to 2022. The primary reason for using this dataset was to extract project types based on the TIP and contract numbers.

2.2.2 Clean data

Prior to conducting data analysis, the dataset must be preprocessed and filtered to ensure optimal outcomes. The following paragraphs describe the procedures to clean the claims and supplementary agreements data, thus making them suitable for the subsequent steps. The first step involves identifying the project type, as the analysis of the claims and supplemental agreements is based on project type. The NCSU research team used the contract identification designations found in the contract dataset to identify the project type for each claim or supplemental agreement. Specifically, the team used the contract data extracted from HiCAMS to determine the TIP designations assigned by the NCDOT to all projects. The team then used these TIP designations to identify the project type based on the first one or two letters, as per the guidelines outlined in the NCDOT State Transportation Improvement Program (STIP) document [34]. Figure 2.3 is taken from the STIP document and provides keys for identifying different project types based on their corresponding TIP designations [34].

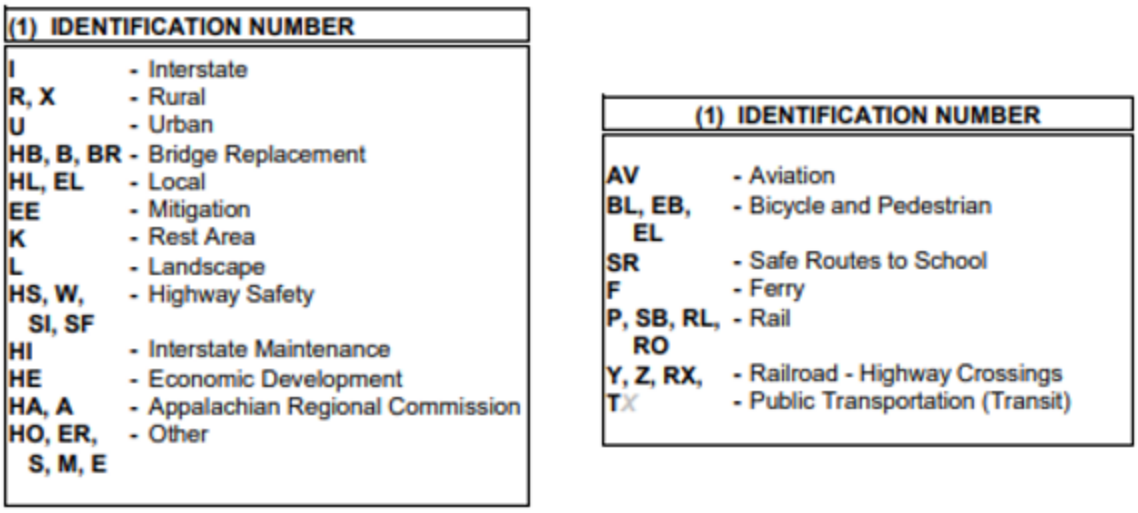

Figure 2.3: NCDOT State Transportation Improvement Program Designation Identifications [34].

Cleaning claims data: The initial step in cleaning the claims data is to identify the project type based on the TIP designations and removing cases without an associated project type. Next, the research team filtered out claims with an unresolved status, including those that were voided, pending, or denied. Further, claims without compensation and time granted were removed, ensuring that only claims that impacted time, cost, or both were retained in the dataset for further analysis. This strategy facilitated a more precise evaluation of the impact of claims on the analyzed variables. Lastly, duplicate cases with identical information were eliminated across all the dataset's variables. Following the removal of all unsuitable claims and duplicates, the total number of claims available for analysis was reduced to approximately 7,000, down from the initial 13,000 claims.

Cleaning supplementary agreements data: The initial step in cleaning the supplementary agreements data also involved identifying the project type based on the TIP designation and removing cases without an associated project type. In the next step, the researchers filtered out supplementary agreements with unresolved status, including those that were voided, pending, or denied. Subsequently, only supplementary agreements that were approved or agreed upon by the contractor or FHWA were kept. To further refine the dataset, duplicate cases with the same contract designations descriptions, and justifications were eliminated. Removing duplicates ensured that only supplementary agreements that provided new and relevant information would be analyzed. The supplementary agreements data contained several duplicates, as the NCDOT had documented the entire case on each row of the spreadsheet instead of merely updating the status when each supplementary agreement was being processed. Following the removal of all unsuitable supplementary agreements and duplicates, the total number of supplementary agreements available for analysis was reduced to approximately 19,000, down from the initial 230,000 supplementary agreements.

Figure 2.4 presents the number and percentage of claims and supplementary agreements relative to each other. This information was necessary prior to developing a sampling plan. The figure clearly shows that the number of supplementary agreements is significantly higher than that of claims, with 80% of the total cases being supplementary agreements and only 20% being claims. In short, supplementary agreements are more common than claims for the NCDOT.

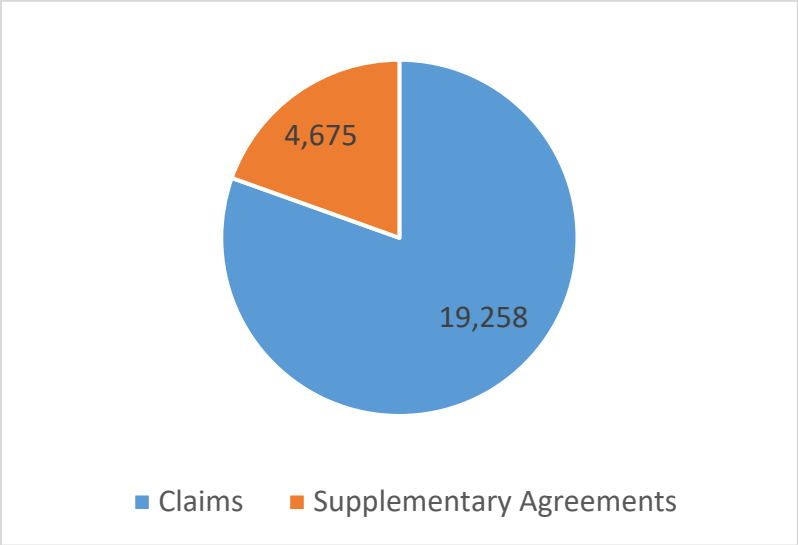

Figure 2.4: Distribution of claims and supplementary agreements prior to sampling.

Table 2.2 shows the final number of claims and supplementary agreement cases based on project type. The table shows the distribution of the claims and supplementary agreements across different project types after the data cleaning step. For the claims data, out of the thirteen project types identified in the dataset, Bridge Replacement projects correlate with the highest number of claims, followed by Rural, Urban, Interstate, and Highway Safety projects. These top five project types account for almost 95% of all the claims data, indicating that these project types are more susceptible to claims than the other project types. Similarly, for the supplementary agreements data, the top five project types with the highest number of cases account for over 95% of the total supplementary agreements. The only difference observed here compared to the claims data is that Rural projects correlate with the highest number of supplementary agreement cases, followed by Urban, Bridge Replacement, and Highway Safety projects. This information helps to identify the project types that are the most prone to problems and require more effort in terms of the risk management process.

Table 2.2: Final Number of Claims and Supplementary Agreement Cases, by Project Type

Claims			Supplementary Agreements		
Project Type	**Count**	**Proportion**	**Project Type**	**Count**	**Proportion**
Bridge Replacement	1410	30.2%	Rural	6231	32.4%
Rural	1090	23.3%	Urban	4790	24.9%
Urban	815	17.4%	Bridge Replacement	3573	18.6%
Interstate	598	12.8%	Interstate	2536	13.2%
Highway Safety	490	10.5%	Highway Safety	1172	6.1%
Rail	76	1.6%	Rest Area	238	1.2%
Other	59	1.3%	Rail	205	1.1%
Rest Area	40	0.9%	Appalachian Regional Commission	182	1.0%
Bicycle and Pedestrian	36	0.8%	Ferry	140	0.7%
Appalachian Regional Commission	22	0.5%	Other	123	0.6%
Safe Routes to School	16	0.3%	Bicycle and Pedestrian	36	0.2%
Ferry	15	0.3%	Railroad - Highway Crossings	22	0.1%
Railroad - Highway Crossings	8	0.2%	Safe Routes to School	10	0.1%
All Project Types	**4675**	**100%**	**All Project Types**	**19258**	**100%**

2.2.3 Sample data

After observing many cases in both the claims and supplementary agreements datasets and considering the level of detail required for the content analysis, the research team acknowledged that analyzing each case individually would be impractical. Therefore, the researchers used a sample from each dataset while ensuring that the sample size was sufficient to capture meaningful information without sacrificing data quality. As the datasets contained various project types, each project type could be considered as a separate dataset within the primary claims and supplementary agreements datasets. The research team implemented a stratified sampling approach using thirteen different project types in the datasets to ensure a representative sample from each project type in the claims and supplementary agreements datasets. According to Neuman (2014), "For populations under 1,000, a minimum ratio of 30 percent (300 individuals) is advisable to ensure representativeness of the sample. For larger populations, such as a population of 10,000, a comparatively small minimum ratio of 10 percent (1,000) of individuals is required to ensure representativeness of the sample" [35]. Based on Neuman's sampling approach, the research team

selected a 10% to 30% sample size for each project type based on the number of cases available in either the claims or supplementary agreements dataset. Table 2.3 and Table 2.4 present the final sample sizes for the claims and supplementary agreements based on project type, respectively. Note that the cases to be analyzed were randomly selected for each project type.

Table 2.3 presents the sample sizes used in the analysis for the claims data. For the top five project types with the highest number of cases, a 30% sampling factor was used due to the greater volume of cases for these project types, ensuring better results. Given the relatively small sample sizes for the remaining project types, all available data were included in the sample to avoid missing any important information. Note that the numbers listed in the Sample Size column indicate the number of cases analyzed for each project type. Any discrepancies observed, such as the total number of claims being 22 for the Appalachian Regional Commission, but the sample size being 21, can be attributed to a special case in which that project type was incomplete or lacking information. As a result, that particular case was removed from the dataset, leading to differences between the count and sample size number.

Table 2.3: Claims Data Sample Size Based on Project Type

Project Type	Count	Sampling Factor	Sample Size
Bridge Replacement	1,410	30.0%	425
Rural	1,090	30.0%	344
Urban	815	30.0%	244
Interstate	598	30.0%	183
Highway Safety	490	30.0%	148
Rail	76	100.0%	70
Other	59	100.0%	53
Rest Area	40	100.0%	37
Bicycle and Pedestrian	36	100.0%	35
Appalachian Regional Commission	22	100.0%	21
Safe Routes to School	16	100.0%	15
Ferry	15	100.0%	14
Railroad - Highway Crossings	8	100.0%	7
Total	**4,675**	**34.1%**	**1,596**

Table 2.4 shows that a sampling factor of 10% was selected for project types with over 1,000 cases. This factor was determined to be sufficient for yielding reliable results based on Neuman's approach [35]. For five project types, i.e., Rest Area, Rail, Appalachian Regional Commission, Ferry, and Other, a sampling factor of approximately 30% was employed. All available data were utilized for the remaining project types to ensure that no vital information was overlooked. Despite analyzing only 11.3% of all supplementary agreements, the sample size comprised 2,177 cases, which is more significant than the number of cases examined for claims.

Table 2.4*:* Supplementary Agreement Sample Size Based on Project Type

Project Type	Count	Sampling Factor	Sample Size
Rural	6,231	10.0%	624
Urban	4,790	10.0%	479
Bridge Replacement	3,573	10.0%	358
Interstate	2,536	10.0%	254
Highway Safety	1,172	10.1%	118
Rest Area	238	30.3%	72
Rail	205	30.2%	62
Appalachian Regional Commission	182	30.2%	55
Ferry	140	35.7%	50
Other	123	30.1%	37
Bicycle and Pedestrian	36	100.0%	36
Railroad - Highway Crossings	22	100.0%	22
Safe Routes to School	10	100.0%	10
Total	**19,258**	**11.3%**	**2,177**

Figure 2.5 provides a quantitative comparison of the analyzed claims and supplementary agreements in terms of total number of cases and their proportions. Out of the 3,773 cases analyzed for both claims and supplementary agreements, claims accounted for 42% (1,596) and supplementary agreements accounted for 58% (2,177) of the total.

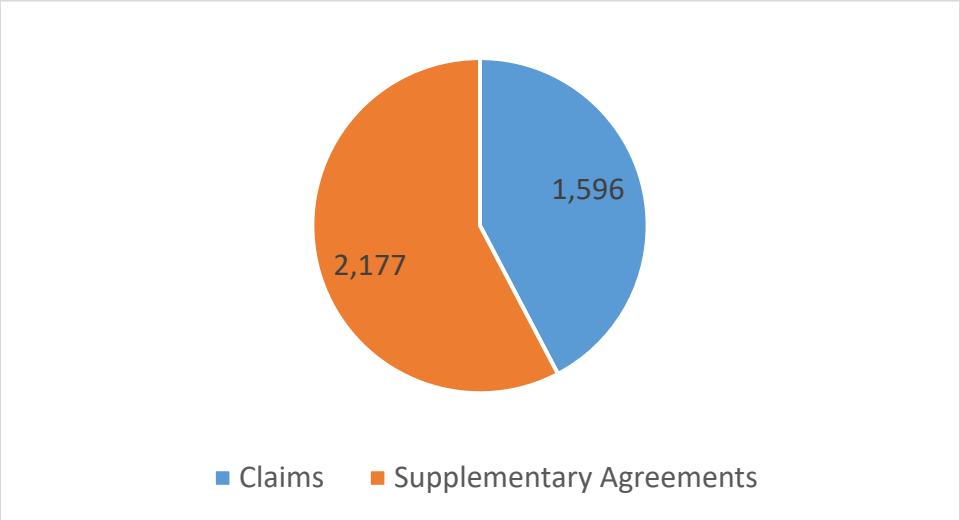

Figure 2.5: Distribution of claims and supplementary agreements after sampling.

2.2.4 Analyze content

Once the data cleaning and random sampling processes were completed for each project type, the data analysis phase commenced. During this phase, content analysis was selected as the primary analytical approach because it entailed a comprehensive examination of the information contained within the datasets, with specific focus on the claims and supplementary agreements. For each individual case, whether it pertained to a claim or supplementary agreement, multiple items were meticulously recorded as part of the content analysis. These recorded items helped to identify the root cause of the filed claim or supplementary agreement and determine the subsequent effects of the identified cause on the project. A detailed description of the methodology employed for conducting the content analysis of the claims and supplemental agreements data is as follows.

Claims data: The Excel dataset for claims includes 40 distinct columns that provide information about each claim. The content analysis of each claim focused on the following columns:

- **Claim description:** Provides an extensive explanation of the nature of the claim, including pertinent information about the underlying problem that led to the claim.
- **Issue description:** Supplements the information found in the claim description and provides additional details regarding the issue at hand.
- **Issue specification:** Outlines the specific effects that are associated with each claim and identifies one of several potential outcomes, such as alteration of plans or construction

details, changes in work extension, controlling operation delay extension, extra work, no applicable specification, suspension of work, or other.

Figure 2.6 provides a visual representation of the steps taken so far, along with the various items captured and analyzed during the content analysis phase for the claims data. The content analysis process involves capturing various items for each claim. The terminology and classification provided in WSDOT's RBS (see Appendix A) were utilized in this study.

The first item, Generic Cause, records the underlying conditions or cause(s) that led to the filing of each claim. For this item, generic keywords are used to represent the causes of the claims. For claims related to Design/Plan Issues, additional information has been recorded to identify the specific discipline or area to which the Design/Plan Issue relates. Specific Cause summarizes the cause of each claim with a few sentences that describe the claim. Involved Item/Activity captures the item or activity related to the claim, either as the cause of or being involved in the claim. Effect captures the effect(s) of the claim on the project, thereby providing a record of the claim's impact on the project.

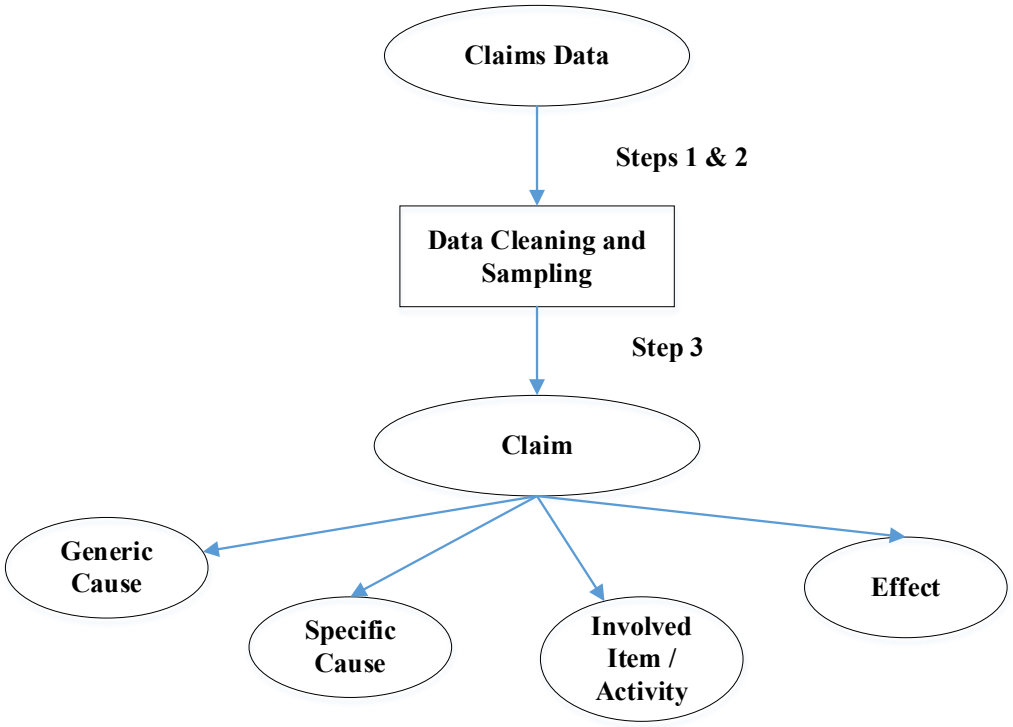

Figure 2.6: Overview of content analysis of claims data.

The objective of the content analysis is to capture essential information that would enable the claim description to be identified by merely reviewing the captured items. The following example illustrates how each of the items works in practice.

Claim description:

"NCDOT Chief Engineer suspension of work - Hurricane Irma - No lane closures (4 days) -9/8/17 @7PM thru 9/11/17 (lifted in afternoon on 9/11/17)"

1. Generic Cause: Natural disaster (hurricane)
2. Specific Cause: Suspension of lane closure due to hurricane
3. Involved Item/Activity: Lane closure
4. Effect: Suspension of work

Supplementary agreements data: The Excel supplementary agreements dataset consists of 14 unique columns, each containing information about the respective supplementary agreement. In order to perform content analysis of each supplementary agreement, focus was directed toward the following columns:

- **Supplementary agreement description**: Contains a comprehensive narrative of the nature of the supplementary agreement, including relevant information about the underlying issue that necessitated the documentation of the supplementary agreement.
- **Supplementary agreement justification**: Augments the information in the supplementary agreement description and offers supplementary details regarding the matter at hand.

Similar to the claims data, content analysis was performed after the supplementary agreement data were cleaned and a random sample was taken.

Figure 2.7 provides an overview of the steps taken thus far and the items captured during the content analysis process for supplementary agreements. The items captured are Generic Cause, Specific Cause, Involved Item/Activity, Effect, and an additional item called Risk Area. Generic Cause captures each supplementary agreement's main generic cause(s) or problem(s). Specific Cause details the Generic Cause and summarizes each supplementary agreement. Involved Item/Activity identifies the items or activities involved in filing the supplementary agreement. Effect captures the primary effect of each supplementary agreement on the project. Risk Area represents information that is captured after gathering all the other items, with particular attention to the supplementary agreement description and captured Generic Cause. The Risk Area item aims to capture the area of risk that is associated with the supplementary agreement and to summarize the overall nature of the supplementary agreement.

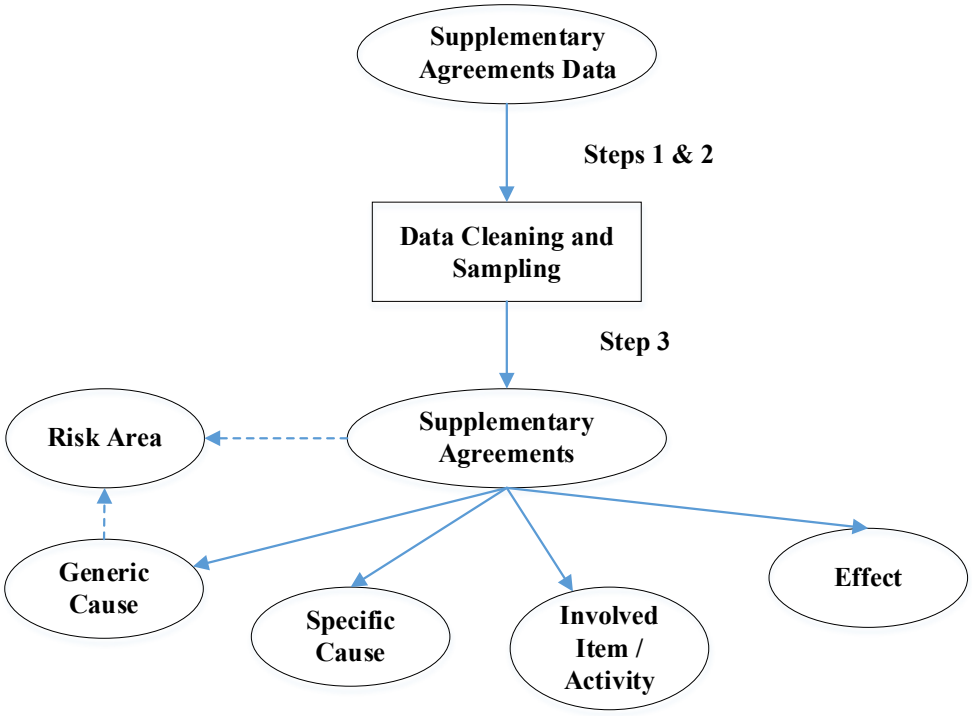

Figure 2.7: Overview of content analysis of supplementary agreements data.

Similar to claims, the reason for conducting content analysis of supplementary agreements is to extract crucial information that facilitates the identification of the supplementary agreement description by examining the captured items. The following example illustrates how each of the items works in practice.

Supplementary agreement description:

"CLASS AA CONCRETE FOR REVISED BRIDGE DECK QUANTITIES. This supplemental agreement provides compensation for Class AA concrete that was incorrectly calculated for the bridge deck. Plan quantity shows 73.1 cubic yards for Pour #1. The amount of concrete was recalculated by the Bridge Design Unit and the corrected quantity for Pour #1 is 81.9 cubic yards. A difference of 8.8 cubic yards of class AA concrete is the amount that was not accounted for by the contractor. This supplemental agreement provides all compensation necessary to furnish, haul, and any other fees for NCDOT approved Class AA concrete."

1. Generic Cause: Quantities overrun/underrun
2. Specific Cause: Supplemental agreement provides compensation for Class AA concrete that was incorrectly calculated for the bridge deck.
3. Involved Item/Activity: Concrete
4. Effect: Modify unit cost
5. Risk Area: Structural

2.2.5 Group similar categories of items

After thorough analysis of all the claims and supplementary agreements to identify the causes and effects of problems encountered during projects, the next step involved refining the findings to enhance the quality of the results. Various items were collected during the content

analysis process, including Generic Cause, Specific Cause, Involved Item/Activity, Effect, and Risk Area (the latter specific to supplementary agreements). The intention was to gather as much information as possible for each case, resulting in a proliferation of categories for each item. To improve the presentation of the findings and make them more comprehensible, a refinement process was initiated that entailed creating broader categories that allowed the results to be condensed and streamlined. To achieve this refinement, similar categories within the Generic Cause and Risk Area items were grouped. This process was iterative, consisting of three rounds of grouping to ensure that no two categories were alike. Figure 2.8 presents an overview of the grouping process. In each round, the same categories were grouped together and new categories were formulated. The previous categories were then employed as Level 2 Generic Causes for the new Generic Cause items, thereby providing additional information.

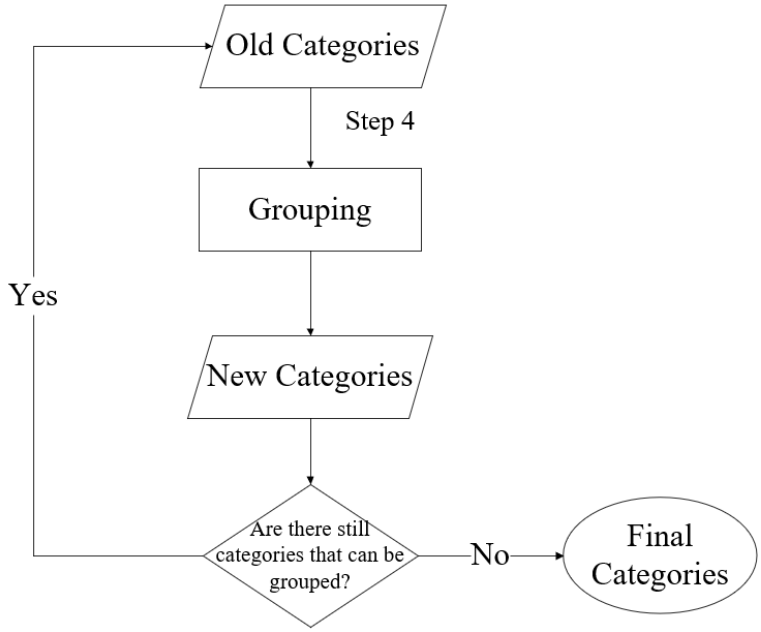

Figure 2.8: Overview of grouping process for item categories.

After three rounds of grouping, a notable reduction in the number of categories for each item was achieved. Table 2.5 displays the initial count of the categories captured for each item prior to grouping as well as the final count of categories following the grouping process.

Table 2.5: Number of Categories in Grouping Step

Before Grouping		
	Claims	**Supplementary Agreements**
Generic Cause	≈ 300	≈ 370
Specific Cause	≈ 1100	≈ 2,200
Involved Item/Activity	≈ 800	≈ 1,700
Effects	≈ 200	≈ 50
Risk Area	-	≈ 110
After Grouping		
	Claims	**Supplementary Agreements**
Generic Cause	18	18
Risk Area	-	25

2.3 Results

This Section 2.3 provides a comprehensive overview of the root causes of problems encountered in NCDOT projects. The categories of the root causes include Generic Cause, Generic Cause Level 2, and Risk Area. The primary objective of this study is to provide valuable insights into project risks based on project type. So, based on the results for the causes of claims and supplementary agreements, the NCSU research team created a tool in the form of an Excel file called the NCDOT Risk Insights Tool. This tool contains information regarding claims, supplementary agreements, and the impacts of both.

The Risk Insights Tool contains over 30 sets of tables for both claims and supplementary agreements, with 14 sets of tables for claims (13 different project types and one set of tables for all project types combined) and 14 sets of tables for supplementary agreements, along with additional sets of tables that are discussed later in this report. Note that the results for all project types are presented together in order to be consistent with the format used to present the results for each project type separately. Detailed results for each project type can be found in the NCDOT Risk Insights Tool.

The results are organized into three parts. The first part presents the results for claims, which include Generic Cause, Generic Cause Level 2, and impacts of the claims, i.e., time and compensation, for the various Generic Causes. The second part presents the results for supplementary agreements, which include Generic Cause, Generic Cause Level 2, Risk Area, and impacts of the supplementary agreements (which pertain only to compensation, as time data were unavailable). The third part discusses the various types of information provided in the Risk Insights Tool.

2.3.1 Claims

Table 2.6 presents the Generic Causes of problems that led to claims that were identified across all project types. The table highlights a total of 18 distinct Generic Causes. The analysis

shows that the five primary causes of problems are Design/Plan Issues, Issues with Underground Utilities, Natural Disaster, Scheduling and Coordination Issues (Except Start of Work and/or Project Closeout), and Contract Amendment. These five generic causes are responsible for roughly 50% of all claims recorded across all NCDOT projects.

Table 2.6: Generic Causes of Claims for All Project Types

Generic Cause	Count	% Total
Design/Plan Issues	258	16.2%
Issues with Underground Utilities	235	14.7%
Natural Disaster	141	8.8%
Scheduling and Coordination Issues (Except Start of Work and/or Project Closeout)	141	8.8%
Contract Amendment	127	8.0%
Project Closeout Issues	109	6.8%
Constructability Issues (Except Geotechnical/Underground Conflicts)	94	5.9%
Quantities Overrun/Underrun	76	4.8%
M&R/Replacement	75	4.7%
Environmental/Community Concerns	68	4.3%
Design Approval Waiting Period/Indecision/Negotiation	55	3.4%
Differing Site Conditions (Except Utilities)	49	3.1%
Procurement Issues	48	3.0%
Access/ROW/Easement	34	2.1%
Start Date Delays	33	2.1%
Survey/Test Issues	24	1.5%
Permit	17	1.1%
Other	12	0.8%

Brief descriptions of each Generic Cause listed in Table 2.6 are as follows.

1. Design/Plan Issues: Problems that arise from flaws in the project design or plans.
2. Issues with Underground Utilities: Difficulties encountered during construction due to conflicts with existing underground utilities.
3. Natural Disaster: Unforeseen natural disasters, such as hurricanes, tornadoes, and floods, that impact project progress and completion.
4. Scheduling and Coordination Issues (Except Start of Work and/or Project Closeout): Challenges with coordinating different aspects of the project, such as subcontractor schedules or scheduling of inspections.
5. Contract Amendment: Modifications made to the project contract, resulting in changes in contract line items, schedule, or budget.
6. Project Closeout Issues: Difficulties encountered during project closeout, such as delays in scheduling final inspections or resolving outstanding disputes.

7. Constructability Issues (Except Geotechnical/Underground Conflicts): Issues related to the feasibility and practicality of constructing the project, with the exception of conflicts with geotechnical or underground conditions.
8. Quantities Overrun/Underrun: Variances between the planned and actual amounts of materials, labor, or other resources required for the project.
9. M&R/Replacement: Costs incurred due to maintenance and repair or replacement of existing infrastructure or equipment.
10. Environmental/Community Concerns: Issues that arise from environmental regulations, community opposition, or other social factors.
11. Design Approval Waiting Period/Indecision/Negotiation: Delays in obtaining approval for the project design that are due to indecision or negotiation issues.
12. Differing Site Conditions (Except Utilities): Unforeseen subsurface or soil conditions that differ from those indicated in the project plans, with the exception of conflicts with underground utilities.
13. Procurement Issues: Difficulties with the procurement of materials or equipment needed for the project.
14. Access/ROW/Easement: Challenges related to obtaining the necessary right-of-way or easements to access the project site.
15. Start Date Delays: Delays in starting the project due to issues such as delays related to the preconstruction meeting, approvals, or unforeseen circumstances.
16. Survey/Test Issues: Problems that arise from inaccuracies or inconsistencies in project surveys or tests.
17. Permit: Difficulties in obtaining necessary permits for the project from regulatory agencies.
18. Other: Any other issues or challenges that are not covered by the previous categories.

As noted in the method overview Section 2.2.4, the content analysis process for Design/Plan Issues is based on WSDOT's Risk Breakdown Structure (refer to Appendix A) that provides a more specific list of design issues. Following this breakdown structure, Table 2.7 presents the Risk Areas associated with Design/Plan Issues with respect to claims. As shown, Roadway, Hydraulics, Traffic, and Structural Design are responsible for most (about 65%) Design/Plan Issues.

Table 2.7: Risk Areas of Claims Associated with Design/Plan Issues

Design/Plan Issues	Percentage of Design/Plan Issues
Roadway Design: Vertical/horizontal alignment, earthwork, pavement, grade, etc.	20.9%
Hydraulic Design: Flow control, criteria changes, drainage, irrigation, system design, etc.	18.2%
Traffic Design: Intelligent transportation systems (ITS), illumination, signals, intersections, roadway signs, safety factors (concrete island, sight distance, etc.).	14.7%
Structural Design: Bridge superstructure, bridge substructure, etc.	10.5%
Geotechnical Design: Foundations, retaining walls, pile driving, etc.	7.4%
Utilities Design, as-builts, etc.	5.0%
Environmental: Vegetation plans, habitat mitigation, etc.	3.9%
Traffic Control & Staging: Maintenance of traffic, work zone traffic control, etc.	3.1%
Unspecified	16.3%

Note: This list of Design/Plan Issues is taken from Washington State Department of Transportation's Risk Breakdown Structure.

Table 2.8 is extracted from a table in the Risk Insights Tool that presents a detailed breakdown of the Generic Causes Level 2 that are associated with each Generic Cause. Appendix B presents the complete Risk Insights Tool table and offers a detailed breakdown of the identified Generic Causes, which enables a better understanding of the categorization of these causes. In addition, Table 2.8 provides information regarding the frequency of Generic Causes Level 2 as well as the impacts of the Generic Causes, such as expected and average cost and time granted per claim. The Generic Cause column in Table 2.8 indicates that approximately 15% of all filed claims can be attributed to Issues with Underground Utilities. The Generic Cause Level 2 column indicates that, within this subset of claims related to Issues with Underground Utilities, 30.6% were caused by delays in utility relocation and the remaining claims were due to utility conflicts. The other columns in the table provide insights into the financial implications and time impacts associated with each utility-related claim, indicating an expected cost of approximately $24,500 and time of 14 days per claim.

Table 2.8: Generic Cause Level 2 and Impacts of Claims for All Project Types (Issues with Underground Utilities)

Generic Cause	*Generic Cause (Level 2)*	*Count*	Level 2-GC Ratio	Total	% Total	Average Cost per Claim ($)	Expected Cost per Claim ($)	Average Time Granted per Claim (days)	Expected Time Granted per Claim (days)
Issues with Underground Utilities	Utilities not Relocated on Time	72	30.6%	235	14.7%	165,812.26	24,414.71	95.6	14.1
	Utility Conflict	163	69.4%						

Figure 2.9 visually depicts the relationship between the Generic Causes and their corresponding effects on project duration and financial resources. The x-axis of the chart denotes the ratio of compensation granted to the bid amount, and the y-axis denotes the ratio of time granted to project duration. The rationale behind these ratios is to standardize the values for cost and time, thereby enabling this information to be plotted on a single chart. The findings suggest that Contract Amendments and Access/ROW/Easement issues are more likely to affect the project cost, and Environmental/Community Concerns are more likely to impact project schedules (i.e., time impacts). By referring to this chart, project managers can clearly understand potential risks and their impacts with regard to claims. Furthermore, integrating the outcomes presented in Figure 2.9 with the other tables presented in this Section 2.3.1 will significantly enhance the efficiency of risk management practices with regard to claims.

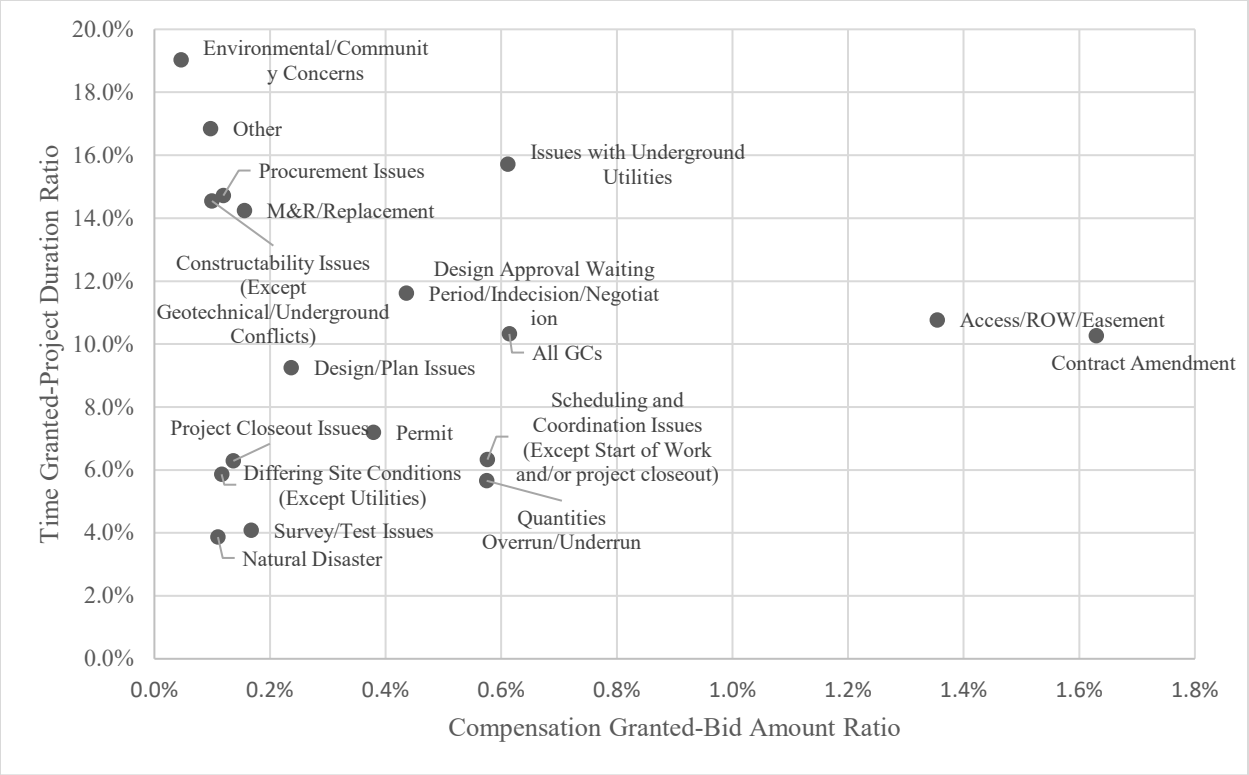

Figure 2.9: Impact profile of claims based on generic causes: compensation versus time.

Finally, Table 2.9 displays the final set of results for the claims data. This table presents the risk profile of all Generic Causes for different project types, providing project managers with a quick overview of the most frequent causes of claims for each type of project. (Note that Table 2.9 is merely a subset of the complete table available in the Risk Insights Tool.) The table is organized by project type, with the Generic Causes listed alphabetically. The columns indicate the percentage of claims for each project type filed for each Generic Cause. This table shows that the most frequent causes of claims vary depending on the project type. For example, the most frequent cause of claims for Highway Safety projects is Issues with Underground Utilities, whereas the most frequent cause of claims for Urban projects is Design/Plan Issues.

Table 2.9: Risk Profile of Generic Causes: Overview of Frequent Causes of Claims for Different Project Types

Generic Cause\Project Type	Bridge Replacement	Highway Safety	Interstate	Rural	Urban
Access/ROW/Easement	1.2%	2.7%	2.2%	2.0%	2.5%
Constructability Issues (except Geotechnical/Underground conflicts)	7.5%	5.4%	7.1%	6.4%	2.9%
Contract Amendment	5.9%	3.4%	7.1%	11.3%	7.8%
Design Approval Waiting Period/Indecision/Negotiation	4.5%	2.0%	3.8%	2.0%	3.3%
Design/Plan Issues	13.9%	14.2%	12.6%	18.3%	23.0%
Differing Site Conditions (except Utilities)	5.4%	2.0%	2.2%	2.3%	2.9%
Environmental/Community Concerns	7.3%	4.7%	1.6%	3.8%	2.9%
Issues with Underground Utilities	13.9%	17.6%	3.3%	13.4%	18.9%
M&R/Replacement	2.8%	4.1%	10.4%	6.4%	3.3%
Natural Disaster	9.4%	12.2%	11.5%	8.7%	7.0%
Other	0.5%	0.0%	0.0%	1.5%	0.4%
Permit	2.4%	0.0%	0.5%	1.2%	0.4%
Procurement Issues	2.6%	2.0%	3.8%	3.5%	2.0%
Project Closeout Issues	7.8%	14.2%	8.2%	2.6%	5.7%
Quantities Overrun/Underrun	2.1%	7.4%	9.8%	3.5%	6.6%
Scheduling and Coordination Issues (except Start of Work and/or Project Closeout)	8.5%	6.1%	13.7%	8.4%	9.4%
Start Date Delays	1.6%	1.4%	1.1%	2.9%	0.0%
Survey/Test Issues	2.8%	0.7%	1.1%	1.7%	1.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

2.3.2 Supplementary Agreements

This section presents the results of the content analysis of the supplementary agreements in a similar fashion to the presentation of the results for claims, but with some differences. Due to the unavailability of the granted time (number of days) data for supplementary agreements, the time impacts associated with the causes of the supplementary agreements could not be calculated. Additionally, because an extra feature was captured during the supplementary agreements content analysis that records Risk Areas, tables are included that show the proportions for Risk Areas as well as the Generic Cause, Generic Cause Level 2, and risk profile for all project types.

Table 2.10 presents the distribution of the Generic Causes of supplementary agreements for all project types. The captured categories for the Generic Causes are mostly the same as those for the claims; however, some issues resulted only in claims whereas others resulted only in supplementary agreements. For instance, Vegetation Establishment and Natural Disaster are two categories with a considerable number of recorded cases for claims, whereas Stakeholder Request, which may be associated with change orders requested by stakeholders such as local governments

for future development, is a major category in the supplementary agreements. This table shows that the most frequent Generic Cause is Design/Plan Issues, which accounts for 26.8% of all supplementary agreements. Other major Generic Causes of supplementary agreements are Contract Amendment, Stakeholder Request, Differing Site Conditions (Except Utilities), and M&R/Replacement.

Table 2.10: Generic Causes of Supplementary Agreements for All Project Types

Generic Cause	Count	%
Design/Plan Issues	583	26.8%
Contract Amendment	324	14.9%
Stakeholder Request	178	8.2%
Differing Site Conditions (Except Utilities)	173	7.9%
M&R/Replacement	156	7.2%
Issues with Underground Utilities	127	5.8%
Safety Concerns (Except Contaminated Soil)	118	5.4%
Constructability Issues (Except Geotechnical/Underground Conflicts)	112	5.1%
Construction Method Revision	75	3.4%
Access/ROW/Easement	54	2.5%
Erosion Control Problems	54	2.5%
Quantities Overrun/Underrun	50	2.3%
Drainage Issues	41	1.9%
Scheduling and Coordination Issues	34	1.6%
Environmental/Community Concerns	32	1.5%
Procurement Issues	30	1.4%
Survey/Test Issues	20	0.9%
Other	16	0.7%

Brief descriptions of each Generic Cause listed in Table 2.10 are as follows.

1. Design/Plan Issues: Problems that arise from flaws in the project design or plans.
2. Contract Amendment: Modifications made to the project contract, resulting in changes in contract line items, schedule, or budget.
3. Stakeholder Request: Requests made by external stakeholders, such as local government entities or nearby residents, that require changes to the project.
4. Differing Site Conditions (Except Utilities): Unforeseen site conditions that differ from those expected but do not involve underground utilities.
5. M&R/Replacement: Maintenance and repair or replacement of existing infrastructure or equipment.
6. Issues with Underground Utilities: Issues related to underground utilities, such as conflicts or damages.
7. Safety Concerns (Except Contaminated Soil): Safety-related issues that arise during the project, such as accidents or hazards, excluding those related to contaminated soil.

8. Constructability Issues (Except Geotechnical/Underground Conflicts): Issues related to the constructability of the project, such as difficulties in executing the design or plans, excluding issues related to geotechnical or underground conflicts.
9. Construction Method Revision: Changes made to the construction methods or techniques used in the project.
10. Access/ROW/Easement: Issues related to access to the project site or right-of-way or easement concerns.
11. Erosion Control Problems: Issues related to erosion control measures or practices.
12. Quantities Overrun/Underrun: Variances in the quantities of materials or labor required for the project, resulting in overruns or underruns.
13. Drainage Issues: Issues related to drainage systems or measures.
14. Scheduling and Coordination Issues: Issues related to project scheduling or coordination with other stakeholders or activities.
15. Environmental/Community Concerns: Issues related to environmental or community impacts of the project.
16. Procurement Issues: Issues related to the procurement of materials or services for the project.
17. Survey/Test Issues: Issues related to surveys or tests conducted during the project.
18. Other: Any other issues not covered by the other categories.

Table 2.11 is extracted from a table in the Risk Insights Tool (refer to Appendix B for the complete table) and presents results that focus on Generic Cause Level 2, which offers a more detailed categorization of the identified Generic Causes. Table 2.11 presents valuable extra information in addition to Generic Causes, including the Generic Cause Level 2 distribution within the respective Generic Cause categories. Furthermore, the table provides insights into the average and expected costs associated with each supplementary agreement filed, thereby enriching the understanding of the financial implications of each supplementary agreement. For instance, approximately 6% of all filed supplementary agreements can be attributed to Issues with Underground Utilities. The Generic Cause Level 2 column indicates that, within this subset of supplementary agreements, 89% of cases were caused by utility conflicts. The remaining supplementary agreements were due to the inability to locate utilities and to utility relocations that did not happen on time. The subsequent columns provide insights into the financial implications, indicating an expected cost of approximately $1,700 per utility-related supplementary agreement.

Table 2.11: Generic Cause Level 2 and Impacts of Supplementary Agreements for All Project Types (Issues with Underground Utilities)

Generic Cause	Specific Cause (Level 2 Generic Cause)	Count	% (Specific Cause)	Count (Generic Cause)	% (Generic Cause)	Average Cost per supplementary agreement	Expected Cost per supplementary agreement
Issues with Underground Utilities	Inability to Locate Utilities	7	5.5%	127	5.8%	$ 29,096.63	$ 1,697.41
	Utilities not Relocated on Time	7	5.5%				
	Utility Conflict	113	89.0%				

Table 2.12 shows the distribution of the Risk Areas in the supplementary agreements. The most common Risk Area (which also refers to the NCDOT Unit that is most prone to experience risk) is Utilities, followed by Hydraulics, Geotechnical, Roadway Design, and Traffic Control Systems (Except Pavement Markings). These findings are consistent with previous studies that have shown that these Risk Areas are among the most common areas of risk in transportation projects [25] [28] [36] [37].

Table 2.12: Distribution of Risk Areas in Supplementary Agreements

Risk Areas of Supplementary Agreements for All Project Types	Count	%
Utilities	370	17.0%
Hydraulics	241	11.1%
Geotechnical	191	8.8%
Roadway Design	178	8.2%
Traffic Control Systems (Except Pavement Markings)	160	7.3%
Pavement	153	7.0%
Traffic Control Plan (Construction Phase)	144	6.6%
Environmental	138	6.3%
Structural	100	4.6%
Traffic Control Systems (Pavement Markings)	78	3.6%
Corridor/Traffic Design	70	3.2%
Procurement	47	2.2%
Safety	46	2.1%
Access/ROW/Easement	42	1.9%
Contract	37	1.7%
Roadway Alignment	35	1.6%
Finishing and Interior Work	32	1.5%
Ferry	30	1.4%
Other	25	1.1%
Schedule	25	1.1%
Survey	10	0.5%
Security/Protection	9	0.4%
Railroad	7	0.3%
Natural Disaster	6	0.3%
Permit	3	0.1%

Brief descriptions of each Risk Area listed in Table 2.12 are as follows.

1. Utilities: Risks related to utility services, such as gas, water, electricity, and telecommunications.
2. Hydraulics: Risks related to water management, including drainage systems, flood control, and stormwater management.
3. Geotechnical: Risks related to soil and rock mechanics, including slope stability, foundation design, and earthworks.
4. Roadway Design: Risks associated with the design of roadway elements, including but not limited to, guardrail installation.
5. Traffic Control Systems (Except Pavement Markings): Risks related to the design, installation, and maintenance of traffic control devices, such as signals, signs, and lighting.
6. Pavement: Risks related to pavement design, construction, and maintenance, including materials, drainage, and skid resistance.

7. Traffic Control Plan (Construction Phase): Risks related to temporary traffic control measures during construction, including traffic diversions, detours, and work zone safety.
8. Environmental: Risks related to environmental compliance and impact, including air quality, water quality, and noise.
9. Structural: Risks related to bridge and other structural elements, including design, materials, and construction.
10. Traffic Control Systems (Pavement Markings): Risks related specifically to pavement markings as a traffic control device.
11. Corridor/Traffic Design: Risks related to the design of the transportation corridor, including land use, access, and connectivity.
12. Procurement: Risks related to the procurement process, including contract management, bid evaluation, and contractor selection.
13. Safety: Risks related to safety hazards, including worker safety, traffic safety, and public safety.
14. Access/ROW/Easement: Risks related to access and right-of-way acquisition, including property acquisition, relocation, and compensation.
15. Contract: Risks related to contract terms and conditions, including payment, dispute resolution, and termination.
16. Roadway Alignment: Risks related specifically to the horizontal and vertical alignment of the roadway.
17. Finishing and Interior Work: Risks associated with the completion of the interior work and finishing touches of buildings and structures within the project.
18. Ferry: Risks related to ferry projects, including design, construction, and operation.
19. Other: Risks that are not covered by the other categories.
20. Schedule: Risks related to project schedule, including delays and schedule conflicts.
21. Survey: Risks related to survey data accuracy, including data acquisition and processing.
22. Security/Protection: Risks related to security and protection, including cybersecurity, physical security, and protection of critical infrastructure.
23. Railroad: Risks related to railroad transportation, including track design, construction, and maintenance.
24. Natural Disaster: Risks related to natural disasters, including hurricanes, floods, and landslides.
25. Permit: Risks related to the permitting process, including environmental permits and building permits.

Table 2.13 displays the risk profile of the Generic Causes of supplementary agreements for various project types. Note that this table is a subset of the original table presented in the Risk Insights Tool that contains information for all thirteen project types.

Table 2.13: Risk Profile of Generic Causes: Overview of Frequent Causes of Supplementary Agreements for Different Project Types

Generic Cause\Project Type	Bridge Replacement	Highway Safety	Interstate	Rural	Urban
Access/ROW/Easement	2.0%	3.4%	1.2%	2.6%	3.1%
Constructability Issues (Except Geotechnical/Underground Conflicts)	5.3%	2.5%	7.9%	5.0%	4.8%
Construction Method Revision	2.5%	0.8%	3.5%	4.5%	4.6%
Contract Amendment	15.6%	14.4%	11.8%	16.2%	15.4%
Design/Plan Issues	26.8%	28.0%	27.2%	27.9%	21.7%
Differing Site Conditions (Except Utilities)	8.7%	10.2%	5.5%	6.9%	8.8%
Drainage Issues	1.7%	0.8%	2.8%	1.3%	2.1%
Environmental/Community Concerns	1.4%	0.8%	0.8%	2.9%	0.6%
Erosion Control Problems	5.6%	3.4%	2.0%	1.3%	1.7%
Issues with Underground Utilities	4.7%	9.3%	0.8%	5.0%	10.9%
M&R/Replacement	5.0%	11.9%	12.6%	6.7%	6.1%
Other	1.4%	0.0%	0.0%	0.3%	0.4%
Procurement Issues	1.7%	0.8%	0.4%	1.0%	1.0%
Quantities Overrun/Underrun	3.1%	2.5%	2.8%	2.4%	1.0%
Safety Concerns (Except Contaminated Soil)	4.5%	5.1%	9.8%	5.6%	5.0%
Scheduling and Coordination Issues	0.8%	0.8%	0.4%	2.4%	2.3%
Stakeholder Request	6.7%	5.1%	10.2%	7.7%	9.8%
Survey/Test Issues	2.5%	0.0%	0.4%	0.5%	0.6%
All Generic Causes	100.0%	100.0%	100.0%	100.0 %	100.0%

Table 2.14 is an alternative to Table 2.13 in that it focuses on the Risk Area item instead of the Generic Cause categories for supplemental agreements. It provides an overview of the distribution of risks across different Risk Area items for each project type. This table also is a subset of the table presented in the Risk Insights Tool that contains data for all thirteen project types.

Table 2.14: Risk Profile of Project Types Based on Risk Area Items for Supplementary Agreements

Risk Area\Project Type	Bridge Replacement	Highway Safety	Interstate	Rural	Urban
Access/ROW/Easement	1.4%	0.0%	1.2%	2.1%	2.9%
Contract	0.8%	0.8%	1.6%	1.9%	2.1%
Corridor/Traffic Design	2.5%	2.5%	6.7%	3.4%	4.0%
Environmental	8.7%	5.9%	3.9%	5.9%	4.2%
Ferry	0.0%	0.0%	0.0%	0.0%	0.0%
Finishing and Interior Work	0.3%	0.0%	0.0%	0.2%	0.6%
Geotechnical	12.8%	8.5%	7.9%	9.0%	7.5%
Hydraulics	9.2%	7.6%	10.2%	12.7%	13.2%
Natural Disaster	0.6%	0.0%	0.0%	0.5%	0.0%
Other	1.1%	0.8%	0.8%	1.4%	1.3%
Pavement	3.9%	11.9%	14.2%	7.2%	5.2%
Permit	0.0%	0.0%	0.0%	0.5%	0.0%
Procurement	2.0%	1.7%	1.2%	1.3%	1.0%
Railroad	0.0%	0.0%	0.4%	0.0%	0.4%
Roadway Alignment	3.1%	1.7%	1.2%	1.8%	1.5%
Roadway Design	11.5%	12.7%	8.7%	8.0%	7.3%
Safety	1.1%	1.7%	2.8%	2.1%	2.3%
Schedule	1.4%	0.8%	1.2%	1.6%	1.0%
Security/Protection	0.8%	0.0%	0.0%	0.5%	0.2%
Structural	9.5%	0.0%	7.5%	3.5%	2.3%
Survey	0.8%	0.0%	0.0%	0.5%	0.6%
TCP (Construction Phase)	5.9%	12.7%	7.1%	5.8%	7.5%
Traffic Control Systems (Except Pavement Markings)	2.8%	4.2%	11.4%	8.0%	8.6%
Traffic Control Systems (Pavement Markings)	4.7%	3.4%	5.1%	3.4%	2.9%
Utilities	15.1%	22.9%	7.1%	18.9%	23.4%
All Risk Areas	100.0%	100.0%	100.0%	100.0 %	100.0 %

Table 2.15 provides a summary of the findings for supplementary agreements and a visual presentation of the associations and interactions between the two variables, i.e., Risk Area and Generic Causes. The table is a condensed version of the complete table in the Risk Insights Tool that includes comprehensive data for each project type. This table helps determine areas with the most considerable risk associated with a specific Generic Cause. For instance, in the case of Design/Plan Issues, Roadway Design (13.7%) has the highest percentage, followed by Traffic Control Systems (Except Pavement Markings) (10.8%), and Hydraulics (10.6%) as the areas most impacted by risk.

Table 2.15: Distribution of Risk Areas across Generic Causes of Supplementary Agreements

Generic Cause\Project Type	Appalachian Regional Commission	Bicycle and Pedestrian	Bridge Replacement	Ferry	Highway Safety	Interstate	Other	Rail	Railroad - Highway Crossings	Rest Area	Rural	Safe Routes to School	Urban	All Project Types
Access/ROW/Easement	3.6%	2.8%	2.0%	0.0%	3.4%	1.2%	2.7%	4.8%	4.5%	1.4%	2.6%	0.0%	3.1%	2.5%
Constructability Issues (Except Geotechnical/Underground Conflicts)	5.5%	0.0%	5.3%	0.0%	2.5%	7.9%	0.0%	9.7%	18.2%	4.2%	5.0%	0.0%	4.8%	5.1%
Construction Method Revision	3.6%	5.6%	2.5%	0.0%	0.8%	3.5%	0.0%	0.0%	0.0%	2.8%	4.5%	0.0%	4.6%	3.4%
Contract Amendment	18.2%	13.9%	15.6%	8.0%	14.4%	11.8%	18.9%	11.3%	18.2%	9.7%	16.2%	20.0%	15.4%	14.9%
Design/Plan Issues	23.6%	5.6%	26.8%	72.0%	28.0%	27.2%	21.6%	21.0%	36.4%	36.1%	27.9%	10.0%	21.7%	26.8%
Differing Site Conditions (Except Utilities)	9.1%	8.3%	8.7%	0.0%	10.2%	5.5%	18.9%	11.3%	9.1%	6.9%	6.9%	20.0%	8.8%	7.9%
Drainage Issues	5.5%	8.3%	1.7%	0.0%	0.8%	2.8%	2.7%	0.0%	0.0%	2.8%	1.3%	0.0%	2.1%	1.9%
Environmental/Community Concerns	3.6%	0.0%	1.4%	0.0%	0.8%	0.8%	2.7%	0.0%	0.0%	0.0%	2.9%	0.0%	0.6%	1.5%
Erosion Control Problems	0.0%	8.3%	5.6%	0.0%	3.4%	2.0%	5.4%	4.8%	4.5%	0.0%	1.3%	0.0%	1.7%	2.5%
Issues with Underground Utilities	3.6%	11.1%	4.7%	2.0%	9.3%	0.8%	5.4%	4.8%	0.0%	1.4%	5.0%	10.0%	10.9%	5.8%
M&R/Replacement	3.6%	11.1%	5.0%	2.0%	11.9%	12.6%	2.7%	3.2%	0.0%	13.9%	6.7%	10.0%	6.1%	7.2%
Other	1.8%	0.0%	1.4%	6.0%	0.0%	0.0%	0.0%	4.8%	0.0%	0.0%	0.3%	0.0%	0.4%	0.7%
Procurement Issues	3.6%	0.0%	1.7%	4.0%	0.8%	0.4%	8.1%	4.8%	0.0%	1.4%	1.0%	0.0%	1.0%	1.4%
Quantities Overrun/Underrun	7.3%	0.0%	3.1%	0.0%	2.5%	2.8%	8.1%	1.6%	0.0%	1.4%	2.4%	0.0%	1.0%	2.3%
Safety Concerns (Except Contaminated Soil)	3.6%	5.6%	4.5%	0.0%	5.1%	9.8%	0.0%	3.2%	9.1%	4.2%	5.6%	10.0%	5.0%	5.4%
Scheduling and Coordination Issues	0.0%	2.8%	0.8%	0.0%	0.8%	0.4%	0.0%	3.2%	0.0%	0.0%	2.4%	0.0%	2.3%	1.6%
Stakeholder Request	1.8%	16.7%	6.7%	6.0%	5.1%	10.2%	2.7%	8.1%	0.0%	12.5%	7.7%	20.0%	9.8%	8.2%
Survey/Test Issues	1.8%	0.0%	2.5%	0.0%	0.0%	0.4%	0.0%	3.2%	0.0%	1.4%	0.5%	0.0%	0.6%	0.9%
All Generic Cause	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

2.4 Risk Insights Tool

The Risk Insights Tool comprises approximately 30 sheets within an Excel workbook. Table 2.16 provides an example of ways the Risk Insights Tool can be used and then applied for other data. Specifically, this table presents the risk profile of different project types and the Generic Causes of claims. By referring to this table, users can gain a comprehensive overview of the most common causes of claims and make comparisons among various project types. As such, Table 2.16 serves as a valuable starting point for utilizing the Risk Insights Tool effectively. Other tables in the Risk Insights Tool can be used similarly as resources for other information such as supplementary agreements data.

Table 2.16: Risk Profile: Distribution of Generic Causes of Claims across Project Types

Generic Cause\Project Type	Appalachian Regional Commission	Bicycle and Pedestrian	Bridge Replacement	Ferry	Highway Safety	Interstate	Other	Rail	Railroad - Highway Crossings	Rest Area	Rural	Safe Routes to School	Urban	All Project Types
Access/ROW/Easement	0.0%	2.9%	1.2%	0.0%	2.7%	2.2%	0.0%	10.0%	0.0%	0.0%	2.0%	0.0%	2.5%	2.1%
Constructability Issues (Except Geotechnical/Underground Conflicts)	9.5%	2.9%	7.5%	0.0%	5.4%	7.1%	3.8%	7.1%	0.0%	2.7%	6.4%	6.7%	2.9%	5.9%
Contract Amendment	14.3%	5.7%	5.9%	14.3%	3.4%	7.1%	7.5%	8.6%	0.0%	13.5%	11.3%	26.7%	7.8%	8.0%
Design Approval Waiting Period/Indecision/Negotiation	4.8%	11.4%	4.5%	7.1%	2.0%	3.8%	7.5%	1.4%	0.0%	0.0%	2.0%	0.0%	3.3%	3.4%
Design/Plan Issues	38.1%	20.0%	13.9%	7.1%	14.2%	12.6%	11.3%	8.6%	0.0%	21.6%	18.3%	0.0%	23.0%	16.2%
Differing Site Conditions (Except Utilities)	0.0%	2.9%	5.4%	7.1%	2.0%	2.2%	3.8%	0.0%	0.0%	0.0%	2.3%	0.0%	2.9%	3.1%
Environmental/Community Concerns	4.8%	0.0%	7.3%	0.0%	4.7%	1.6%	5.7%	0.0%	0.0%	5.4%	3.8%	6.7%	2.9%	4.3%
Issues with Underground Utilities	4.8%	22.9%	13.9%	7.1%	17.6%	3.3%	13.2%	37.1%	42.9%	2.7%	13.4%	33.3%	18.9%	14.7%
M&R/Replacement	0.0%	5.7%	2.8%	7.1%	4.1%	10.4%	3.8%	2.9%	0.0%	2.7%	6.4%	0.0%	3.3%	4.7%
Natural Disaster	9.5%	2.9%	9.4%	28.6%	12.2%	11.5%	5.7%	0.0%	0.0%	10.8%	8.7%	6.7%	7.0%	8.8%
Other	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	1.9%	4.3%	0.0%	0.0%	1.5%	0.0%	0.4%	0.8%
Permit	0.0%	0.0%	2.4%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	2.7%	1.2%	0.0%	0.4%	1.1%
Procurement Issues	0.0%	2.9%	2.6%	7.1%	2.0%	3.8%	5.7%	1.4%	0.0%	10.8%	3.5%	0.0%	2.0%	3.0%
Project Closeout Issues	4.8%	5.7%	7.8%	0.0%	14.2%	8.2%	13.2%	1.4%	14.3%	8.1%	2.6%	13.3%	5.7%	6.8%
Quantities Overrun/Underrun	4.8%	0.0%	2.1%	0.0%	7.4%	9.8%	0.0%	11.4%	0.0%	0.0%	3.5%	6.7%	6.6%	4.8%
Scheduling and Coordination Issues (Except Start of Work and/or project closeout)	4.8%	8.6%	8.5%	14.3%	6.1%	13.7%	5.7%	5.7%	42.9%	8.1%	8.4%	0.0%	9.4%	8.8%
Start Date Delays	0.0%	5.7%	1.6%	0.0%	1.4%	1.1%	11.3%	0.0%	0.0%	10.8%	2.9%	0.0%	0.0%	2.1%
Survey/Test Issues	0.0%	0.0%	2.8%	0.0%	0.7%	1.1%	0.0%	0.0%	0.0%	0.0%	1.7%	0.0%	1.2%	1.5%
Grand Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

The next step involves selecting the relevant sheet within the Risk Insights Tool based on the specific project type of interest to project managers. These sheets contain comprehensive results and tables, akin to those presented in

Table 2.6 to Table 2.9, allowing users to access pertinent insights. For instance, project managers can access the Bridge Replacement projects claims result sheet where they can explore a multitude of tables and glean insights that pertain to this specific project type. By analyzing these findings, project managers can gain a deeper understanding of the primary causes of claims associated with specific projects, enabling them to better identify and manage risks specific to the project type. A similar approach can be employed for the supplementary agreements results as well. The following list provides detailed information about each sheet included in the Risk Insights Tool.

- Descriptions Sheet: Contains descriptions of the various categories used for Generic Causes and Risk Area items for claims and supplementary agreements.
- Results (Generic Cause) Sheet: Includes a table that encompasses all the Generic Causes associated with claims and supplementary agreements. The tables provide the distributions for each Generic Cause across all project types, the granted compensation and time amounts (minimum, most likely, and maximum), and the expected values for compensation and time (calculated as the product of the most likely compensation time and the percentage of the Generic Cause). Time impacts for supplementary agreements are not provided because information about the number of days granted for such agreements is unavailable.
- Results (Generic Cause Level 2) Sheet: Similar in format to the Results (Generic Cause) Sheet. The only difference is that this sheet presents information based on Generic Cause Level 2 instead of Generic Cause. It details distribution percentages, compensation time amounts, and expected values.
- Claim – Project Type Name Sheets: Fourteen sheets follow this naming format, with 13 sheets designated for each project type respectively and one dedicated to the overall results for all project types. For example, the Claim – Bridge Replacement Sheet contains tables that present results specifically for bridge replacement projects. Multiple tables in these 14 sheets present various results. Table 2.8 includes the Generic Cause, Generic Cause Level 2, distributions, and average and expected costs and time per claim based on the Generic Causes. Table 2.6 displays a sorted form of Generic Causes with the corresponding percentages. Within Table 2.7 is the category Design/Plan Issues. Table 2.7 illustrates the distributions of Risk Areas (or Units) for this particular category of Generic Cause. Finally, for the Claim – All Project Types Sheet, Table 2.9 (unique to this sheet) provides an overview of the risk profile of all Generic Causes based on different project types.
- Supplementary Agreement – Project Type Name Sheets: Fourteen sheets follow this format, with 13 sheets designated for each different project type respectively and one dedicated to the overall results across all project types. For example, the Supplementary Agreement – Rural Sheet presents the results specific to rural projects. The tables in these sheets (similar to the format followed in the claims results) also have different numbers. Table 2.11 includes the Generic Cause, Generic Cause Level 2, distributions, and average and expected costs per supplementary agreement based on the Generic Causes. Table 2.10 displays the Generic Causes distributions, arranged from highest to lowest percentage. Table 2.12 presents the distributions of Risk Areas (or Units). Table 2.14 presents the risk profile for the interactions between Generic Cause and Risk Area items. The

Supplementary Agreement – All Project Types Sheet contains two additional tables. Table 2.16 provides an overview of the risk profile of all Generic Causes based on different project types. Finally, Table 2.15 presents an overview of the risk profile of all Risk Areas based on different project types.

The described sheets comprise the Risk Insights Tool and offer comprehensive information and analysis for effective risk management and decision-making in transportation projects.

2.5 Discussion and Future Work

The findings of this Study I offer valuable insights into the causes and impacts of common risks faced in transportation projects and are drawn from an extensive examination of past project claims and supplementary agreements obtained from the NCDOT. By investigating these records, this research contributes to a deeper understanding of risk management practices within the transportation sector. A significant outcome of this study is the development of the NCDOT Risk Insights Tool, which provides risk profiles for claims and supplementary agreements based on different project types. Project managers can utilize this tool according to the specific project at hand and to enhance the identification of risks that have a history of impacting projects through claims or supplementary agreements. By presenting the associated impacts, the Risk Insights Tool assists the risk management team in prioritizing risks during risk assessment.

As mentioned, this Study I is part of a larger project to enhance the existing risk management program at the NCDOT. Although the NCDOT has a risk management program in place, more formal risk management guidelines are under development [12]. As for future work, several avenues can be explored. First, the NCDOT can implement the Risk Insights Tool as its primary risk identification and assessment tool. The tool's effectiveness can be assessed by collecting project data from project managers who utilized the tool and comparing project outcomes with projects whose managers did not utilize the tool. Second, collaboration among transportation agencies and sharing best practices can significantly improve risk management practices across the industry. Future research can explore opportunities for knowledge exchange and collaborative research efforts and establishing standardized risk management frameworks. Such initiatives can facilitate a more comprehensive and consistent risk identification, assessment, and mitigation approach. Third, the use of natural language processing and machine learning technologies hold promise, given that almost 3,800 claims and supplementary agreements were analyzed for this study. By training models based on the items identified from content analysis, the content analysis process could be automated and the entire dataset analyzed. This approach would provide a more comprehensive understanding of the risks and their impacts instead of analyzing only a sample of the claims and supplementary agreements.

In summary, this study's analysis of past project data has yielded valuable insights into risk causes and impacts in transportation projects. The development of the NCDOT Risk Insights Tool represents a significant advancement. It holds substantial potential as a valuable asset for the NCDOT and its successful implementation will enhance risk management practices within the organization. Future research directions involve evaluating the tool's effectiveness, promoting collaboration and knowledge sharing among transportation agencies, and exploring advanced technologies to automate content analysis. All of these efforts aim to enhance risk management practices, foster industry-wide improvements, and support more informed decision-making processes within the transportation sector.

2.6 Conclusion

The NCSU research team analyzed nearly 3,800 past project claims and supplementary agreements obtained from the NCDOT for this study. These data encompass a diverse range of project types. Through this examination, the research team successfully identified common causes of risks and their corresponding impacts across thirteen distinct project types. A notable achievement of this research is the development of the NCDOT Risk Insights Tool. This tool is an Excel-based resource that is specifically designed to deliver comprehensive risk insights tailored to different project types.

By emphasizing the importance of leveraging historical records to fortify the risk identification process, the findings serve as a foundation for strengthening risk management practices within the NCDOT. Integrating the NCDOT Risk Insights Tool and incorporating findings into existing platforms such as the NCDOT's Communicate Lessons, Exchange, Advice, Record (CLEAR) database will foster knowledge exchange within the department. More broadly, the insights gleaned from this study also hold significant value for other transportation agencies and project stakeholders, equipping them with guidance to proactively address risks and enhance project outcomes.

3 STUDY II: DEVELOPMENT OF RISK MANAGEMENT PLAYBOOK

Transportation projects involve numerous stakeholders, from contractors and engineers to government officials and the general public. These projects are often complex, with many moving parts that can introduce significant risks to the project's success. Schedule delays and cost overruns can significantly impact the project and the community it serves [21] [22]. In order to enhance the chances of successful project delivery, one approach is to employ risk management strategies [7] [16] – [20]. The process of risk management entails the identification and analysis of potential risks, followed by the determination of suitable responses [5] [6]. This approach allows the project team to gain control over uncertainties and adopt a proactive stance rather than reacting to issues as they arise. Brainstorming, case-based approaches, and checklists are among the commonly employed tools and techniques for risk management, especially in the risk identification and response steps [7] [8].

Like many other large organizations, transportation agencies in the United States have recognized the significance of implementing effective risk management practices, which has led many agencies to adopt specific tools and techniques within their risk management programs [28]. The NCDOT is also actively seeking ways to enhance its risk management guidelines, especially as they pertains to risk mitigation strategies. This Study II of the NCDOT Risk Management Report addresses this goal by introducing a novel tool, the NCDOT Risk Management Playbook (see Appendix C). This tool is designed to give project managers and team members valuable risk insights, enabling them to identify and effectively mitigate potential risks associated with transportation projects.

3.1 Background

Risk mitigation is an integral component of comprehensive risk management practices, with specific focus on minimizing the potential consequences associated with identified risks. Within the domain of transportation and infrastructure development, the implementation of effective risk mitigation strategies assumes paramount importance in ensuring project success and mitigating potential disruptions. This Study II centers around prevailing risk management practices, tools, and procedures employed within the NCDOT, with particular emphasis on the risk mitigation and response stage. The NCSU research team conducted comparative analysis that encompasses standard practices employed by the DOTs of three other states, Washington (WSDOT), California (Caltrans), and Texas (TxDOT). The primary objective of this analysis is to identify potential opportunities to adopt successful risk mitigation practices within the NCDOT's existing risk management program.

The risk management guide published by the NCDOT concentrates on the preconstruction phase of project delivery in which risk management is deemed essential for all project and business units, regardless of project size and complexity. This guide therefore represents a best practice approach. The process of risk identification commences during the Project Initiation Stage (Stage 1) of the Project Delivery Network, immediately following the project's inclusion in the State Transportation Improvement Program (STIP). Subsequently, the project team collaborates with the project manager to select appropriate strategies after risks have been identified. The Risk Assessment Worksheet (RAW) undergoes regular updates throughout the project's various stages to ensure the incorporation of the most effective risk mitigation strategies as the project evolves [12].

In 2020, Jaselskis and Leca investigated the current state of the NCDOT's risk management program through interviews with NCDOT personnel. The findings of their study revealed that, although risk management practices are not formalized across all projects in all cases, risks are consistently considered as an inherent component of decision-making throughout all project phases. The interview respondents indicated that subject matter experts within the NCDOT, as well as external consultants in situations where the NCDOT lacks sufficient expertise, are responsible for identifying suitable mitigation strategies for the identified risks. The NCDOT also frequently convenes brainstorming sessions and conducts reviews of lessons learned and documentation from prior projects to inform decision-making processes for future endeavors [27].

Risk response strategies also hold significant importance within the risk management programs of other state DOTs such as WSDOT, Caltrans, and TxDOT [10] [11] [38]. These three innovative departments employ various tools, techniques, and formalized processes to ensure effective risk management, but the efficacy of their risk mitigation strategies is heavily reliant on the expertise and input provided by subject matter experts. A study by Baumann et al. in 2016 confirms and highlights the increased efficiency of risk management approaches that leverage the expertise of diverse groups of subject matter experts as opposed to relying solely on individual assessments [39]. The highest levels of risk management effectiveness are attained when appropriate response strategies are diligently executed in response to identified risks [10].

In sum, Study II explores the tools and procedures employed within the NCDOT and three other state DOTs in the context of risk response strategies. Across all the studied DOTs, the effectiveness of the risk response strategies hinges on the substantial input provided by subject matter experts. Therefore, the current lack of comprehensive tools for the development of in-house risk response and mitigation strategies serves as the primary impetus for conducting this study. The subsequent sections expound upon the study's objectives, provide an overview of the methodology employed, and present the final results achieved.

3.2 Methodology

The objective of Study II is to create a tool that will aid NCDOT project teams in identifying and mitigating potential risks in transportation projects. The NCSU research team achieved this objective by developing the NCDOT Risk Management Playbook and validating it with input from subject matter experts at the NCDOT. The Playbook is made up of six spreadsheets, each focusing on a critical area of transportation projects: (1) Roadway, (2) Right-of-Way (ROW), (3) Structures, (4) Utilities, (5) Rail, and (6) Other. The Playbook outlines Primary Risks in these areas and suggests Key Questions that project managers should consider when assessing these risks, as well as potential Mitigation Strategies to avoid or minimize risks if they occur (see Appendix C).

The research team analyzed the NCDOT's past project claims and supplementary agreements to identify Primary Risks in the six critical areas. The team also conducted a comprehensive literature review to verify identified risks and potential mitigation strategies [40] [41]. During regular meetings, the research team presented the Playbook to NCDOT staff and project managers to refine and further validate the findings. After creating an initial draft, the research team sent the Playbook, along with a series of questions, to the NCDOT for feedback. The technical staff from various NCDOT Units, including Integrated Mobility, Photogrammetry, Signaling and Delineation, Hydraulics, and Environmental, provided feedback for the final version of the Playbook by answering specific questions. The questions put to NCDOT staff for final input on the Playbook are as follows.

- Which office or discipline best describes the area of your expertise?
- Do the Primary Risks listed in the Risk Management Playbook capture the most common or influential risks that you have experienced during a project?
- What are other risks you have faced on a typical project that should be captured in the Risk Management Playbook?
- Do the Key Questions help in determining the information that is needed to address the Primary Risks?
- Are there any additional questions you would ask yourself or your team when working on a typical project? (Please provide which Primary Risk such questions would pertain to.)
- Are the mitigation strategies listed in the Playbook the most effective ways to deal with these risks?
- Are there any additional strategies you would recommend for a typical project? (Please provide which Primary Risk such additional strategies would pertain to.)

3.3 Results

The NCDOT Risk Management Playbook comprises six spreadsheets in table format that correspond to the six transportation project areas. Rather than displaying the tables, Figure 3.1 to Figure 3.7 present each area's Primary Risk, Key Questions, and Mitigation Strategies. However, as these figures do not provide all the details, see Appendix C that presents the complete Playbook.

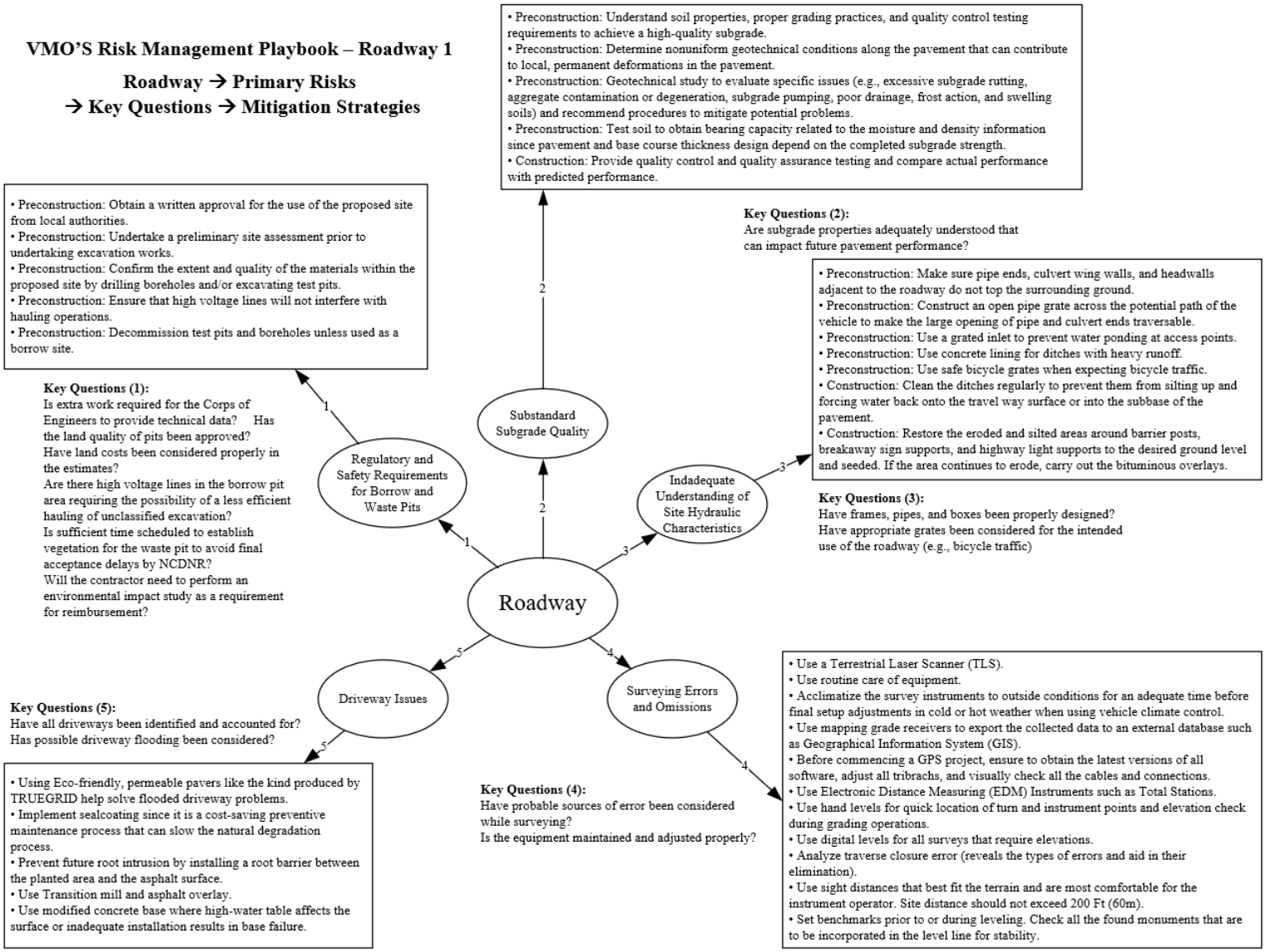

Figure 3.1: NCDOT Risk Management Playbook – Roadway (Part A).

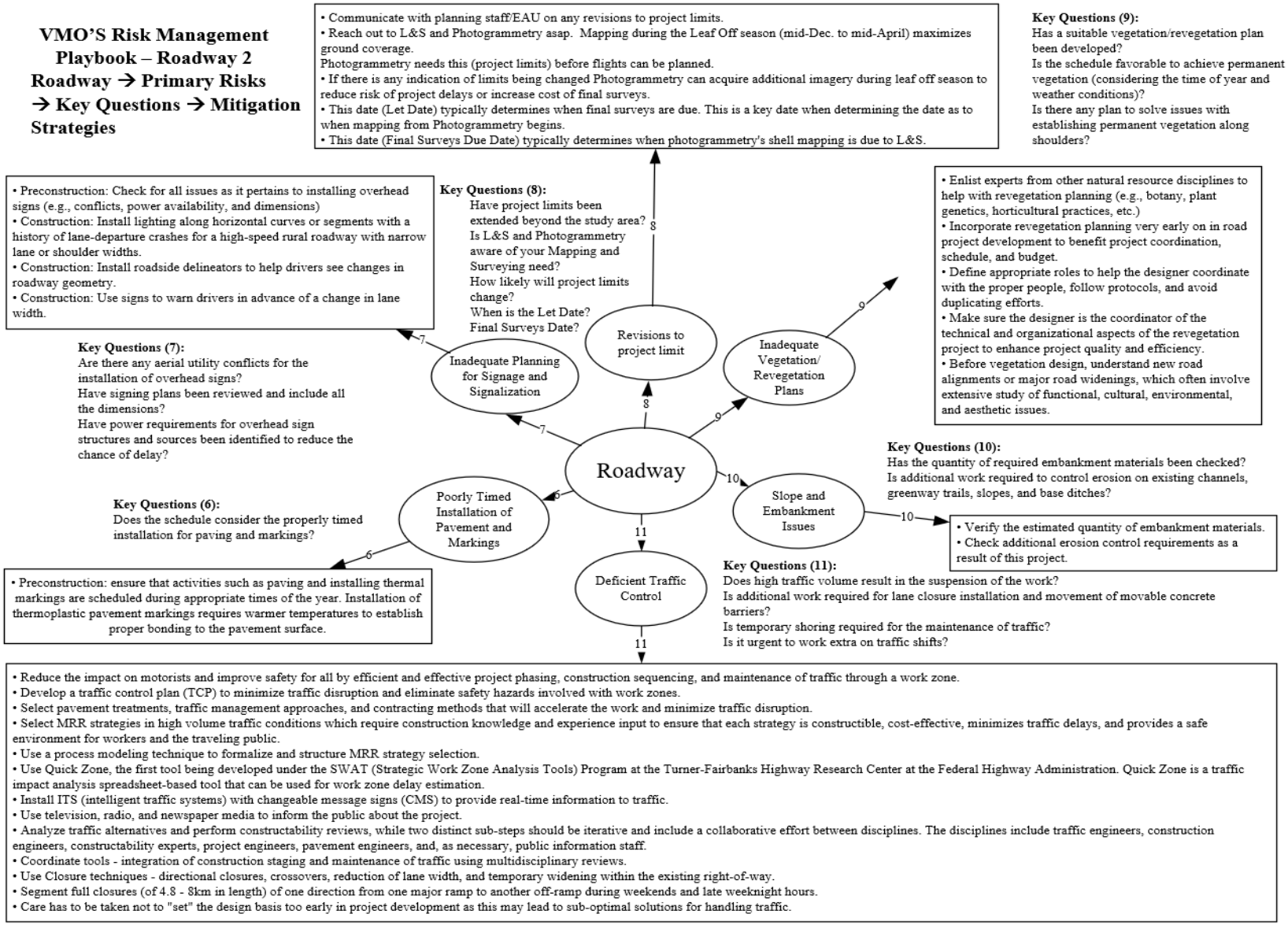

Figure 3.2: NCDOT Risk Management Playbook – Roadway (Part B).

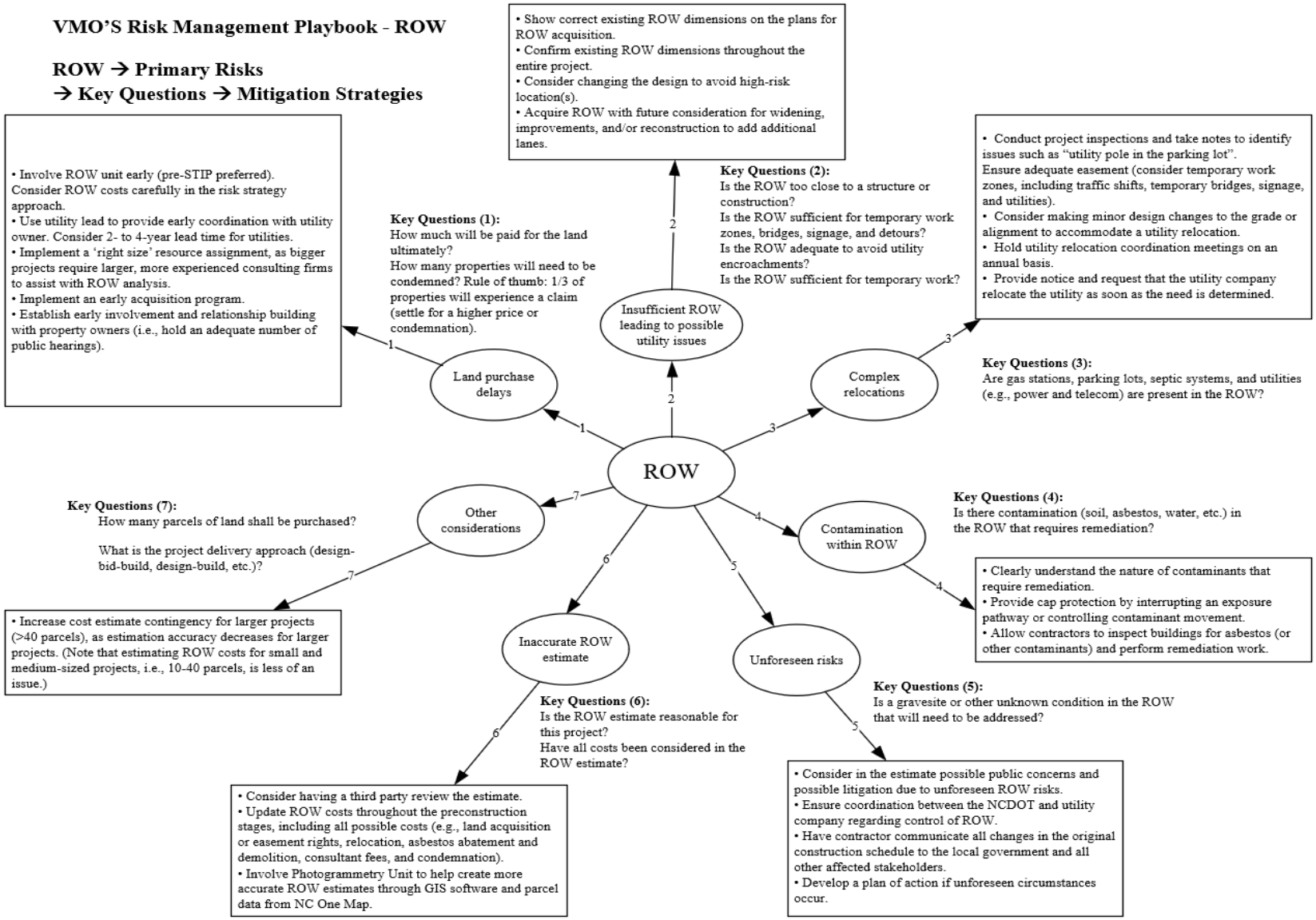

Figure 3.3: NCDOT Risk Management Playbook – Right of Way.

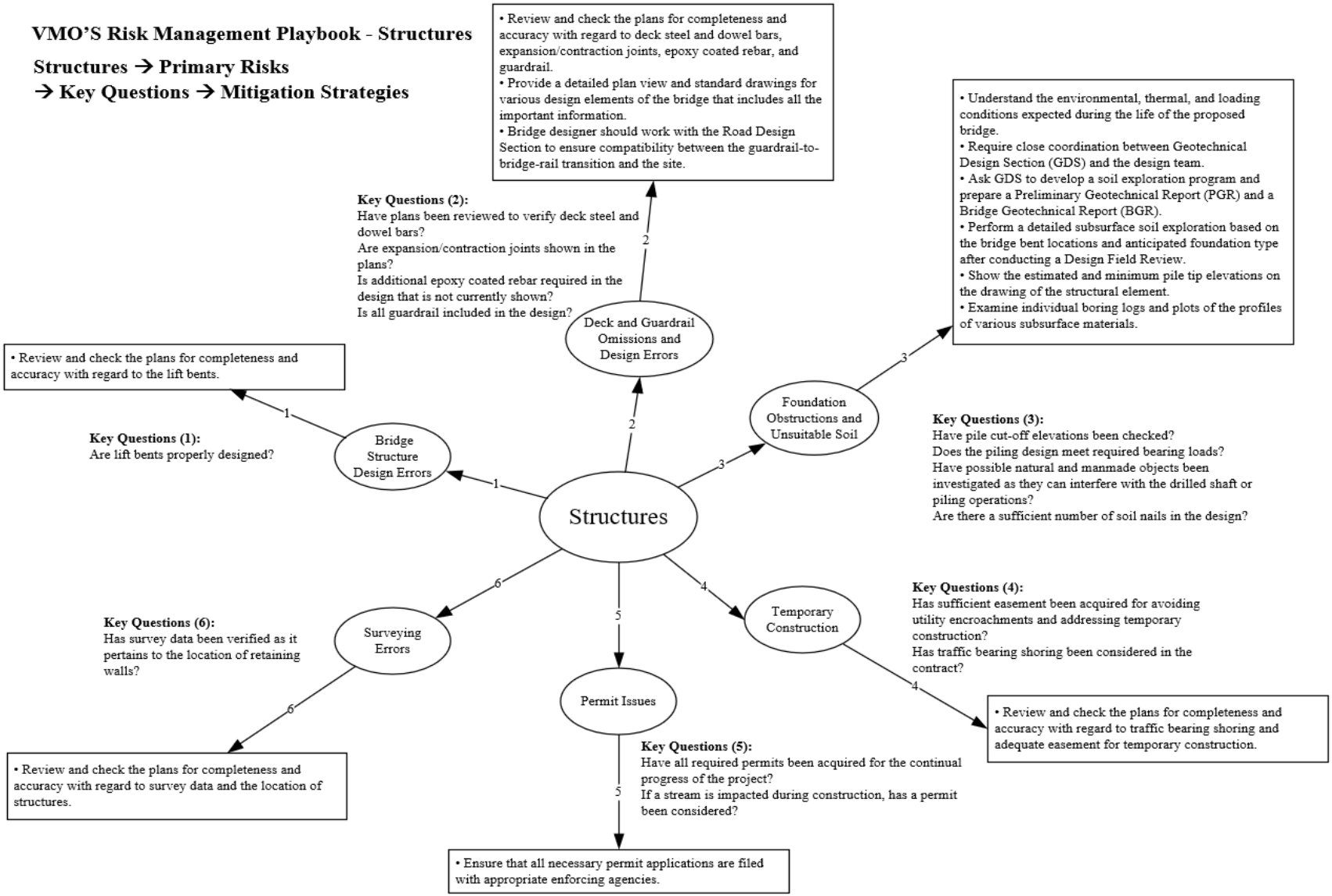

Figure 3.4: NCDOT Risk Management Playbook – Structures.

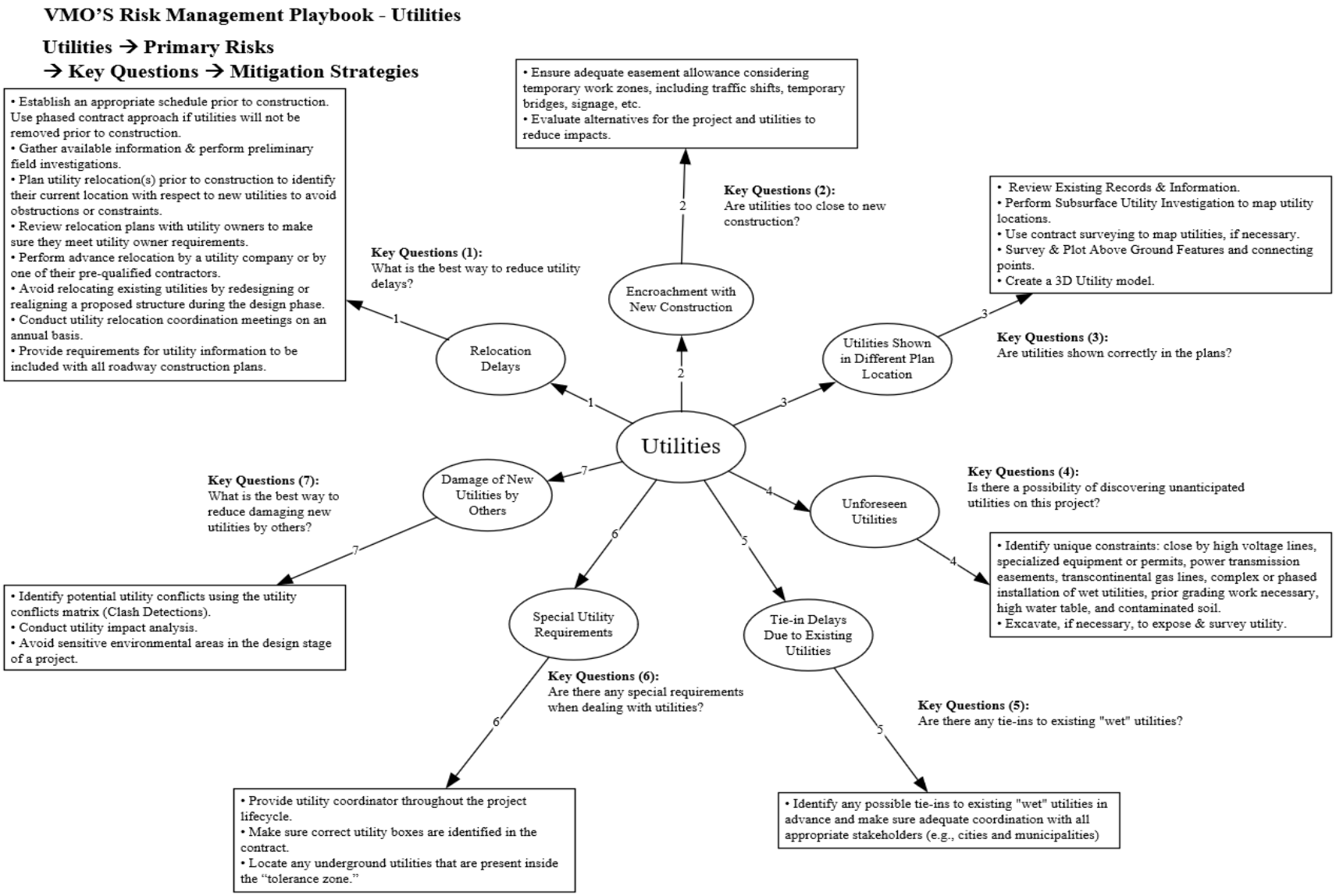

Figure 3.5: NCDOT Risk Management Playbook – Utilities.

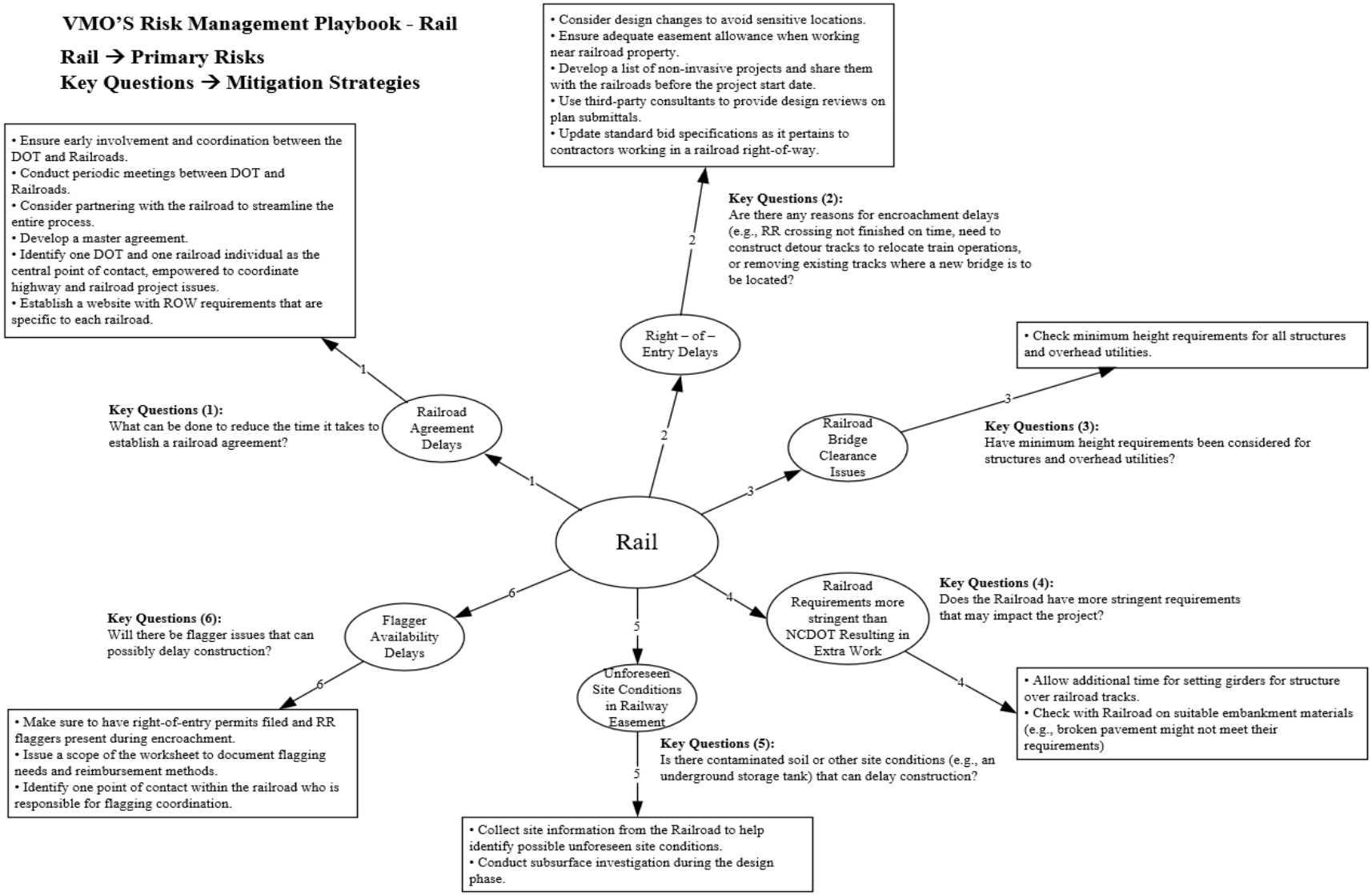

Figure 3.6: NCDOT Risk Management Playbook – Rail.

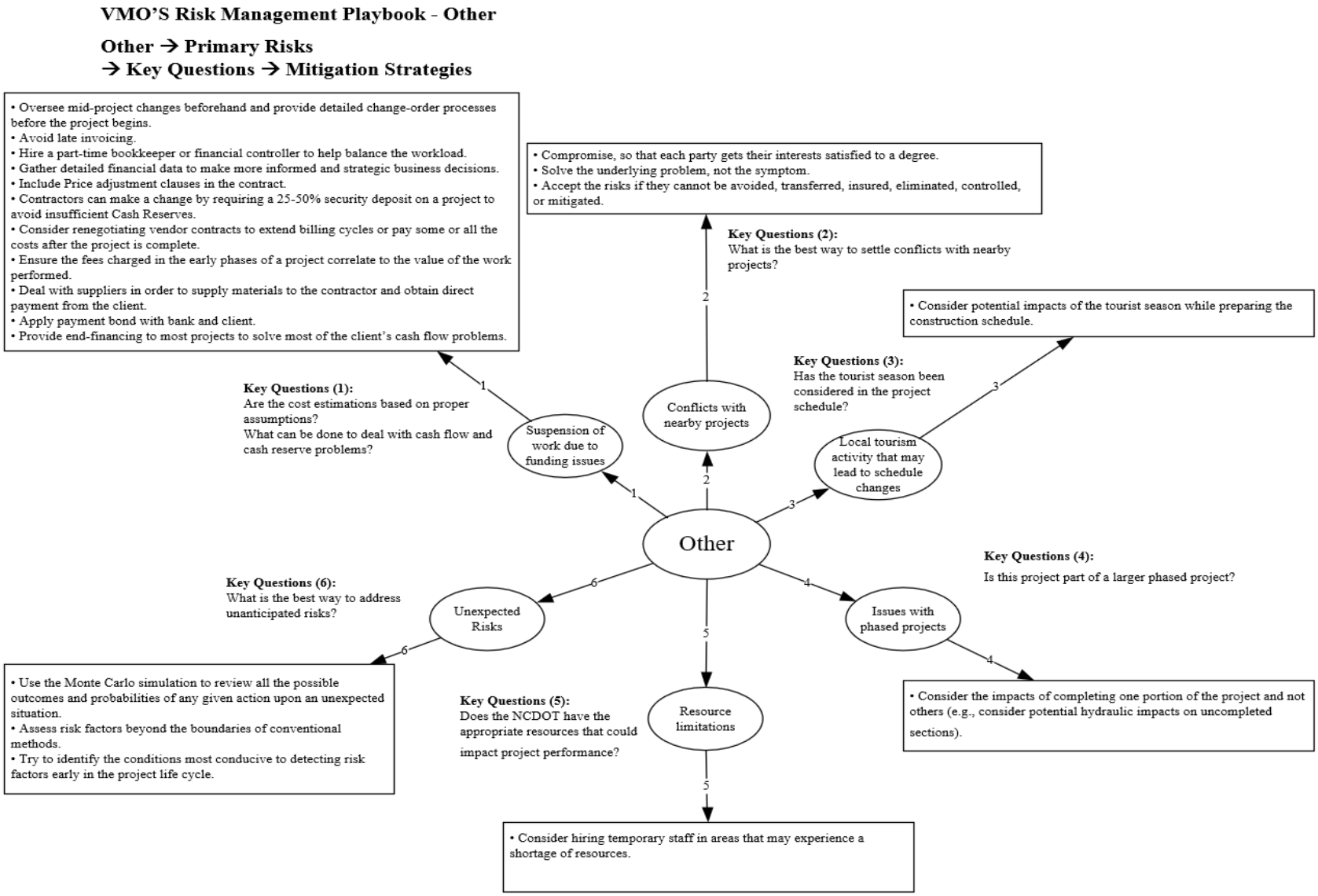

Figure 3.7: NCDOT Risk Management Playbook – Other.

3.4 Discussion and Future Work

The findings of Study II have significant implications for the risk management practices at the NCDOT. Although the Risk Management Playbook has limitations in terms of capturing all potential risks that could arise in a transportation project, and project managers' experience is still a factor in identifying and mitigating the risks, the Playbook nonetheless offers a strong foundation for project teams to identify and reduce risks because it was developed using actual claims and supplementary agreements. One notable aspect of the Playbook that has been positively recognized by NCDOT staff is its organized presentation. The way this tool presents the Primary Risks, Key Questions, and Mitigation Strategies makes the risk identification and response processes more effective for project managers.

Several avenues for future research can be explored to improve the effectiveness of the NCDOT Risk Management Playbook. One promising direction is to assess the efficacy of the Playbook based on actual transportation projects. By collecting data on the projects whose project managers have used the Playbook, the effectiveness of the Playbook in reducing project risks and improving project outcomes could be evaluated. Another area of research that shows promise is the development of automated risk management tools that can be integrated into existing project management software. Such tools would enable project teams to identify and mitigate risks, thereby potentially reducing project delays and cost overruns more efficiently by automating the risk identification and mitigation processes. Finally, to further improve the Playbook, additional categories that are specific to individual NCDOT Units could be developed to provide more comprehensive coverage of potential risks. By capturing a wider range of risks, the Playbook could become an even more effective tool for risk management practices.

In sum, this study has contributed to risk management for transportation projects by developing a comprehensive playbook for the NCDOT. Although the Playbook has limitations, it provides a solid starting point for project teams to identify and mitigate potential risks. Further research is needed to evaluate the Playbook's effectiveness and develop more advanced risk management tools for transportation projects.

3.5 Conclusion

In this Study II, the NCSU research team developed a formal framework to improve the NCDOT's risk management program by providing project teams with the necessary tools and procedures to identify and mitigate potential risks on transportation projects. Common risks and mitigation strategies were identified for six critical areas of transportation projects through a literature review and analysis of NCDOT's past project claims and supplementary agreements. The resulting NCDOT Risk Management Playbook offers project teams a structured approach to identify and address potential risks at each project stage, ultimately leading to better risk management outcomes and a more effective program overall. This work can be integrated into the NCDOT's formal risk management program, which is currently under development, and the identified mitigation strategies can be added to the Communicate Lessons, Exchange, Advice, Record (CLEAR) program, which is a SharePoint platform used at the NCDOT to collect employee-generated ideas, best practices, and lessons learned.

4 CONCLUSION, LIMITATIONS, AND FUTURE WORK

Transportation projects involve a multitude of challenges and risks that significantly impact their budget and schedule. Numerous state DOTs have proactively established risk management programs to mitigate issues that lead to cost and schedule overruns. Within the NCDOT, an initiative has been initiated through its VMO to identify opportunities for enhancing the NCDOT's existing risk management program. In alignment with this larger project, a thorough examination of the NCDOT's program and those of other DOTs has revealed several areas for opportunities to enhance the NCDOT's risk management program. The project that is the focus of this report is comprised of two comprehensive studies that address the identified areas for enhancement within the NCDOT's risk management practices.

In Study I, the NCSU research team conducted rigorous analysis of nearly 3,800 past project claims and supplementary agreements. The primary objective of this study was to develop a robust tool, the NCDOT Risk Insights Tool, to provide project managers with a valuable resource for accessing project-specific risks. By leveraging this tool, project managers are now empowered to identify and assess risks effectively, thereby facilitating improved risk management practices at the NCDOT.

Study II was focused on developing the Risk Management Playbook, which resembles a risk list with associated mitigation strategies. The NCDOT Risk Management Playbook encompasses Primary Risks, Key Questions, and Mitigation Strategies across six construction project areas. The methodology employed for this study involved analyzing NCDOT's claims and supplementary agreements, conducting a comprehensive literature review, and engaging in interviews with NCDOT staff to identify risks and their corresponding mitigation strategies.

In terms of future work, several avenues for enhancing the risk management practices at the NCDOT and promoting industry-wide improvements can be explored. Integrating the developed tools (the Risk Insights Tool and Risk Management Playbook) into the NCDOT's formal risk management program, which is currently under development, is recommended. This integration would provide project teams with standardized tools and procedures for identifying, assessing, and mitigating risks, thereby enhancing the program's effectiveness. To evaluate the impact of these tools on actual transportation projects, conducting evaluations and comparing project outcomes with and without the tools' use would provide valuable insights into their effectiveness in reducing project risks and improving overall project outcomes. Also, the effectiveness of the NCDOT Risk Management Playbook could be expanded to cover additional categories specific to individual NCDOT Units and enhance the Playbook's effectiveness in addressing potential risks. By capturing a more comprehensive range of risks, the Playbook thus could become an even more valuable tool for risk management practices, ensuring that all relevant risks are adequately considered.

Promoting collaboration among transportation agencies and sharing best practices can significantly improve risk management practices across the industry. Future research also could explore opportunities for knowledge exchange, collaborative research efforts, and establishing standardized risk management frameworks. Such initiatives would foster a more comprehensive and consistent approach to risk identification, assessment, and mitigation, thereby improving project outcomes and industry-wide advancements.

Given the extensive analysis of almost 3,800 claims and supplementary agreements that was undertaken in the two studies outlined in this report, the utilization of natural language processing and machine learning technologies also holds promise for future efforts. Automating

the content analysis process and analyzing the entire dataset would be possible by training models based on the items identified from content analysis. This approach would allow a more comprehensive understanding of the risks and their impacts instead of analyzing only a sample of the claims and supplementary agreements. Applying these advanced technologies would expedite the identification of risks, improve data analysis efficiency, and enhance the accuracy of risk assessments.

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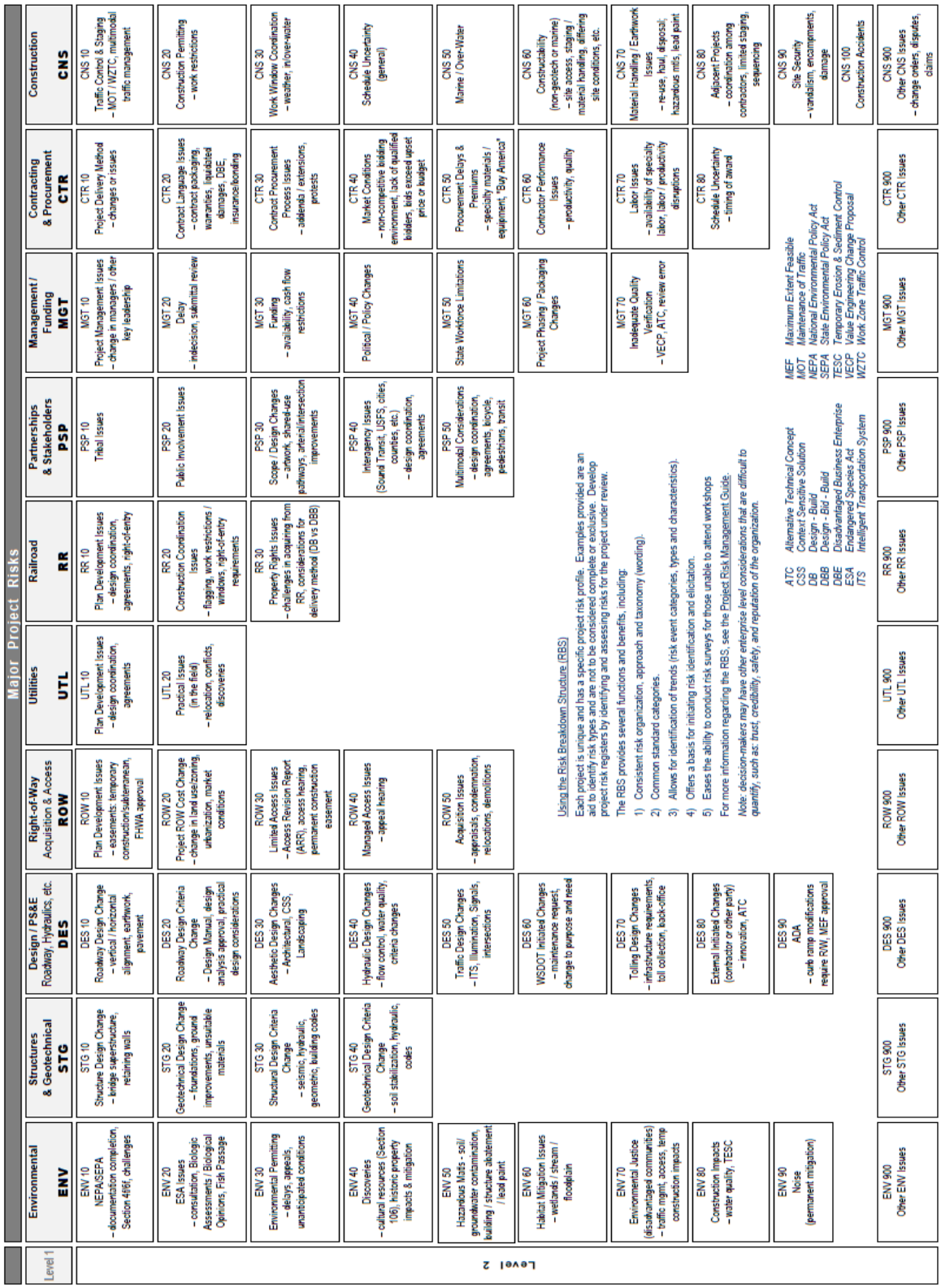
6 APPENDICES

6.1 Appendix A: Washington State Department of Transportation's Risk Breakdown Structure [42]



6.2 Appendix B: Risk Insight Tool

Table B.1: Generic Causes and Impacts of Claims for All Project Types

Generic Cause	Generic Cause Level 2	Count	Generic Cause Level 2 to Generic Cause Ratio	Total	% Total	Average Cost per Claim	Expected Cost per Claim	Average Time Granted per claim	Expected Time Granted per claim
Design/Plan Issues	Compliance with Standard Specifications	12	4.7%	258	16.2%	$64,426.24	$10,414.77	53.6	8.7
	Design/Plan Error-Unspecified	71	27.5%						
	Design/Plan Revision-Unspecified	172	66.7%						
	Increased Traffic Volume	3	1.2%						
Issues with Underground Utilities	Utilities not Relocated on Time	72	30.6%	235	14.7%	$165,812.26	$24,414.71	95.6	14.1
	Utility Conflict	163	69.4%						
Natural Disaster	Natural Disaster-Drought	2	1.4%	141	8.8%	$37,302.78	$3,295.55	27.2	2.4
	Natural Disaster-Flood	1	0.7%						
	Natural Disaster-Hurricane	133	94.3%						
	Natural Disaster-Sinkhole	1	0.7%						
	Natural Disaster-Slide	2	1.4%						
	Natural Disaster-Thunderstorm	1	0.7%						
	Natural Disaster-Tropical Depression	1	0.7%						
Scheduling and Coordination Issues (Except Start of Work and/or project closeout)	Conflict/Overlap with Other Projects	11	7.8%	141	8.8%	$137,963.92	$12,188.54	37.4	3.6
	Coordination Issues-DOT Personnel Unavailability	12	8.5%						
	Coordination Issues-Unspecified	3	2.1%						
	Early Project Completion	1	0.7%						
	Miscommunication (Construction Progress)	3	2.1%						
	Purposeful Limited Work Schedule	42	29.8%						
	Scheduling Conflicts-Inspection	10	7.1%						
	Timely Completion of Project	1	0.7%						
	Waiting for Other Entities to Perform Work	13	9.2%						
	Work Out of Sequence	9	6.4%						

	Work Restriction-Social Event	20	14.2%						
	Work Restriction-Unspecified	16	11.3%						
Contract Amendment	Contract Error	6	4.7%	127	8.0%	$695,798.92	$55,367.46	69.2	5.0
	Contract Time Adjustment	4	3.1%						
	Contractor Replacement	2	1.6%						
	Elimination of Contract Line Item	9	7.1%						
	Error in Entering Time Extensions in HiCAMS	49	38.6%						
	Line Item Omission	23	18.1%						
	Revise Measurement and Payment Method	2	1.6%						
	Settlement and Release Agreement	27	21.3%						
	Unavailability of Funds/Cash Flow Considerations	5	3.9%						
Project Closeout Issues	Delay in Project Acceptance	1	0.9%	109	6.8%	$2,000.00	$136.59	19.2	1.5
	Delay in Receipt of Final Punchlist	1	0.9%						
	Final Punchlist Extra Work	12	11.0%						
	Scheduling Conflicts-Final Inspection/Punchlist	95	87.2%						
Constructability Issues (Except Geotechnical/Underground Conflicts)	Conflict with Existing (Surface) Objects	4	4.3%	94	5.9%	$34,563.11	$2,035.67	79.9	5.2
	Constructability Issues-Seasonal Limitations (Weather)	87	92.6%						
	Constructability Issues-Unspecified	3	3.2%						
Quantities Overrun/Underrun	Quantities Overrun/Underrun-Unspecified	76	100.0%	76	4.8%	$ 98,518.41	$4,691.35	32.1	0.9
M&R/Replacement	M&R/Replacement-Damaged Objects	4	5.3%	75	4.7%	$41,356.24	$1,943.43	68.9	2.5
	M&R/Replacement-Unspecified	68	90.7%						
	Vehicular Accident	3	4.0%						
Environmental/ Community Concerns	Animal Protection/Endangered Species	2	2.9%	68	4.3%	$8,527.21	$363.31	117.3	5.2
	Environmental Concerns/Unspecified	6	8.8%						
	Erosion Control Problems	4	5.9%						
	Historical Site	1	1.5%						

	Vegetation Establishment	53	77.9%						
	Wetland Discovery	2	2.9%						
Design Approval Waiting Period/Indecision/Negotiation	Document Misplacement	1	1.8%	55	3.4%	$16,409.96	$565.51	51.9	2.1
	Indecision-Unspecified	31	56.4%						
	Negotiation Delays	2	3.6%						
	Untimely Receipt of Design	3	5.5%						
	Untimely Review and Return of Submittals	14	25.5%						
	Untimely Review of Approvals	4	7.3%						
Differing Site Conditions (Except Utilities)	Differing Site Conditions-Buried Objects	10	20.4%	49	3.1%	$18,494.21	$567.80	32.0	0.8
	Differing Site Conditions-Contaminated Groundwater	1	2.0%						
	Differing Site Conditions-Contaminated Soil	2	4.1%						
	Differing Site Conditions-Groundwater Discovery/High Groundwater Level	8	16.3%						
	Differing Site Conditions-Hazardous Materials	4	8.2%						
	Differing Site Conditions-Incomplete Work by Others	7	14.3%						
	Differing Site Conditions-Unspecified	3	6.1%						
	Differing Site Conditions-Unsuitable Materials	14	28.6%						
Procurement Issues	DOT Furnished Materials/Equipment Delays	6	12.5%	48	3.0%	$20,273.35	$609.72	77.5	2.5
	Material Acquisition Delays/Long Lead Items	11	22.9%						
	Material Cost Fluctuation	2	4.2%						
	Material Fabrication Delay	1	2.1%						
	Power Supply Delays	17	35.4%						
	Unavailability of Materials/Material Shortage	8	16.7%						
	Wrong Order Placement	3	6.3%						
Access/ROW/Easement	Extra Work Associated with ROW Agreement	2	5.9%	34	2.1%	$754,429.91	$16,071.82	78.6	1.8
	Insufficient Right of Entry	1	2.9%						
	Insufficient ROW	3	8.8%						
	Railroad Right of Entry	9	26.5%						

	Right of Entry Acquisition Delays	1	2.9%						
	ROW Acquisition Delays-Property Owners Agreement	2	5.9%						
	ROW Acquisition Delays-Unspecified	16	47.1%						
Start Date Delays	Delay in Availability of Project	1	3.0%	33	2.1%	$-	$-	29.5	0.7
	Delay in Contract Execution	16	48.5%						
	Delay in Preconstruction Meeting	9	27.3%						
	Delay in Project Award	4	12.1%						
	Delay in Receipt of Contract Information and Bonds	1	3.0%						
	Start Date Delays-Unspecified	2	6.1%						
Survey/Test Issues	Additional Survey-Test Required	4	16.7%	24	1.5%	$51,268.07	$770.95	16.3	0.2
	Survey Error	18	75.0%						
	Survey Results Delays	2	8.3%						
Permit	Insufficient Permit	2	11.8%	17	1.1%	$44,341.66	$472.31	47.6	0.6
	Permit Acquisition Waiting Period	11	64.7%						
	Permit Expiration	1	5.9%						
	Permit Limitation	2	11.8%						
	Permit Violation	1	5.9%						
Other	Covid 19 Impact	3	25.0%	12	0.8%	$45,898.37	$345.10	120.1	0.6
	Lawsuit Costs	1	8.3%						
	Misinterpretation of Plans	2	16.7%						
	Unavailability of Labor	2	16.7%						
	Unforeseen Issues-Unspecified	4	33.3%						

Table B.2: Generic and Specific Causes and Impacts of Supplementary Agreements for All Project Types

Generic Cause	Specific Cause (Generic Cause Level 2)	Specific Cause (#)	Specific Cause (%)	Generic Cause (#)	Generic Cause (%)	Average Cost per supplementary agreement ($)	Expected Cost per supplementary agreement ($)
Access/ROW/Easement	Easement Acquisition Delays	1	1.9	54	2.5	26,726.07	662.93
	Extra Work Associated with ROW Agreement	11	20.4				
	Insufficient ROW	10	18.5				
	Insufficient Utility Easement	2	3.7				
	Property Owners Access	10	18.5				
	Providing Access to Site	6	11.1				
	Railroad Right of Entry Delays	2	3.7				
	ROW Acquisition Delays	1	1.9				
	ROW Revision	1	1.9				
	Traffic Access Point	10	18.5				
Constructability Issues (Except Geotechnical/Underground Conflicts)	Conflict with Existing (Surface) Objects	24	21.4	112	5.1	34,581.11	1,779.09
	Constructability Issues: Unspecified	87	77.7				
	Height Clearance Issues	1	0.9				
Construction Method Revision	Construction Method Revision: Unspecified	75	100.0	75	3.4	183,383.72	6,317.77
Contract Amendment	Change in Contract Provisions	6	1.9	324	14.9	52,388.51	7,796.91
	Contingency Item	1	0.3				
	Elimination of Contract Line Item	7	2.2				
	Insufficient Insurance	1	0.3				
	Issues with Previous Supplementary Agreement	6	1.9				
	Line Item Omission	269	83.0				

	Material Substitution Allowance	2	0.6				
	Mitigation of Potential Risk	2	0.6				
	Permission to Hold Additional Retainage	1	0.3				
	Revise Measurement and Payment Method	18	5.6				
	Risk Management	1	0.3				
	Settlement and Release Agreement	5	1.5				
	Unavailability of Funds/Cash Flow Considerations	5	1.5				
Design/Plan Issues	Compliance with Standard Specifications	65	11.1	583	26.8	75,025.98	20,091.94
	Construction Plans Error/Discrepancy	40	6.9				
	Design Error: Elevation Difference with Existing Objects	19	3.3				
	Design Error: Unspecified	49	8.4				
	Design Revision: Achieve Higher/Acceptable Quality	16	2.7				
	Design Revision: Change in Design Criteria	1	0.2				
	Design Revision: Fix Impacts of Previous Revisions	10	1.7				
	Design Revision: Functionality Issues	8	1.4				
	Design Revision: Future Maintenance Concerns	16	2.7				
	Design Revision: per Contractor Request	36	6.2				
	Design Revision: Toll Collection	1	0.2				
	Design Revision: Uniformity with Adjacent Projects/Objects	8	1.4				
	Design Revision: Unspecified	275	47.2				

	Design Revision: Value Engineering Proposal	10	1.7				
	Incomplete Design	3	0.5				
	Increased Traffic Volume	9	1.5				
	Scope Change	17	2.9				
Differing Site Conditions (Except Utilities)	Differing Site Conditions: Buried Objects	2	1.2	173	7.9	32,991.12	2,621.71
	Differing Site Conditions: Changes in Site After Bid/During Construction	4	2.3				
	Differing Site Conditions: Contaminated Soil	3	1.7				
	Differing Site Conditions: Encountered Rock	3	1.7				
	Differing Site Conditions: Extra Work from Previous Projects	4	2.3				
	Differing Site Conditions: Groundwater Discovery/High Groundwater Level	12	6.9				
	Differing Site Conditions: Incomplete Work by Others	2	1.2				
	Differing Site Conditions: Not Shown in Construction Plans	25	14.5				
	Differing Site Conditions: Unspecified	71	41.0				
	Differing Site Conditions: Unsuitable Materials	20	11.6				
	Slope Protection/Soil Stabilization	27	15.6				
Drainage Issues	Drainage Issues: Unspecified	36	87.8	41	1.9	13,523.69	254.70
	Stormwater Concerns	5	12.2				
Environmental/Community Concerns	Animal Protection/Endangered Species	3	9.4	32	1.5	514,825.62	7,567.49
	Avoid Historical Structure	1	3.1				
	Construction Impacts	2	6.3				
	Environmental Concerns: Unspecified	8	25.0				

	Natural Disaster (Drought)	1	3.1				
	Noise Control	2	6.3				
	Vegetation Establishment	13	40.6				
	Wetland Delineation	2	6.3				
Erosion Control Problems	Erosion Control Problems: Unspecified	52	96.3	54	2.5	14,589.70	361.89
	Waste Site Erosion Control	2	3.7				
Issues with Underground Utilities	Inability to Locate Utilities	7	5.5	127	5.8	29,096.63	1,697.41
	Utilities not Relocated on Time	7	5.5				
	Utility Conflict	113	89.0				
M&R/Replacement	Damaged Objects	6	3.8	156	7.2	42,963.24	3,078.67
	M&R/Replacement: Unspecified	147	94.2				
	Vehicular Accident	3	1.9				
Other	Contractor Error	2	12.5	16	0.7	11,380.93	83.64
	Covid 19 Impact	2	12.5				
	Equipment/Items Protection	3	18.8				
	Permit Acquisition Issues	1	6.3				
	Permit Requirements	4	25.0				
	Permit Restrictions	2	12.5				
	Site Security	2	12.5				
Procurement Issues	Error in Bill of Materials	2	6.7	30	1.4	14,827.20	204.33
	Material Acquisition Delays/Long Lead Items	5	16.7				
	Material Fabrication Delay	1	3.3				
	Shop Drawing Error	3	10.0				
	Unavailability of Materials/Material Shortage	18	60.0				
	Wrong Order Placement	1	3.3				
Quantities Overrun/Underrun	Quantities Overrun/Underrun: Unspecified	48	96.0	50	2.3	84,632.44	1,943.79
	Waste Excessive Material	2	4.0				
	Falling Hazard	5	4.2	118	5.4	30,830.56	1,671.11

Safety Concerns (Except Contaminated Soil)	Hazardous Materials Removal	8	6.8				
	Safety Concerns: Unspecified	91	77.1				
	Sight Distance Concerns	1	0.8				
	Travelers/Public Safety	12	10.2				
	Tripping Hazard	1	0.8				
Scheduling and Coordination Issues	Additional Intermediate Contract Time (ICT)Required	1	2.9	34	1.6	230,636.14	3,602.03
	Availability Date Delays	5	14.7				
	Conflict with Other Projects	2	5.9				
	Conflict/Overlap with Adjacent Projects	3	8.8				
	Early Project Completion	14	41.2				
	Miscommunication (Construction Progress)	1	2.9				
	Overtime Hour Request	1	2.9				
	Project Phasing Problems	3	8.8				
	Statewide Initiative to Accelerate Projects	2	5.9				
	Timely Completion of Project	2	5.9				
Stakeholder Request	DOT Request: Unspecified	71	39.9	178	8.2	178,200.68	14,570.38
	Stakeholder Request: Future Development Concerns	11	6.2				
	Stakeholder Request: Unspecified	96	53.9				
Survey/Test Issues	Additional Survey/Test Required	6	30.0	20	0.9	23,243.90	213.54
	Survey Error: Staking	5	25.0				
	Survey Error: Unspecified	9	45.0				

6.3 Appendix C: North Carolina Department of Transportation Risk Management Playbook

This Appendix C describes the components of the NCDOT Risk Management Playbook and includes the Primary Risks, with Key Questions and Mitigation Strategies, for each of the six critical areas: Roadway, Right-of-Way, Structures, Utilities, Rail, and Other.

6.3.1 NCDOT Playbook – Roadway

Primary Risk: Regulatory and safety requirements for borrow and waste pits

Key Questions:

- Is extra work required for the Corps of Engineers to provide technical data?
- Has the NC Department of Environmental Quality approved the land quality of the pits?
- Have land costs been considered properly in the estimates?
- Are high voltage lines present in the borrow pit area, which could lead to the possibility of less efficient hauling of unclassified excavation materials?
- Has sufficient time been scheduled for the establishment of vegetation for the waste pit to avoid final acceptance delays by the NC Department of Natural Resources?
- Will the contractor need to perform an environmental impact study as a prerequisite for reimbursement?

Mitigation Strategies:

- Obtain written approval from local authorities for use of the proposed site.
- Undertake a preliminary site assessment prior to excavation work.
- Confirm the extent and quality of the materials within the proposed site by drilling boreholes and/or excavating test pits.
- Ensure that high voltage lines will not interfere with hauling operations.
- Decommission test pits and boreholes unless they are used as borrow sites.

Primary Risk: Substandard subgrade quality

Key Questions:

- Are subgrade properties that could impact future pavement performance adequately understood?

Mitigation Strategies:

- Understand the soil properties, proper grading practices, and quality control testing requirements to achieve a high-quality subgrade.
- Determine the non-uniform geotechnical conditions throughout the pavement that could contribute to local permanent deformation.
- Conduct a geotechnical study to evaluate specific problems (e.g., excessive subgrade rutting, aggregate contamination or degeneration, subgrade pumping, poor drainage, frost action, and/or swelling soil) and recommend procedures to mitigate potential problems.
- Test the soil to determine the bearing capacity that relates to moisture and density information, as the pavement and designed base course thickness depend on the resultant subgrade strength.

- Perform quality control and quality assurance testing and compare actual performance with predicted performance.

Primary Risk: Inadequate understanding of site hydraulic characteristics

Key Questions:

- Have frames, pipes, and boxes been designed properly?
- Have appropriate grates been considered for the intended use of the roadway (e.g., bicycle traffic)?

Mitigation Strategies:

- Ensure that pipe ends, culvert wing walls, and headwalls adjacent to the roadway do not extend past the surrounding ground.
- Install a grated inlet to prevent water ponding at access points.
- Install flexible lining for ditches with heavy runoff.
- Install safe bicycle grates when expecting bicycle traffic.
- Clean the ditches regularly to prevent silting and forcing water back onto the roadway surface or into the sub-base of the pavement.
- Restore eroded and silted areas around barrier posts, breakaway sign supports, and highway light supports to the desired ground level, and seed those areas. If the area continues to erode, install bituminous overlays.

Primary Risk: Surveying errors and omissions

Key Questions:

- Have probable sources of surveying errors been considered?
- Has the survey equipment been maintained and calibrated properly?

Mitigation Strategies:

- Use a terrestrial laser scanner (TLS) to create 3D site models.
- Maintain routine care of equipment.
- Acclimatize the survey instruments to outside conditions prior to final setup in cold or hot weather when using vehicle climate control.
- Use mapping grade receivers to export collected data to an external database, such as a geographical information system (GIS).
- Before commencing a GPS project, obtain the latest versions of all software, adjust all tribraches, and visually check all cables and connections.
- Employ electronic distance measuring instruments, such as total stations.
- Use hand levels for the quick location of turn and instrument points and conduct elevation checks during grading operations.
- Use digital levels for all surveys that require elevations.
- Analyze traverse closure errors to identify and mitigate specific types of error.
- Use sight distances that best fit the terrain and are most comfortable for the instrument operator. Sight distances should not exceed 200 ft (60 m).

- Set benchmarks prior to or during leveling. Check for all found monuments that are to be incorporated in the level line for stability.

Primary Risk: Driveway issues

Key Questions:
- Have all driveways been identified and taken into account for roadway construction?
- Has the possibility of driveway flooding been considered? From roadside ditch? From nearby stream?

Mitigation Strategies:
- Using eco-friendly permeable pavers, such as TRUEGRID© pavers, to help solve flooded driveway problems.
- Implement seal-coating, a cost-saving preventive maintenance process that can slow the natural degradation process.
- Prevent future root intrusion by installing a root barrier between the planted area and asphalt surface.
- Install a transition mill and asphalt overlay.
- Install a modified concrete base where a high water table affects the surface or inadequate installation results in base failure.

Primary Risk: Poorly timed installation of pavement and markings

Key Questions:
- Does the schedule accommodate the properly timed installation of pavement and markings?

Mitigation Strategies:
- Ensure that activities such as the paving and installation of thermal markings are scheduled during appropriate times of the year. For example, the installation of thermoplastic pavement markings requires warm temperatures to establish proper bonding to the pavement surface.

Primary Risk: Inadequate planning for signage and signalization

Key Questions:
- Are there any aerial utility conflicts that could affect the installation of overhead signs?
- Have signage plans been reviewed and do they include all necessary dimensions?
- Have power requirements for overhead sign structures and sources been identified to reduce the chance of delay?
- Has sufficient ROW been acquired for the installation of signs?

Mitigation Strategies:
- Check for all issues that pertain to the installation of overhead signs (e.g., utility conflicts, power availability, and dimensions).

- Install lighting along horizontal curves or segments of high-speed rural roadways that have narrow lanes and/or shoulders and a history of lane departure crashes.
- Install roadside delineators to help drivers see changes in the roadway geometry.
- Install signs to warn drivers of an upcoming change in lane width.

Primary Risk: Slope and embankment issues

Key Questions:

- Has the quantity of required embankment materials been checked?
- Is additional work required to control the erosion of existing channels, greenway trails, slopes, and base ditches?

Mitigation Strategies:

- Verify the estimated quantity of embankment materials.
- Check for additional erosion control requirements that may be needed for this project.

Primary Risk: Inadequate vegetation /revegetation plans

Key Questions:

- Has a suitable vegetation/revegetation plan been developed?
- Is the schedule favorable to achieve permanent vegetation (considering time of year and weather conditions)?
- Does the establishment of permanent vegetation along shoulders involve any potential problems?

Mitigation Strategies:

- Enlist experts from natural resource disciplines (e.g., botany, plant genetics, horticulture, etc.) to help with revegetation planning.
- Incorporate revegetation planning early in the road project development process to benefit project coordination, schedule, and budget.
- Define appropriate roles to help the designer coordinate work with appropriate personnel, follow protocols, and avoid duplicating efforts.
- Ensure that the designer is the coordinator of the technical and organizational aspects of the revegetation project to enhance project quality and efficiency.
- Prior to vegetation design, understand any new road alignments or major road widenings, which often involves extensive study of functional, cultural, environmental, and aesthetic issues.

Primary Risk: Inadequate traffic control

Key Questions:

- Will high-volume traffic result in the suspension of work?
- Is additional work required for lane closures and movable concrete barriers?
- Is temporary shoring required for the control of traffic through the project site?

Mitigation Strategies:

- Reduce project impacts on motorists and improve safety by implementing efficient and effective project phasing, construction sequencing, and control of traffic through the work zone.
- Develop a traffic control plan to minimize traffic disruption and eliminate safety hazards typically associated with work zones.
- Select pavement treatments, traffic management approaches, and contracting methods that will accelerate the work and minimize traffic disruption.
- Select strategies for high-volume traffic conditions that require construction knowledge and experience input to ensure that each strategy is constructible and cost-effective, minimizes traffic delays, and provides a safe environment for workers and the traveling public.
- Use a process modeling technique to formalize and structure the maintenance repair and rehabilitation (MRR) strategy selection.
- Use Quick Zone, which is a traffic impact analysis spreadsheet-based tool that can be used for work zone delay estimation. Quick Zone is a tool being developed under the Strategic Work-Zone Analysis Tools (SWAT) program at the Federal Highway Administration's Turner-Fairbanks Highway Research Center.
- Install intelligent traffic systems with changeable message signs to provide real-time traffic information for drivers.
- Segment full closures (4.8 km to 8 km in length) in one lane direction from one major ramp to another off-ramp during weekends and late weeknight hours.
- Use media to inform the public about the project.
- Analyze traffic alternatives and perform constructability reviews. These two distinct sub-steps should be iterative and include a collaborative effort among traffic engineers, construction engineers, constructability experts, project engineers, pavement engineers, and, as necessary, public information staff.
- Coordinate tools and integrate construction staging and maintenance of traffic via multidisciplinary reviews.
- Use appropriate road closure techniques, including directional closures, crossovers, reduced lane width, and temporary widening within existing right-of-way.
- Dot not set the design basis too early in the project development process to avoid suboptimal solutions for handling traffic.

Primary Risk: Revisions to project limits

Key Questions:

- Have project limits been extended beyond the study area?
- Are the Location and Surveys (L&S) and Photogrammetry Units aware of the project's mapping and surveying needs?
- How likely is it that project limits will change?
- When is the let date?
- When is the final survey date?

Mitigation Strategies:

- Communicate with planning staff and the Environmental Analysis Unit regarding any revisions to project limits.
- Reach out to the L&S and Photogrammetry Units as soon as possible. Mapping during the leaf off-season (mid-December to mid-April) maximizes ground coverage.
- Provide project limits information to the Photogrammetry Unit in good time for the Photogrammetry Unit to plan flights.
- If limits are likely to be changed, then the Photogrammetry Unit can acquire additional imagery during the leaf off-season to reduce the risk of project delays or increase the cost of final surveys.
- Because the let date typically determines when final surveys are due, be aware that it is a key date when determining the date for the Photogrammetry Unit to begin mapping.
- Be aware that the date for the final surveys typically determines when shell mapping by the Photogrammetry Unit is due to the L&S Unit.

6.3.2 NCDOT Playbook – Right of Way

Primary Risk: Land purchase delays

Key Questions:

- How much will be paid for the land ultimately?
- How many properties will need to be condemned? Rule of thumb: 1/3 of properties will experience a claim (settle for a higher price or condemnation).

Mitigation Strategies:

- Involve ROW Unit early (pre-STIP is preferred).
- Consider ROW costs carefully in the risk mitigation strategy approach.
- Use the Utility lead to provide early coordination with utility owner. Consider 2- to 4-year lead time for utilities.
- Implement a 'right size' resource assignment, as bigger projects require larger, more experienced consulting firms to assist with ROW analysis than smaller projects.
- Implement an early acquisition program.
- Establish early involvement and relationship building with property owner(s) (i.e., hold an adequate number of public hearings).

Primary Risk: Insufficient ROW leading to possible utility relocation delays, redesign to accommodate existing easement, and/or purchase of additional easement

Key Questions:

- Is the ROW too close to a structure or construction?
- Is the ROW sufficient for temporary work zones, bridges, signage, and detours?
- Is the ROW adequate to avoid utility encroachments?
- Is the ROW sufficient for temporary work?

Mitigation Strategies:

- Show correct existing ROW dimensions on the plans for ROW acquisition.

- Confirm existing ROW dimensions throughout the entire project.
- Consider changing the design to avoid high-risk locations.
- Acquire ROW with future consideration for widening, improvements, and/or reconstruction to add additional lanes.

Primary Risk: Complex relocations

Key Questions:

- Are gas stations, parking lots, septic systems, and utilities (e.g., power and telecom) present in the ROW?

Mitigation Strategies:

- Conduct project inspections and take notes to identify issues such as "utility pole in the parking lot".
- Ensure adequate easement (consider temporary work zones, including traffic shifts, temporary bridges, signage, and utilities).
- Consider making minor design changes to the grade or alignment to accommodate a utility relocation.
- Hold utility relocation coordination meetings on an annual basis.
- Provide notice and request that the utility company relocate the utility as soon as the need is determined.

Primary Risk: Contamination within ROW

Key Questions:

- Is there contamination (soil, asbestos, water, etc.) in the ROW that requires remediation?

Mitigation Strategies:

- Clearly understand the nature of contaminants that require remediation.
- Provide cap protection by interrupting an exposure pathway or controlling contaminant movement.
- Allow contractors to inspect buildings for asbestos and/or other contaminants and perform remediation work.

Primary Risk: Unforeseen risks

Key Questions:

- Is a gravesite or other unknown condition in the ROW that will need to be addressed?

Mitigation Strategies:

- Consider in the estimate possible public concerns and possible litigation due to unforeseen ROW risks.
- Ensure coordination between the NCDOT and the utility company regarding the control of ROW.

- Have the contractor communicate all changes in the original construction schedule to the local government and all other affected stakeholders.
- Develop a plan of action if unforeseen circumstances occur.

Primary Risk: Inaccurate ROW estimate

Key Questions:
- Is the ROW estimate reasonable for this project?
- Have all costs been considered in the ROW estimate?

Mitigation Strategies:
- Consider having a third party review the estimate.
- Update ROW costs throughout the preconstruction stages, including all possible costs (e.g., costs associated with land acquisition or easement rights, relocation, asbestos abatement and demolition, consultant fees, and condemnation).
- Involve the Photogrammetry Unit to help create more accurate ROW estimates through GIS software and parcel data from NC One Map.

Primary Risk: Other considerations

Key Questions:
- How many parcels of land shall be purchased?
- What is the project delivery approach (design-bid-build, design-build, etc.)?

Mitigation Strategies:
- Increase cost estimate contingency for larger projects (> 40 parcels), as estimation accuracy decreases for larger projects. (Note that estimating ROW costs for small and medium-sized projects, i.e., 10 to 40 parcels, is less of an issue.)

6.3.3 NCDOT Playbook – Structures

Primary Risk: Bridge structure design errors

Key Questions:
- Are lift bents properly designed?

Mitigation Strategies:
- Review and check the plans for completeness and accuracy with regard to lift bents.

Primary Risk: Deck and guardrail omissions and design errors

Key Questions:
- Have plans been reviewed to verify deck steel and dowels?
- Are expansion/contraction joints shown on the plans?
- Is additional epoxy-coated rebar required in the design that is not shown in the plans?

- Are all guardrails included in the design?

Mitigation Strategies:

- Review and check the plans for completeness and accuracy with regard to deck steel and dowels, expansion/contraction joints, epoxy-coated rebar, and guardrails.
- Provide a detailed plan view and standard drawings for the various design elements of the bridge that include all important information.
- Ensure that the bridge designer works with the Road Design Section to ensure compatibility between the guardrail-to-bridge-to-rail transition and the site.

Primary Risk: Foundation obstructions and/or unsuitable soil

Key Questions:

- Have pile cut-off elevations been checked?
- Does the pile design meet sufficient bearing load criteria?
- Have natural and manmade objects been investigated for their possible interference with drilled shafts or piling operations?
- Are soil nails sufficient in terms of number and type in the design?

Mitigation Strategies:

- Understand the environmental, thermal, and loading conditions that are expected during the life of the proposed bridge.
- Require close coordination between the Geotechnical Design Section (GDS) and the design team.
- Ask GDS personnel to develop a soil exploration program and prepare a preliminary geotechnical report and bridge geotechnical report.
- Perform a detailed subsurface soil investigation based on the bridge bent locations and anticipated foundation type after conducting a design field review.
- Ensure that the drawings show the estimated and minimum pile tip elevations of the structural elements.
- Examine individual boring logs and plots of the profiles of the various subsurface materials.

Primary Risk: Temporary construction omissions

Key Questions:

- Has sufficient easement been acquired to avoid utility encroachments and to address temporary construction?
- Has traffic bearing shoring been considered in the contract?

Mitigation Strategies:

- Review and check the plans for completeness and accuracy with regard to traffic bearing shoring and adequate easement for temporary construction.

Primary Risk: Untimely or late permit acquisition

Key Questions:

- Have all required permits been acquired to ensure continual progress of the project?
- Has a permit been considered for the possible impact of a stream during the construction phase?

Mitigation Strategies:

- Ensure that all necessary permit applications are filed with the appropriate enforcement agencies and that they are filed in good time.

Primary Risk: Surveying errors

Key Questions:

- Have survey data been verified as they pertain to the location of retaining walls?

Mitigation Strategies:

- Review and check the plans for completeness and accuracy with regard to survey data and the location of structures.

6.3.4 NCDOT Playbook – Utilities

Primary Risk: Relocation delays

Key Questions:

- What is the best way to reduce utility delays?

Mitigation Strategies:

- Establish an appropriate schedule prior to construction. Use a phased contract approach if utilities will not be removed prior to construction.
- Gather available information and perform preliminary field investigations.
- Plan utility relocations prior to construction to identify their current location with respect to new utilities to avoid obstructions or constraints.
- Review relocation plans with utility owners to ensure that the plans meet utility owner requirements.
- Relocate utilities in advance (by the utility company or one of its prequalified contractors).
- Avoid relocating existing utilities by redesigning or realigning a proposed structure during the design phase.
- Conduct utility relocation coordination meetings on a regular basis.
- Require that utility information is included with all roadway construction plans.

Primary Risk: Encroachment on new construction

Key Questions:

- Are utilities too close to new construction?

Mitigation Strategies:

- Ensure adequate easement to accommodate temporary work zones, including traffic shifts, temporary bridges, signage, etc.
- Evaluate alternatives for the project and utilities to reduce impacts.

Primary Risk: Utilities shown in different plan location

Key Questions:

- Are utilities shown correctly in the plans?

Mitigation Strategies:

- Review existing utilities records and information.
- Perform subsurface utility investigation to map utility locations.
- Conduct contract survey to map utilities, if necessary.
- Survey and plot above-ground features and connecting points.
- Create a 3D utility model.

Primary Risk: Unforeseen utilities

Key Questions:

- Is the discovery of unanticipated utilities possible on this project?

Mitigation Strategies:

- Identify unique constraints, such as nearby high voltage lines, specialized equipment or permits, power transmission easements, transcontinental gas lines, complex or phased installation of wet utilities, prior grading work, high water table, and/or contaminated soil.
- Excavate, if necessary, to expose and survey utilities.

Primary Risk: Tie-in delays due to existing utilities

Key Questions:

- Are there any tie-ins to existing wet utilities?

Mitigation Strategies:

- Identify any possible tie-ins to existing wet utilities in advance and ensure adequate coordination with all appropriate stakeholders (e.g., owners and municipalities).

Primary Risk: Special utility requirements

Key Questions:

- Are there any special requirements when dealing with utilities?

Mitigation Strategies:

- Provide a utilities coordinator to be available throughout the project's lifecycle.
- Ensure that correct utility boxes are identified in the plans.
- Locate any underground utilities that are inside the tolerance zone.

Primary Risk: Damage of new utilities by others

Key Questions:
- What is the best way to mitigate damage to new utilities made by others?

Mitigation Strategies:
- Identify potential utility conflicts using a utility conflicts matrix (Clash Detections).
- Conduct utility impact analysis.
- Avoid sensitive environmental areas in the design stage of the project.

6.3.5 NCDOT Playbook – Rail

Primary Risk: Railroad agreement delay

Key Questions:
- How can the time to establish a railroad agreement be reduced?

Mitigation Strategies:
- Ensure early involvement and coordination between the NCDOT and railroad company.
- Conduct periodic meetings between the NCDOT and railroad company.
- Consider partnering with the railroad company to streamline the entire process.
- Develop a master agreement.
- Identify one NCDOT representative and one railroad company representative as the central points of contact and empower those persons to coordinate highway and railway project issues.
- Establish a website with ROW requirements that are specific to each railroad company.

Primary Risk: Right-of-entry delay

Key Questions:
- What are the reasons for any encroachment delays (e.g., RR crossing not finished on time, the need to construct detour tracks to relocate train operations, or removing existing tracks where a new bridge is to be located)?

Mitigation Strategies:
- Consider design changes to avoid high-risk locations.
- Ensure adequate easement when working near railroad property.
- Use third-party consultants to provide a design review of plan submittals.
- Update standard bid specifications as they pertain to contractors working in a railway right-of-way.
- Determine railroad company's insurance requirements.

Primary Risk: Railroad bridge clearance issues

Key Questions:

- Have minimum height requirements been considered for structures and overhead utilities?

Mitigation Strategies:

- Check with railroad company regarding suitable clearance requirements.

Primary Risk: Railroad company's specific requirements are more stringent than those of the NCDOT, resulting in extra work

Key Questions:

- Does the railroad company have more stringent requirements than the NCDOT that may impact the project?

Mitigation Strategies:

- Allow additional time for setting girders for any structure over railroad tracks.
- Check with railroad company regarding suitable embankment materials (e.g., broken pavement might not meet the railroad company's requirements).

Primary Risk: Unforeseen site conditions within railway easement

Key Questions:

- Is there contaminated soil or other site conditions (e.g., an underground storage tank) that could delay construction?

Mitigation Strategies:

- Collect site information from the railroad company to help identify possible unforeseen site conditions.
- Conduct subsurface investigations during the design phase.

Primary Risk: Flagger availability delay

Key Questions:

- Will flagger issues possibly delay construction?

Mitigation Strategies:

- Make sure to have right-of-entry permits filed and railway flaggers present during encroachment.
- Issue a Scope of Work worksheet to document flagging needs and the reimbursement method.
- Identify one point of contact within the railroad company who is responsible for coordination of flagging.

6.3.6 NCDOT Playbook – Other

Primary Risk: Suspension of work due to funding issues

Key Questions:

- Are the cost estimations based on proper assumptions?
- How should cash flow and cash reserve problems be addressed?

Mitigation Strategies:

- Avoid late invoicing.
- Hire a part-time bookkeeper or financial controller to help balance the workload.
- Gather detailed financial data to make informed and strategic business decisions.
- Include price adjustment clauses in the contract.
- Allow contractors to make a change by requiring a 25% to 50% security deposit to avoid insufficient cash reserves.
- Consider renegotiating vendor contracts to extend billing cycles or to pay some or all costs after the project is complete.
- Ensure that the fees charged in the early phases of the project correlate with the value of the work performed.
- Contract with suppliers directly in order to supply materials to the contractor and obtain direct payment from the client.
- Apply payment bond with bank and client.
- Provide end-financing to most projects to solve most of the client's cash flow problems.

Primary Risk: Issues with phased projects

Key Questions:

- Is this project part of a larger phased project?

Mitigation Strategies:

- Consider the impacts of completing one portion of the project and not others (e.g., consider potential hydraulic impacts on uncompleted sections).

Primary Risk: Conflicts with nearby projects

Key Questions:

- What is the best way to settle conflicts with nearby projects?

Mitigation Strategies:

- Compromise so that each party's interests are satisfied to a degree.
- Solve the underlying problem, not the symptom.
- Accept risks if they cannot be avoided, transferred, insured, eliminated, controlled, or mitigated.

Primary Risk: Local tourism activity that may lead to schedule changes

Key Questions:

- Has the tourist season been considered in the project schedule?

Mitigation Strategies:

- Consider potential impacts of the tourist season when preparing the construction schedule.

Primary Risk: Resource limitations

Key Questions:

- Does the NCDOT have the appropriate resources that could impact project performance?

Mitigation Strategies:

- Consider hiring temporary staff in areas that may experience a shortage of resources.

Primary Risk: Unexpected risks

Key Questions:

- How are unexpected risks identified in a timely fashion?

Mitigation Strategies:

- Use Monte Carlo simulations to review all possible outcomes and probabilities of any given action in response to unexpected situations.
- Try to identify conditions that are most conducive to detecting risk factors early in the project's lifecycle.