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Analysis of the Effectiveness of Construction Management Plans

Carlos Caldas
Zhe Han
Jingran Sun
Chris Rausch
Chaeyoung Kim

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Carlos Caldas, Ph.D.https://orcid.org/0000-0003-1933-1953
Zhe Han, Ph.D. https://orcid.org/0000-0001-9104-0179
Jingran Sun, Ph.D. https://orcid.org/0000-0001-6525-849X
Chris Rausch, Ph.D. https://orcid.org/0000-0002-8927-2285
Chaeyoung Kim https://orcid.org/0009-0007-3014-6149</td><td colspan="2">8. Performing Organization Report No.
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This study aimed to assess the effectiveness of Construction Management Plans (CMPs). To achieve this goal, data from TxDOT highway projects was collected and analyzed. The analyses employed descriptive statistics, correlation analysis, hypothesis testing, and exploratory factor analysis to identify significant relationships between project characteristics, CMP components, change orders, and project performance indicators. The results indicated that CMP projects are generally larger and more complex than non-CMP projects. CMPs were considered effective since the number of change orders and the project cost variation due to change orders was lower in the period after CMP implementation. Correlations between conflict clearance delays and change orders on CMP projects suggested opportunities for improvement and the need for more proactive conflict clearance management. These findings confirm that CMPs serve as an effective tool for project conflict management and provide data-driven insights for improving project delivery practices in TxDOT.</td></tr>
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Zhe Han
Jingran Sun
Christopher Rausch
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Center for Transportation Research
The University of Texas at Austin
3925 W. Braker Lane, 4th floor
Austin, TX 78759

http://ctr.utexas.edu/

Disclaimers

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Patent Disclaimer: There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine manufacture, design or composition of matter, or any new useful improvement thereof, or any variety of plant, which is or may be patentable under the patent laws of the United States of America or any foreign country.

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Project Engineer: Carlos H. Caldas
Professional Engineer License State and Number: Texas No. 109476
P.E. Designation: Research Supervisor

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Chapter 1. Introduction

1.1. Background

Highway construction projects require rigorous planning and effective management to ensure timely delivery within predefined budgets and schedules. Given their complexity and public visibility, Departments of Transportation (DOTs) adopt comprehensive and proactive project management strategies that minimize delays and mitigate risks throughout the project lifecycle.

In this regard, Texas Department of Transportation (TxDOT) issued the “Ready to Let” memorandum in 2016. It tightened the definition and requirements for when a project can be considered ready to let. In addition to the requirement to have 100% PS&E completed, the memo highlighted the need to have environmental approval and mitigation complete, environmental permits secured, project agreements in place, railroad coordination complete and agreement in place, right-of-way cleared, and utility agreements in place and relocations in progress. The memo further clarified that the requirement to complete these items was to be "cleared sufficiently to proceed into construction without delays" and that any other remaining issues should be cleared within three months after letting. If a TxDOT district concluded that it would not be possible to meet this deadline, the district would have to submit a construction management plan (CMP) describing specific activities and a schedule of completion of the pending items. CMPs require administrative approval because of the increased risk if pending items remain during construction.

A CMP serves as a structured framework that outlines how construction can progress while concurrently addressing pending issues such as utility conflicts, ROW acquisition or relocation, ROW encroachments, and unresolved railroad agreements. By providing a schedule and sequence of construction activities in the presence of these constraints, CMPs aim to facilitate better coordination among stakeholders and reduce the risk of schedule slippage and contractual disputes.

After several years of CMP implementation across TxDOT districts, it is timely to evaluate the effectiveness of its use. This research aims to examine the impact of CMPs on highway project performance, particularly with respect to change orders, cost increases, and schedule delays due to unclear conflict issues. Additionally, this study seeks to provide practical recommendations for enhancing the effectiveness and consistency of CMPs across the state. The Value of Research (VoR) is presented on Appendix C.

1.2. Research Objective

The primary objective of this research is to determine the effectiveness of CMP, which is TxDOT's conflict clearance approval and management document. By certifying the clearance of potential conflicts before the project execution, the CMP aims to minimize the risk of unforeseen challenges that could result in cost escalations and schedule delays—issues often documented and approved through change orders. However, since the implementation of CMP, no comprehensive analysis has been conducted to assess its effectiveness on project performance, particularly in relation to change orders. Therefore, this study aims to quantify its impact with statistical analysis approaches to provide data-driven insights for future project management. To achieve this goal, the research will:

- Collect and compile a comprehensive dataset from TxDOT-managed highway projects, including CMP documents, conflict clearance records, change orders, and project-level performance data.
- Analyze the content, format, and structural components of CMPs to identify standardized elements and variations that may influence conflict management effectiveness.
- Examine trends and patterns in change orders before and after CMP implementation, with a focus on their impact on project cost and schedule performance.
- Perform statistical analyses and tests to identify potential correlations between CMP-related variables and the change orders.
- Evaluate the influence of CMP-related variables on project cost and schedule performance.
- Develop practical, data-driven recommendations for improving the structure, implementation, and policy integration of CMPs as a conflict clearance and project risk management tool.

1.3. Work Plan

The research was structured around a systematic nine-task work plan, which was organized into three major phases: (1) understanding the CMP process and conducting data collection, (2) performing in-depth analyses, and (3) formulating recommendations based on findings and synthesizing knowledge into practical resources.

The first phase focused on building a foundational understanding of the current CMP practices. During this phase, the research team conducted a comprehensive review and synthesis of existing issues, standard procedures, and methodologies used by various DOTs. Concurrently, a significant sample of CMPs and associated project documents was collected and analyzed to identify patterns in structure, content, and implementation. Additionally, relevant data on change orders and claims from the same set of projects were compiled to support subsequent analysis.

The second phase of the research involved a detailed investigation into the relationship between CMPs and project outcomes. This phase included the analysis of the impact that CMP usage had on the frequency and nature of change orders. The research team also explored potential correlations between clearance dates and the occurrence of change orders. Further, the study examined how specific elements within CMPs may influence project performance metrics, identifying which factors are most closely associated with improved project outcomes.

The final phase focused on translating insights into actionable recommendations. Lessons learned throughout the study were compiled and evaluated to determine common challenges and successful practices across TxDOT districts. Based on this synthesis, the team developed a series of recommendations aimed at improving the effectiveness and efficiency of CMPs. To support implementation, the research also produced a draft guidebook and corresponding training materials that can be used to assist practitioners in standardizing and optimizing CMP development and execution in future projects.

Chapter 2. Comprehensive Review of Relevant Background Information

2.1. Introduction

The primary objective of this chapter is to collect and examine diverse perspectives on conflict clearance and associated management practices in highway construction projects, in order to establish a foundational context for this research project. To develop a thorough understanding of current strategies and regulations aimed at mitigating project delays resulting from conflict clearance issues and change orders, the research team conducted an extensive review of relevant literature. This literature review is structured around the following core areas:

- An overview of conflict clearance management, primarily in the context of governmental agencies' highway projects
- An investigation into the causes of change orders and the quantitative methods used to analyze their impacts
- A review of key factors contributing to project schedule delays, particularly within three primary conflict categories: utility relocation, right-of-way acquisition, and railroad agreements

2.2. Conflict Clearance Management in Highway Construction

Unclear conflicts can significantly impact project let dates and performance. Acknowledging this impact, both the federal government and DOTs in multiple states have established strategies aimed at mitigating delays in conflict clearance. A comprehensive review of federal codes and regulations related to conflict clearance and certificates in highway construction is presented here. Additionally, specific guidelines and manuals from transportation agencies in other states were summarized, focusing on procedures and certificates related to conflict clearance strategies.

2.2.1. Significance of Conflict Clearance in Highway Construction Projects

Several studies identified that unclear conflicts from utility adjustments, ROW acquisition, ROW encroachments, ROW relocation, and/or railroad agreements are among the key factors impacting highway construction project performance.

Existing unclear conflicts may result in schedule delays, cost overruns, contract disputes, and quality issues. These factors emphasize the significance of managing pending clearances for the successful execution of construction projects.

Avoiding Delays During the Construction Phase of Highway Projects, published by the Transportation Research Board (2001), identified that unforeseen utilities and delays in utility relocations were among the root causes of project delays and associated cost impacts. Recommendations to prevent risks of conflict clearance delay were suggested for state transportation agencies, including the implementation of Subsurface Utility Engineering (SUE), development of utility depiction standards, early coordination with utility suppliers, and other strategies.

Strategies for Improving the Project Agreement Process Between Highway Agencies and Railroads from the Second Strategic Highway Research Program (SHRP2) by the Transportation Research Board (2010) reported that delays experienced while awaiting railroad reviews and agreements could result in elevated project costs and prolonged renewal of contract elements for transportation agencies.

National Utility Coordination Process Review by the Federal Highway Administration (2018) emphasized utility agreement problems as a major cause of delays, design errors, and non-compliance issues in federal-aid highway programs. This study reviewed state coordination regulations to mitigate the risk of utility agreement delays and utility-related change orders.

2.2.2. **Federal Codes Related to Conflict Clearance Certificates**

Title 23 Highways of the Code of Federal Regulations (CFR) provides detailed regulations regarding highway construction administration and conflict clearance, as well as other construction activities. It requires the completion of adequate coordination of potential conflicts between the state DOTs and multiple project stakeholders. The items pertaining to certificates of conflict clearance are as follows:

- 23 CFR 635.309 Authorization prescribes the conditions to be satisfied before advertising bids for the physical construction. This involves not only approval of the plans, specifications, and estimates (PS&E), but also a statement that all ROW clearance, utility, and railroad work have been completed as required for proper consideration in the highway construction schedules. Where it is deemed not feasible or impractical to complete such work before the commencement of construction, appropriate notification shall be provided in the bid solicitation defining clearance activities that are to be conducted simultaneously with the highway construction work.

- 23 CFR 645 Utilities prescribes the policies, processes, and reimbursement terms governing the adjustment and relocation of utility facilities in projects with federal-aid. The utility and DOT must come to a written agreement on their responsibilities for executing the relocation work. The agreement shall include plans, specifications, and estimation of the work agreed with, and shall be sufficiently informative to the DOT and FHWA with details of required works.
- 23 CFR 646 Railroad regulates policies and procedures for advancing federal-aid projects involving railroad facilities, including the elimination of hazards of railroad on highway crossings and adjustments required by highway construction. A statement indicating that no railroads are affected by the project, that railroad work has been completed, or that arrangements have been made to complete the railroad work shall be provided before the execution of highway construction.

2.2.3. Regulations in Other States Department of Transportation

Based on the federal codes, each state DOT establishes regulations, processes, and guidelines for highway and transportation infrastructure construction project delivery. To ensure successful project execution, manuals and forms were developed to comply with requirements and critical milestones at each stage of the project development. In this context, specific tools to mitigate conflict clearance delays and certifications obtained from other state DOTs were reviewed.

2.2.3.1. CalTrans (California Department of Transportation)

CalTrans offers comprehensive guidelines for developing the state's transportation construction projects through the Project Development Procedures Manual (PDPM). The PDPM encompasses project development processes and provides detailed guidelines for the submission of accompanying documents and certificates at various stages of the project.

CalTrans utilizes a unique tool to review requirements for project letting called Ready to List (RTL). RTL is the list of documents that must be submitted for the project advertisement. Figure 1 presents the document list along with criteria such as expiration and validity dates. After completing the submission of all applicable required documents, the RTL Certificate is issued and shall be included in the final PS&E package (CalTrans, 2019; CalTrans, 2022).

Expiration and Update Requirements for RTL Documents

Document	Expires After	Must Be Valid at (Milestone)	Contact Division of	Reference
R/W Certification	1 Year	Advertisement Date	Right of Way & Land Surveys	R/W manual Section 14
R/R Clearance Memo	PS&E changes impacting R/R are made	Project listed for advertisement	Right of Way & Land Surveys	R/W manual Section 8
Environmental Certification	Permit requirements change	Project listed for advertisement	Environmental Analysis	https://dot.ca.gov/programs/environmental-analysis
DTM or TMP Manager verification	PS&E changes impacting the TMP are made	Project listed for advertisement	Traffic Operations	DD-60-R2
PE Seal on individual Plan Sheets	Perpetual*	Date of signature	Design (Office of Professional Development)	Business and Professions Code
PE Seal on Title Sheet	Perpetual*	Date of signature	Design (Office of Professional Development)	Business and Professions Code
SE Seal on Special Provisions	Perpetual*	Date of signature	Design (Office of Professional Development)	Business and Professions Code
Project Engineer's Certification of Utility Facilities	Perpetual*	Project listed for advertisement	Design (Office of Professional Development)	PDPM, Appendix LL
Storm Water Data Report	When revised permit conditions require a change	Project listed for advertisement	Design	Caltrans Storm Water Quality Handbooks/ Project Planning & Design Guide See Appendix E
Hazardous Waste Report	PS&E changes impacting area of contamination requirements change	Project listed for advertisement	Environmental Analysis	PDPM CH. 18

Figure 2.1 CalTrans - Ready to List Documents (CalTrans, 2019)

2.2.3.2. **VDOT (Virginia Department of Transportation)**

VDOT developed the Project Tasks and Scheduling Guide to describe required activities and completion schedules for each task along the construction process with a unique Task ID. Requirements and deadlines to clear potential conflicts are included in Task ID 67 – Utility Relocations by Others, 68 – Clear Railroad Agreements, and 69X – Right of Way and Utility Certification Date, which are summarized in Table 2.1 below (VDOT, 2018).

Table 2.1 Project Tasks and Scheduling Guide Summary (VDOT, 2018)

Task ID	Schedule	Description
67 – Utility Relocations by Others	30 days prior to Task 80 – Advertise Project	General schedule: Up to ¼ mile (with 3 utilities) – 120 calendar days Up to ½ mile (with 4 utilities) – 180 calendar days Up to 1 mile (with 4 utilities) – 240 calendar days Exception with prior approval from the Chief Engineer
68 – Clear Railroad Agreements	Prior to Task 69X – ROW and Utility Certification	Critical path: Begin as soon as possible during a project scoping or before
69X – Right of Way and Utility Certification Date	30 days prior to Task 80 – Advertise Project	Cannot be certified until the end of Task 69 ROW acquisition, 67 Clear utility relocation, or 68 Clear railroad agreements

Form UT-9 summarizes the pending utility relocation and an estimated time for completion is used to facilitate the relocation process and to address the utility owners' responsibility (TRB, 2012; VDOT, 2021). UT-9 form is usually completed about 2 to 12 months before the project letting. Additionally, a narrative statement and a utility construction work must be submitted with PS&E to proceed with the project advertisement.

2.2.3.3. **GDOT (Georgia Department of Transportation)**

GDOT describes specific guidance to manage core activities for transportation projects through Local Administered Project (LAP) Manual and Plan Development Process (PDP). The manual regulated the submittal schedules of certain certificates to advance to the next steps while providing guidelines for preliminary review prior to submission. In Chapter 10.2 Construction Authorization, the 7-week buffer between the submission of final certificates to FHWA and the certificate review by the state government is addressed, which allows local engineers to prompt conflict resolution (GDOT, 2023). The table below presents descriptions of potential conflict clearance certificates.

Table 2.2 Local Administered Project Summary (GDOT, 2023)

Chapter	Submittal schedule to State Government	Description
9.6 Utility and Railroad Certificate	15 weeks prior to the project letting	Certificates shall include: • Utility Certification Request Letter addressing "Status" for each Utility/Railroad Owner • "No Facilities", "No Cost", or "No Contact" letter from each Utility Owner
10.2 Construction Authorization	18 weeks prior to the project letting 11 weeks prior to the submission to FHWA (7 weeks buffer)	PS&E Package Checklist shall include: • ROW certificates • Utilities/Railroad certificates • Traffic management plan

In order to prevent potential risks after the construction execution, final certifications must be completed 11 weeks prior to the project let date (GDOT, 2023). In cases of the best interest, Conditional Certifications for right-of-way, utilities, and/or environment shall be issued to proceed with the project and to avoid project delays. Before utilizing Conditional Certification, approval must be granted through a request by the Project Manager 11 weeks prior to the project let date. Obtaining Conditional Certification does not exempt the project from final certification requirements.

2.2.3.4. **PennDOT (Pennsylvania Department of Transportation)**

In exceptional circumstances, PennDOT has the authority to issue a Conditional Utility Clearance Certification (CUCC) when all requisite arrangements for the Utility Clearance Certification are pending (PennDOT, 2022). This conditional certification is an extraordinary measure, delineated by specifying the outstanding arrangements, and should not be considered a standard practice. District managers seeking a CUCC must substantiate the necessity, ensuring no delay in the highway contractor's Notice to Proceed, and provide a comprehensive list of outstanding items. The CUCC is a provisional solution and should not be habitual in project delivery.

To manage a series of processes, PennDOT employs a separate system called URMS (Utility Relocation Management System) to store and manage information for all items related to relocation and to approve relocation plans and certificates. During both the preliminary and final reviews in this system, conditional acceptance can be granted if clearance is not achieved, but project progression is imperative. In such cases, the reasons for conditional approval must be documented, with subsequent updates upon the completion of the relocation.

2.3. Causes of Change Orders in Highway Construction

Change orders have been identified as one of the main factors impacting the performance of construction projects since they often result in schedule delays, cost overruns, low productivity, and contractual disputes (Moselhi et al., 2005; Alnuaimi et al., 2010; Keane et al., 2010). In this regard, multiple state DOTs have strived to understand and manage the frequency and causes of change orders through comprehensive analyses. Similar to TxDOT, many state DOTs utilize standardized information systems such as Project SiteManager (AASHTO, 2021; TxDOT, 2021; NYDOT, 2028) to systematically record change orders and classify their reasons. A thorough review of literature from various state DOTs regarding the primary causes of change orders serves as a foundation for this research.

2.3.1. KYTC (Kentucky Transportation Cabinet)

KYTC conducted a study to investigate the causes of change orders. The aim was to identify areas for minimizing change orders and optimizing time and cost in future projects (Goodrum et al., 2010). The agency also pinpointed project characteristics that show correlations with the frequency and magnitude of change orders.

The data source of the study was collected from SiteManager and consisted of 610 projects executed between 2005 and 2008. KYTC employs 30 reason codes to identify the causes of each change order. These reason codes were then classified into two dimensions: administrative and engineering issues. Descriptive statistics were conducted to establish a fundamental understanding of the change orders. The outcomes are presented in Tables 2.3, 2.4, and 2.5 below. Furthermore, the reason codes were subjected to additional analysis based on project characteristics.

Table 2.3 Most Frequent Change Order per Reason Codes (KYTC, 2010)

Reason Code	Reason Code Description	Change Order Frequency	Type of Change Order
4	Contract Omission	243	Engineering
6	Contract Item Overrun	227	Engineering
3	Fuel & Asphalt Adjustment	218	Engineering
1	Asphalt Lot Pay Adjustment	188	Engineering
8	Owner Induced Enhancement	186	Engineering
20	Contract Item Underrun	165	Administrative
7	Geotechnical Issue	71	Engineering
17	Item Special in Nature	67	Administrative
5	Utility Issue	60	Engineering
16	Cost Comparison to Competitive Bid in the Area for Similar Work	51	Administrative

Table 2.4 Largest Change Orders Dollar Amount per Reason Codes (KYTC, 2010)

Reason Code	Reason Code Description	Average CO Amount ($)	Type of Change Order
10	Contract Incentive	$ 246,861.13	Administrative
6	Contract Item Overrun	$ 104,857.53	Engineering
21	Claim Settlement	$ 102,508.19	Administrative
7	Geotechnical Issue	$ 90,777.41	Engineering
15	Itemized Cost Breakdown Supplied by the Contractor	$ 88,357.88	Administrative
8	Owner Induced Enhancement	$ 88,297.13	Engineering
3	Fuel & Asphalt Adjustment	$ 82,336.07	Engineering
18	Cost Plus Worksheets (Errors or Changes)	$ 76,847.60	Administrative
4	Contract Omission	$ 57,410.90	Engineering
17	Item Special in Nature	$ 55,360.59	Administrative
20	Contract Item Underrun	$ (193,171.41)	Administrative

Table 2.5 Largest % Change from Original Contract Amount per Reason Codes (KYTC, 2010)

Reason Code	Reason Code Description	Average % Change	Type of Change Order
10	Contract Incentive	9.26%	Administrative
8	Owner Induced Enhancement	7.80%	Engineering
3	Fuel & Asphalt Adjustment	7.05%	Engineering
6	Contract Item Overrun	6.73%	Engineering
16	Cost Comparison to Competitive Bid in the Area for Similar Work	6.36%	Administrative
4	Contract Omission	4.53%	Engineering
17	Item Special in Nature	4.31%	Administrative
15	Itemized Cost Breakdown Supplied by the Contractor	3.86%	Administrative
18	Cost Plus Worksheets (Errors or Changes)	3.21%	Administrative
5	Utility Issue	3.16%	Engineering
20	Contract Item Underrun	-6.48%	Administrative

After subsequent in-depth statistical analyses based on the project characteristics, KYTC developed Change Order Risk of Impact Tables. The tables below depict the impact of change orders caused by road type, new construction vs. maintenance work, and construction type (Goodrum et al., 2010).

Table 2.6 Risk of Impact by Reason Code and Road Type (KYTC, 2010)

Reason Code	Description	Road Type				
		CR	I	KY	PW	US
1	Asphalt Lot Pay Adjustment	○	○	◎	○	◎
3	Fuel & Asphalt Adjustment	◎	◎	●	●	●
4	Contract Omission	◎	◎	◎	◎	◎
5	Utility Issue	◎	○	○	---	○
6	Contract Item Overrun	●	◎	●	●	◎
7	Geotechnical Issue	---	○	◎	◎	◎
8	Owner Induced Enhancement	◎	◎	◎	◎	◎
9	Environmental Issues	---	○	◎	---	○

○ : Low risk of impact
◎ : Risk of impact
● : Extreme risk of impact
---: Data insufficient

CR: County Road
I: Interstate
KY: State
PW: Parkway
US: US

Table 2.7 Risk of Impact by Reason Code and New Versus Maintenance Project (KYTC, 2010)

Reason Code	Description	New	Maintenance
1	Asphalt Lot Pay Adjustment	○	◎
3	Fuel & Asphalt Adjustment	◎	●
4	Contract Omission	●	◎
5	Utility Issue	◎	◎
6	Contract Item Overrun	●	●
7	Geotechnical Issue	◎	○
8	Owner Induced Enhancement	●	●
9	Environmental Issues	◎	○

Table 2.8 Risk of Impact by Reason Code and Construction Type (KYTC, 2010)

Reason Code	Description	Earthwork	Road Surface	Structures
1	Asphalt Lot Pay Adjustment	◎	◎	○
3	Fuel & Asphalt Adjustment	◎	●	◎
4	Contract Omission	◎	◎	●
5	Utility Issue	◎	○	○
6	Contract Item Overrun	●	◎	●
7	Geotechnical Issue	◎	○	○
8	Owner Induced Enhancement	◎	●	◎
9	Environmental Issues	◎	○	○

2.3.2. INDOT (Indiana Department of Transportation)

INDOT conducted several research projects to develop guidelines and provide recommendations for minimizing the number of change orders in their projects. To address the increasing trend of change orders, INDOT conducted an initial study on cost and time overruns in 2004. Additional research was carried out specifically on change orders related to geotechnical activities in 2011.

The most significant reasons for change orders were obtained from the analysis of 17,992 change orders in 822 projects executed between 1996 and 1999 (Bordat et al., 2004). Table 2.9 presents the reasons for change orders categorized into seven groups, following the change order amount, change order number, and rate of dollar amount by reason code.

Table 2.9 Change Order Summary by Reason Code (INDOT, 2004)

Reason Code	Reason for Change Order		Amount	Number	Rate
0	NO RECORDED REASON		$29,288,445.35	6,024	45.28%
101	ERRORS & OMISSIONS	Contract Related	$1,100,928.48	378	1.70%
102		Design Related	$9,416,964.21	1,743	14.56%
103		Environmental	$70,567.28	42	0.11%
104		Materials Related	$5,574.99	97	0.01%
105		Permits	$2,727.50	4	0.00%
106		Quantity Related	$1,142,288.56	1,358	1.77%
107		R/W Related	$15,450.89	14	0.02%
108		Soils Related	($41,469.41)	14	-0.06%
109		Staging Related	($110,666.64)	14	-0.17%
110		Traffic Control	$723,059.88	260	1.12%
111		Utilities Related	$50,060.88	13	0.08%
201	CONSTRUCT ABILITY	Construction Related	$3,661,076.21	1,792	5.66%
202		Design Related	$3,396,308.49	580	5.25%
203		Environmental Related	$192,384.05	57	0.30%
204		Materials Related	$707,927.02	258	1.09%
205		R/W Related	$71,599.73	19	0.11%
206		Soils Related	$950,976.50	104	1.47%
207		Staging Related	($42,970.52)	43	-0.07%
208		Traffic Control	$670,108.10	300	1.04%
209		Utilities Related	$99,648.15	74	0.15%
301	SCOPE CHANGES	FHWA	$70,921.94	6	0.11%
302		Central Office	$3,110,165.84	277	4.81%
303		District/Subdistrict	$1,555,618.77	290	2.41%
304		District Cons.Eng	$519,015.68	125	0.80%
305		Area Engineer	$305,965.65	288	0.47%
306		Project Engr/Supervisor	($118,425.72)	340	-0.18%
307		Traffic Engineer	$396,932.79	253	0.61%
308		Local Agency Request	$856,812.54	462	1.32%
309		Public/Political Request	$167,123.14	52	0.26%
401	CHANGED CONDITIONS	Construction Related	$1,317,316.52	1,473	2.04%
402		Environmental Related	$248,912.51	48	0.38%
403		Materials Related	$124,549.99	107	0.19%
404		R/W Related	($26,324.45)	20	-0.04%
405		Soils Related	$808,472.88	94	1.25%
406		Staging Related	($149,318.87)	35	-0.23%
407		Utilities Related	$148,829.06	36	0.23%
500	FAILED MATERIAL		($1,062,604.73)	392	-1.64%
601	INCENTIVE/ DISINCENT	Contract Completion	$1,780,056.84	10	2.75%
602		Contract Payments	$138,260.17	8	0.21%
603		Cost Reduction	($34,452.97)	95	-
604		A+B Contract	$1,700,000.00	2	2.63%
605		A+B+C Contract	$700,000.00	1	1.08%
701	STANDARDS/SPECS CHANGE	Completion Time	$298,176.36	124	0.46%
702		Contract Payment	($32,128.47)	15	-0.05%
703		Other	$481,777.95	251	0.74%
	TOTAL		$64,676,643.12	17,992	

2.3.3. IDOT (Illinois Department of Transportation)

An increase in the occurrence of change orders in major freeway construction projects prompted IDOT to conduct a research study. An analysis of documented change orders was performed (Assaad et al., 2022). The data included authorized contract change amount, districts, and main causes of change orders. The percentage of change orders by their causes is presented in Figure 2.2. The study concluded that the top five causes of change orders were contract administration, allowable contingencies, plan quantity omission and error, differing site conditions, and design change. These causes were validated through IDOT project case studies and discussions among experts.

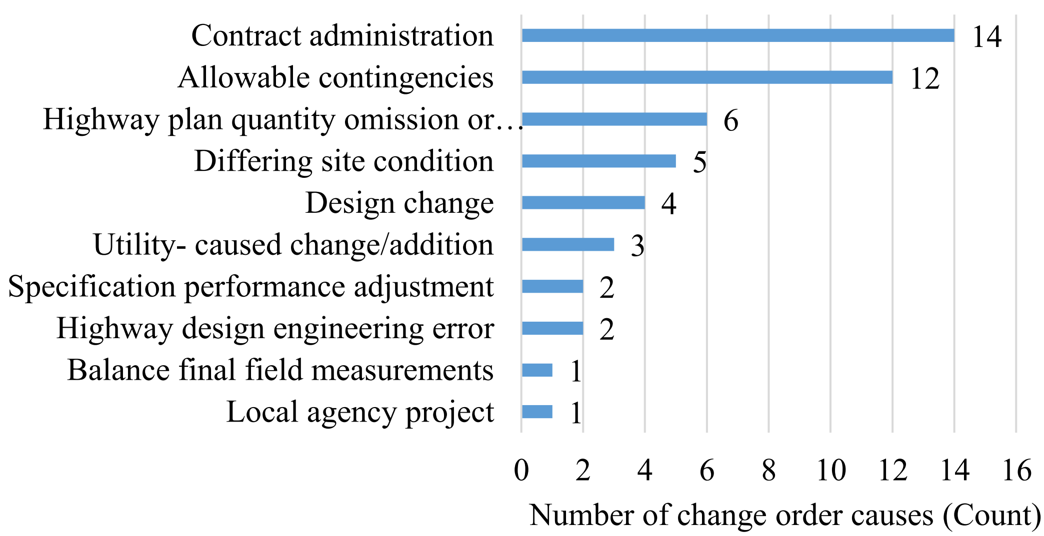


Figure 2.2 Most Frequent Change Order Causes (Illinois DOT, 2022)

2.4. Schedule Delay Factors

Construction schedule delays can be caused by a multitude of factors. Among them, delays in conflict clearance and submission of required certificates during the pre-construction phase emerge as crucial factors (TRB, 2001). With a focus on utility adjustments, right-of-way acquisition, and railroad agreements, this Chapter reviewed factors that contribute to construction schedule delays and their impact on project durations.

2.4.1. Schedule Delay Factors at a Project Level

Several research studies were conducted to analyze the causes of schedule delays in construction projects. These studies considered various conditions, such as project type, location, and size, among others. In public transportation construction projects where the scope is substantial and diverse stakeholders are involved, the risk of construction schedule delays is elevated. Therefore, it is extremely important to identify and mitigate schedule delay factors.

In most studies, inadequate planning, which includes drawing omissions, unrealistic schedules, and unforeseen site conditions, is identified as a major cause of construction schedule delays. Table 2.10 summarizes the main causes of schedule delays identified in the literature.

Table 2.10 Schedule Delay Causes

Title	Author	Major Causes	Methodology
Factors Affecting Schedule Delay, Cost Overrun, and Quality Level in Public Construction Projects	Larsen et al., (2016)	. Unsettled project planning . Lack of project funding . Delays and long approval processes . Errors and omissions in construction works	. Surveying public agencies and identifying 26 factors in five categories . RII analysis, Friedman's & Wilcoxon's test
Causes of Delay in Road Construction Projects	Mahamid et al., (2012)	. Payment delay by the owner . Shortage of equipment . Political situation . Awarding the project to the lowest bid price	. Surveying construction parties and ranking 52 causes in eight categories . Measuring Spearman correlation coefficient
Causes of Delay in Large Construction Projects	Assaf & Al-Hejji, (2006)	. Frequent change orders . Ineffective planning and scheduling . Shortage of labors . Payment delay by the owner	. Surveying construction parties and ranking 73 causes in nine categories . Measuring Spearman correlation coefficient
Causes of Construction Delay: Traditional Contracts	Odeh & Battaineh, (2002)	. Improper planning . Owner interference . Inadequate contractor experience . Low labor productivity	. Surveying construction parties and ranking 28 causes in eight categories . RII analysis
NCHRP Avoiding Delays during the Construction Phase of Highway Projects	TRB (2001)	. Utility relocation . Differing site conditions . Environmental planning and permit issues . Delays in ROW acquisition	. Surveying state DOT and transportation professionals and ranking the scores

2.4.2. **Utility Adjustment Factors that May Impact Schedules**

Utility adjustment is a series of procedures conducted to move or adjust utility infrastructure that interferes with construction development. Utilities encompass items such as electric cables, gas pipes, water and sewer pipes, and telecommunication lines. Utility owners usually share the state's right-of-way. Therefore, significant alterations or development of highways are highly likely to impact utilities. TxDOT is obligated to notify all affected utility owners about the proposed work as early as possible to facilitate necessary utility adjustments (TxDOT, 2019; TxDOT, 2021).

Various factors that contribute to project schedule delays are related to utility relocation. According to a national report by the US General Accounting Office (GAO, 1999), 42 states acknowledged the impact of utility relocation on project delays and identified specific reasons for the delays. The most commonly identified causes of delays in utility relocation include lack of utility resources, insufficient time for planning and design, low prioritization of relocations, increased workload on crews due to the growth in highway construction, and delays in initiating relocations. Some states also indicated that delays caused by utility relocation greatly result in not only overall project schedule delays, but also in project cost overruns and claims.

A study from NCHRP highlighted utility conflicts as a primary cause of construction delays. This study involved surveys of State Highway Agencies (SHA), transportation contractors, and transportation designers (TRB, 2001). Table 2.11 below illustrates the most common causes of project schedule delays, with utility relocation delays and deferring site conditions related to utility conflicts identified as the top two reasons for project delays among all parties.

Table 2.11 Causes of Delay Ranking (TRB, 2001)

Causes of Delay Ranking	SHA	Contractor	Designer
Utility Relocations Delayed	1	1	1
Differing Site Conditions (Utility Conflicts)	2	3	2
Errors in the Plans or Specifications	3	2	13
Weather	4	4	6
Permitting Issues	5	7	4
Delays in Right of Way Acquisition	6	11	9
Delay in Environmental Planning	7	8	3
Insufficient Work Effort by Contractor	8	18	5
Owner Requested Changes	11	5	10
Differing Site Conditions (Other Causes)	9	6	7

Factors contributing to utility relocation delays were also highlighted in case studies of road construction projects (Vilventhan & Kalidindi, 2018). The duration of relocation is notably influenced by the complexity of underground utilities. Urban areas experience greater delays in utility relocation compared to rural areas, primarily due to the complexity of existing utilities. The analysis of case studies emphasized the substantial contribution of utility relocation delays to the overall schedule of road and bridge projects.

The type of utility and the location of conflicts, whether in urban or rural areas, also impact the project. To comprehend and mitigate the additional costs and time associated with utility conflicts in roadway construction, an in-depth case study of Kentucky Transportation Cabinet (KYTC) projects and a statistical analysis based on a survey of 45 state DOTs were conducted (Goodrum et al., 2010). Conflicts involving various types of utilities (i.e., gas pipes, water pipes, above/underground communication lines, and electrical cables, among others) were more frequent and severe in urban areas compared to rural areas. Specifically, conflicts related to underground communication lines exhibited the highest frequency in both urban and rural settings. Additional case studies involving waterline incidents and delayed pole relocations illustrated construction delays and increases in cost.

2.4.3. **Right-of-way Acquisition Factors that May Impact Schedules**

Right-of-way acquisition, a critical activity in most highway and transportation projects, is the legal procedure of the state agency securing the required land or property rights for the development or expansion of a construction project. However, this process has evolved into a more intricate, costly, and time-intensive undertaking in recent decades (Caldas et al., 2006). Due to its timing before the construction begins, there is pressure to expedite the ROW acquisition process. Given that the valuation and negotiations with property owners are integral to the project's critical path, any delays in this acquisition can significantly impact the project's schedule and cost.

Early involvement in ROW during the initial stages of project development offers an opportunity to optimize its impact on the project schedule (TRB, 2000). However, in certain cases, the coordination between the ROW process and project schedule is not guaranteed, and insufficient lead time becomes a hindrance to the timely delivery of ROW, which inevitably causes project delays. With regards to this issue, State DOTs responded to the survey on barriers to expediting ROW delivery within highway construction. A total of 36 states indicated that delayed design and plan changes were the primary factors affecting a prompt ROW process, followed by environmental challenges and unrealistic project timetables (TRB, 2000). The comprehensive survey results are presented in the table below.

Table 2.12 Barriers to Prompt ROW Acquisition (TRB, 2000)

Barriers to Prompt ROW Acquisition	Number of Responding States
Late design and right-of-way plan changes and revisions	36
Environmental impediments	16
Unrealistic project schedules	15
Coordination problems between divisions and between agencies	13
Insufficient or inadequately trained right-of-way staff	12
State, local, or federal requirements, or political priorities	11
Consultant problems	9
Appraisal delays	8
Funding of projects	7
Relocation obstacles	6
Title problems	4
Courts and condemnation processes	4
Releases and title certification	3

Effective use of technology applications	3
Other	2

As the acquisition of ROW is a crucial legal step in the critical path of highway construction development, it is essential to comprehend the duration of ROW acquisition and its influence on the overall project schedule. One noteworthy factor affecting the duration is the transitional area where the ROW parcel is situated, indicating that acquisition durations for urban parcels are twice as long as those for rural and suburban parcels (Le et al., 2010). The type of property ownership is also significant, with the acquisition of a business-owned property taking three months longer than a single-owned property and over five months longer than a multiple-owned property. In the case of projects with mapping and surveying issues, the duration takes an average of 200 days longer than a typical project. Three other factors such as acquisition methods (negotiation or Eminent Domain), property exchange, and title issues have the potential to impact the overall duration of ROW acquisitions.

2.4.4. **Railroad Agreement Factors that May Impact Schedules**

An agreement between state highway agencies and the operating railroad organizations must be established to perform work on the railroad right-of-way before construction letting (TxDOT, 2015). When an active railroad interfaces with construction projects, railroad agreements are made when a highway crosses over, under, or parallel to a railroad. The early coordination between the state agencies and railroad companies reduces project delays and claims on construction schedule extension which would potentially increase project costs. The duration of the entire process, including negotiation, planning, and final decision-making, varies between 4 to 24 months, contingent on the impact of the railroad on the highway (TxDOT, 2015).

An SHRP2 report by the TRB identified some common problems in railroad agreements, with both state and railroad agencies consistently pointing out delays and issues that routinely arise during highway construction. The problems included the inability to reimburse engineering review costs early in the project schedule, the cost and availability of insurance, ROW appraisal processes, and railroad easements (TRB, 2010). Another important factor is the responsibility for maintenance at rail-highway grade crossings, which should be agreed upon by both parties and described in the project agreement.

The survey and feedback obtained from railroad organizations, as well as federal, state, and local transportation agencies, revealed common challenges associated with timely railroad agreements due to the following factors (TRB, 2010; TRB, 2014):

- Delays in agreement processing
- Nonstandard agreements, resulting in each agreement going through extensive reviews
- Delays in coordination
- Transportation agency designs not meeting railroad requirements
- Insufficient insurance limits
- Communication issues
- Failure to anticipate and address construction issues
- Limited understanding of the differences in objectives, cultures, and operational models
- Inefficient workflow and duplications in workflow activities
- Delays in authorizing work and in making payments
- Strategies used often did not benefit both parties
- Differences in institutional priorities
- No shared interest
- Railroads being very risk-averse
- Transportation agencies being cautious about spending taxpayer monies and concerns about public opinion

Case studies on railroad relocation have explored the characteristics that potentially impact the schedule of each project (TRB, 2010; Morgan et al., 2007). The type of project is one factor associated with the duration of railroad agreements. The Class 1 railroads, defined as carriers earning annual revenue greater than $250 million, have been interacting with transportation agencies for decades. In terms of their regular agreements, these carriers have established individual standard agreements, processes, and protocols. However, these variations often lead to delays in aligning agreements. Moreover, as some railroads traverse cities or regions, the scale may be prioritized ahead of typical utility conflict points, necessitating agreements to be more complex.

As the volume of materials and passengers transported by railroad increases, the need for additional bypass railroads also grows, which increases the difficulty of securing the bypasses. Many railroads were constructed decades ago, making it challenging to discover new bypass routes. Therefore, as it tends to prolong the duration of the railroad agreement process, this item should be discussed first in the preliminary engineering planning to secure the project schedule.

To sum up, major delay factors in highway construction range from internal project management issues such as planning, design, funding, contracting to external coordination problems such as utilities, ROW, railroads, and permitting. The literature consistently emphasizes early planning, stakeholder coordination, and flexibility in project schedules as key to mitigating these delay drivers.

Chapter 3. Collection and Analysis of Construction Management Plans

3.1. Introduction

This chapter provides a comprehensive overview of CMP, outlining its purpose and function, and examining its application, standardized formats, and documented content. It also identifies key characteristics of CMPs and the status of associated projects. The analysis includes preliminary reviews of conflict data related to utility relocations, right-of-way acquisitions, and railroad coordination, as well as project data such as scope, conflict types, clearance dates, and change orders.

The findings from Task 3 include:

- Analysis of formats, components, and contents of CMPs.
- Cost and duration information from all projects that were let since the implementation of CMPs.
- Quantification and categorization of conflicts on projects that have CMPs according to their conflict types (i.e., utility adjustments, right-of-way acquisitions, and railroad coordination).
- Quantification and categorization of utility conflicts on projects that have CMPs according to the utility types and owners.

3.2. Analysis of Structure, Format, and Components of CMPs

CMPs are structured as a summary document accompanied by supporting exhibits that detail conflict information, expected clearance dates, project schedules, and specific conflict locations on project layouts. A complete CMP includes the following documents:

- Cover Memo (signed)
- Certifications (signed)
- Construction Time Determination (CTD) (signed)
- Traffic Control Plan (TCP) Phase Narrative (signed & sealed)

- Conflict Layout (signed & sealed).

While the required content across districts is standardized, the detailed format and specific content of CMPs are designed autonomously by each district or project. The notable components, along with recommended examples identified through the analysis, are presented below by each section of the CMP.

3.2.1. Cover Memo

The Memo is the introductory section of the CMP, containing the project name, CSJ, person in charge, recipient, and submission date at the top of the document. It provides a descriptive summary of the entire CMP document, outlining the overall project schedule and highlighting the key conflicts detailed in the CMP. While there is no fixed format for the Memo, any unique aspects of the CMP or project are specifically noted. The format may vary depending on the author, district, and project. The Memo should include signatures certifying a review of the entire CMP document and the conflict clearance schedule.

3.2.1.1. Exhibit A. Certifications

Exhibit A is a major focus of this study, as it describes all conflicts involved in the projects and certifies the proposed clearance under three categories: ROW, RR, and UTL. This section includes tables listing all conflicts with detailed information, which serves as the primary data for this study. The tables contain conflict types, conflict owners, conflict locations, descriptions, proposed clearance dates, and buffer times (if available). The notable elements and exemplary aspects of Exhibit A are presented below.

- Conflict Information Table Format Standardization

One noteworthy practice from various district documents is the conflict information table in Exhibit A. This table should include conflict information and the clearance schedule, organized by categories of ROW, RR, and UTL. While most CMPs contain columns for conflict owners (e.g., ROW stakeholders, railroad companies, utility owners), descriptions, conflict locations, expected clearance dates, and the effects on construction, the format is not standardized. Standardizing the required information columns and the table format would enhance the accuracy and effectiveness of CMPs.

For instance, adding columns that specify the construction phase affected by the conflict and the expected phase start date would make the buffer time between the expected clearance date and the construction start date more intuitive. The buffer time, defined as the period between the expected clearance date and the construction start date for each phase, should also be clearly indicated in a separate column. This approach ensures that conflict clearance certification is clear and allows for an intuitive comparison with key project dates, confirming that any delays in clearance will not impact the construction schedule. Examples are provided in the Figures 3.1 and 3.2.

UTILITY OWNER	LOCATION	ESTIMATED CLEARANCE DATE	PHASE/STEP IMPACTED	PHASE/STEP START DATE	EFFECT ON CONSTRUCTION
CNP Gas	Gas SH 146 721+41 to 735+00	6/1/2023	Phase 1 Step 2	12/11/2023	5 month buffer
CNP Gas	Gas SH 146 722+06 to 723+24	6/1/2023	Phase 1 Step 2	12/11/2023	5 month buffer
CNP Gas	Gas SH 146 740+71 to 741+62	6/1/2023	Phase 1 Step 2	12/11/2023	5 month buffer
Dow/UCAR	Pipeline SH 146 460+00 to 730+91	6/1/2023	Phase 1 Step 2	12/11/2023	5 month buffer
Frontier	Copper SH 146 738+45 to 738+58	6/1/2023	Phase 1 Step 2	12/11/2023	5 month buffer

Figure 3.1 A Conflict Information Table #1

OWNER	UTILITY AND LOCATION	STATUS	EST COMPLETION DATE	PHASE	PHASE START DATE	EFFECT ON CONSTRUCTION
Century Link 15	FOC STA 371+50 to 373+50 33' LT	Located	3/30/2020	Phase III	6/1/2020	To be cleared prior to start of phase
Century Link 16	FOC STA 382+91 to 383+35 45' LT	Located	3/30/2020	Phase III	6/1/2020	To be cleared prior to start of phase
Century Link 17	FOC STA 393+50 to 394+50 45' LT	Located	3/30/2020	Phase III	6/1/2020	To be cleared prior to start of phase
AT&T 23	TEL STA 454+00 to 462+00 16' LT	Located	3/30/2020	Phase IV	1/4/2021	To be cleared prior to start of phase
Centerpoint 1	Gas STA 528+48 to 589+10 51' LT	New Line	**8/31/2020**	Phase VI	1/4/2021	To be cleared prior to start of phase
AT&T 24	TEL STA 581+14 32' LT	Located	3/30/2020	Phase VI	1/4/2021	To be cleared prior to start of phase
AT&T 25	TEL STA 581+14 43' RT	Located	3/30/2020	Phase VI	1/4/2021	To be cleared prior to start of phase

Figure 3.2 A Conflict Information Table #2

- ROW Parcel and Utility Conflict ID Labeling

Labeling unique IDs or numbering for right-of-way parcels or utility conflicts is highly effective for identifying and managing conflicts, as sown in Figure 3.3. Unique IDs facilitate better documentation and tracking by providing a clear and concise way to reference each conflict. For instance, each ID can correspond to specific details such as the type of utility (e.g., water, gas, electricity), the precise location within the project area, and the owners of the conflict. This helps in creating a detailed log that can be referred to during progress meetings and reviews. IDs also help in integrating various project management tools and systems.

Owner	Utility and location	Status	Est. Completion date	Phase	Phase start date	Effect on construction
City of Georgetown 1	OH Electric STA 123+51 59' LT to 139+99 76' LT	Design Complete	12/28/2020	IIB	7/6/2021	To be cleared prior to start of phase
City of Georgetown 2	OH Electric STA 122+82 46' RT to 152+41 47' RT	Design Complete	01/18/2021	IIB	7/6/2021	To be cleared prior to start of phase
City of Georgetown 3	OH Electric Sta. 103+23 53' LT	Design Complete	09/07/2020	IIA	12/15/2020	To be cleared prior to start of phase
Fiberlight 4	OH Cable STA 122+61 40' RT to 149+86 52' RT	Design Complete	12/21/2020	IIB	7/6/2021	To be cleared prior to start of phase
Frontier 5	OH Tele STA 130+03 53' LT to 138+11 51' LT	Design Complete	01/11/2021	IIB	7/6/2021	To be cleared prior to start of phase
Frontier 6	OH Tele STA 122+83 47' RT to 152+41 57' RT	Design Complete	01/11/2021	IIB	7/6/2021	To be cleared prior to start of phase
Frontier 7	TPED STA 130+03 52' LT	Design Complete	01/11/2021	IIB	7/6/2021	To be cleared prior to start of phase
Frontier 8	TPED STA 127+63 47' RT	Design Complete	01/11/2021	IIB	7/6/2021	To be cleared prior to start of phase

Figure 3.3 Example of Utility Numbering and Coloring

3.2.1.2. **Exhibit B. Construction Time Determination**

Exhibit B encompasses the project construction schedule for each task, critical path, and the corresponding conflict clearance schedule. It is imperative that conflict clearance is completed either before or after the project letting, ensuring that it does not impede the progress of construction. The conflict information table provides the expected clearance dates, and it is advisable to include the conflict clearance schedule in the overall project schedule to assess its impact. By identifying which task the clearance is completed, project delays can be prevented, and it is easy to intuitively check the progress of the clearance.

- Separate Conflict Clearance Schedule

Exhibit B presents the overall construction project schedule, but in some cases, it does not include the conflict clearance schedule. However, the conflict information table provides the expected clearance dates, and it is advisable to include the conflict clearance schedule in the overall project schedule to assess its impact. By identifying which task the clearance is completed, project delays can be prevented, and it is easy to intuitively check the progress of the clearance. Good examples of a schedule that includes both the critical path of construction and conflict clearance can be seen in Figures 3.4 and 3.5.

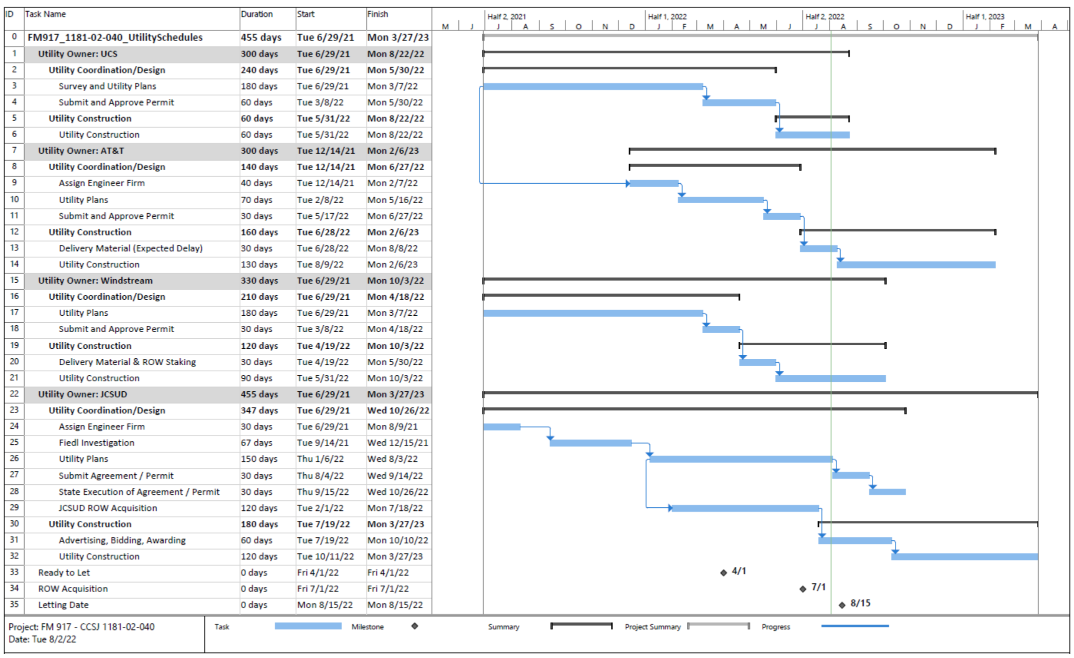


Figure 3.4 Utility Clearance Schedule

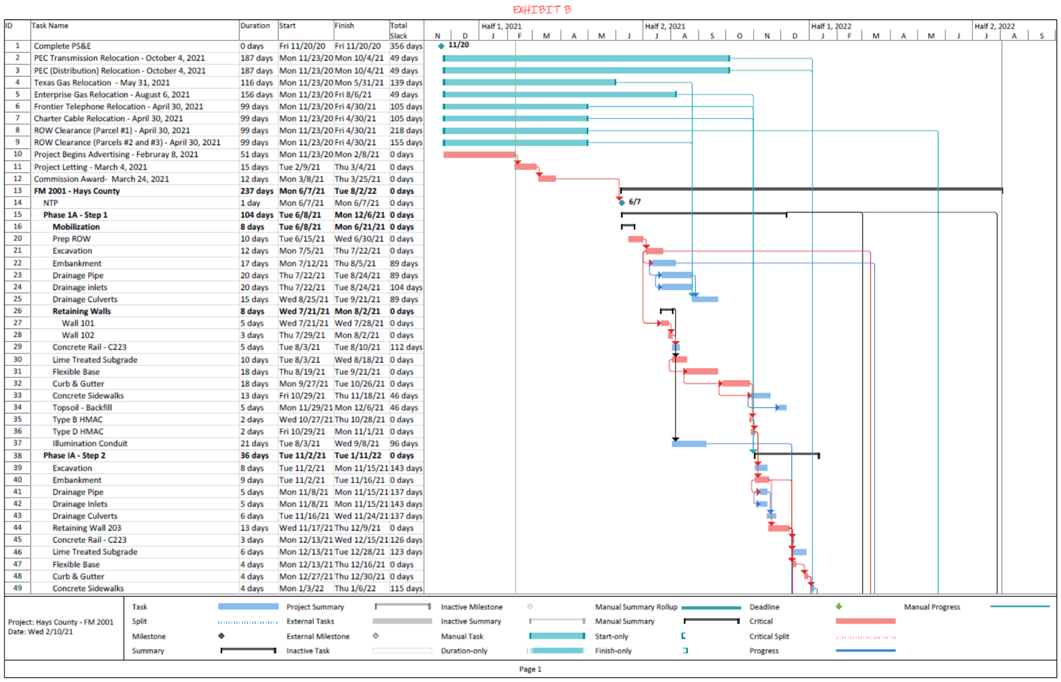


Figure 3.5 Project Schedule with Utility Clearance

3.2.1.3. **Exhibit C. Traffic Control Plan Phase Narrative**

The TCP Phase Narrative provides an overview of the sequence of work shown in the traffic control plans. When a CMP is required, a note must be added to the TCP Phase Narrative restricting the contractor from working in any areas where conflicts have not been resolved and included in the plan set for the 100% PS&E submittal.

3.2.1.4. **Conflict Layout**

The conflict layout sheet depicts all phases of construction and identifies all conflicts at the time letting. Depending on the project scope or length, multiple conflict layout sheets may be appropriate. The sheet(s) must be included in the plan set for the 100% PS&E submittal.

The purpose of these plans is to provide an overview of the expected utility accommodations on the project. These plans show, what TxDOT believes to be, the approximate locations and estimated clear dates of the existing utilities, and proposed relocations, or adjustments. These plans are provided for information purposes only and should not be solely relied upon without field verification. All

Proposed utility adjustments to be included in the highway contract are identified with an asterisk (*) to denote joint bid utility work. The joint bid utility plans and specifications are to be provided by the utility owner as part of their PS&E submittal.

The locations of existing and proposed water mains, gas mains, storm sewers, sanitary sewers, electric, fiber optics lines and other utilities as shown on these plans are based on the best information available to TxDOT and may not include all utilities actually located within the project. The information shown concerning type and location of utilities is not guaranteed to be accurate or all inclusive. It shall be the contractor's responsibility to field verify all exact utility types and locations prior to performing the work.

Notations for unclear conflicts must contain the utility name, parcel owner or ID, railroad name, etc., and clearance date.

Conflict layout showing the conflict information and locations, allows for an intuitive understanding of the specific areas of the construction site that are impacted. Visualizing conflicts allows for an intuitive understanding of the specific areas of the construction site that are impacted. Especially, the colored legend provides a quick visual reference, allowing project managers and stakeholders to understand the nature and ownership of each conflict at a glance. The featured components for the effective CMPs are addressed below.

- Colored Legend

A legend using different colors to represent various owners, utility lines, and categories makes it easier to identify conflicts. The colored legend provides a quick visual reference, allowing project managers and stakeholders to understand the nature and ownership of each conflict at a glance. This enhances the clarity of conflict locations on the project layout and helps in effective decision-making for conflict management. Different examples of TCP and conflict layouts with colored legends are suggested in Figures 3.6 and 3.7.

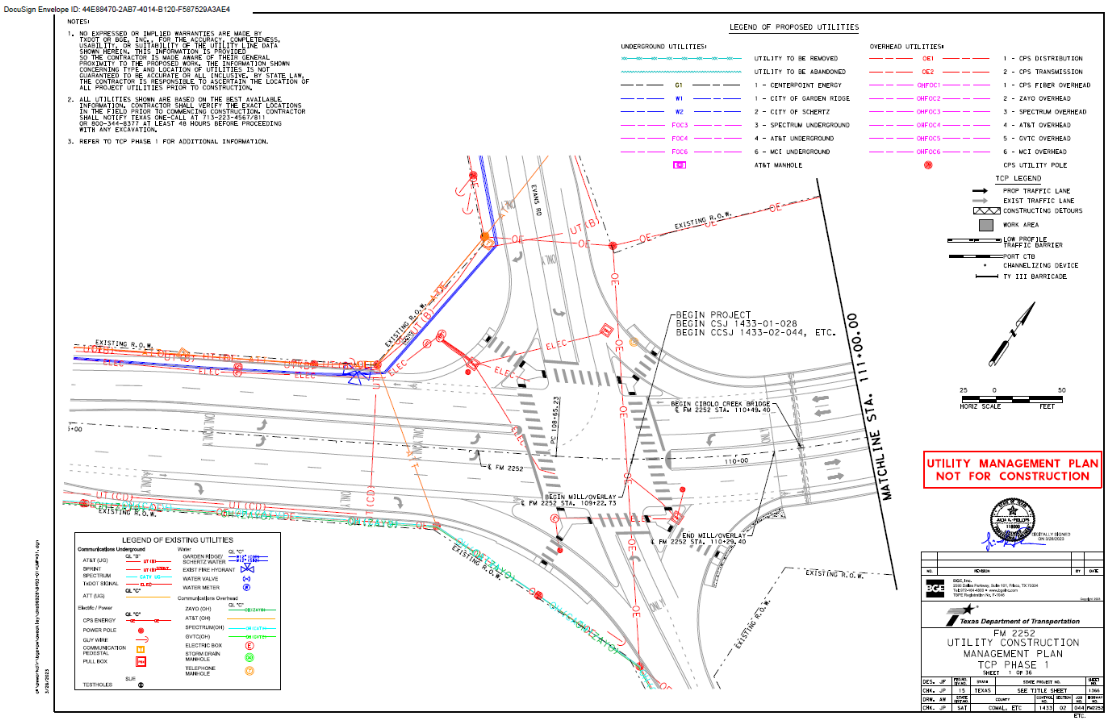


Figure 3.6 TCP and Conflict Layout with Legend – Example 1

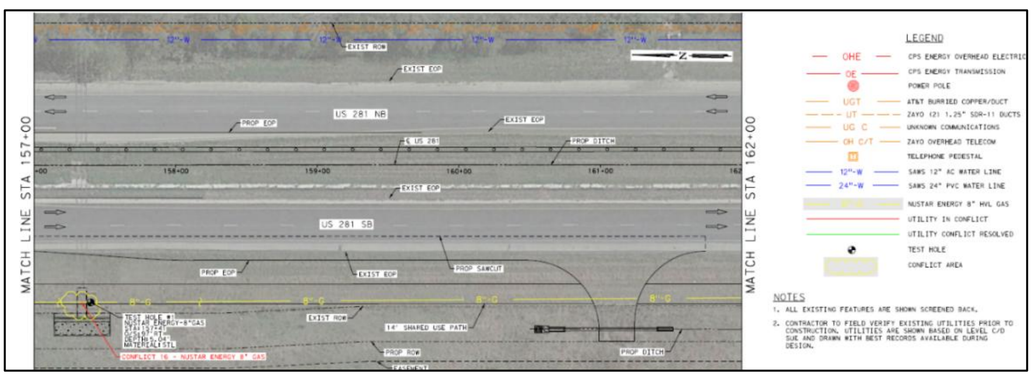


Figure 3.7 TCP and Conflict Layout with Legend – Example 2

- Markings on Conflict Locations

If conflict locations are indicated on the TCP, it facilitates the identification of how and where conflicts affect specific construction areas and where they need to be resolved. Including conflict IDs and relevant information enables effective tracking and management of conflicts that are not being cleared in the designated construction areas. An optimal example is illustrated in Figure 3.8. It is advisable to suit the marking format to align with the specific requirements of the TCP.

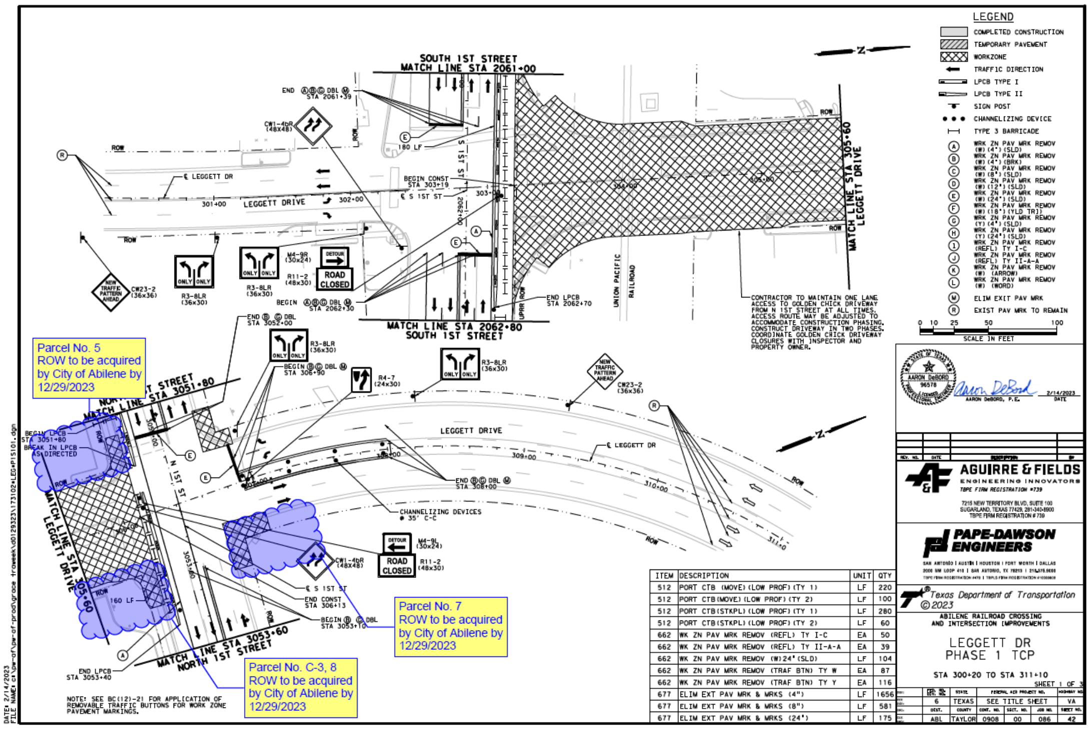


Figure 3.8 TCP and Conflict Layout with Labels

- Matched Colored with Conflict Information Table

Some CMPs use the same colors in the TCP to mark conflicts as those used in the Conflict Information Table in Exhibit A. This practice visualizes the conflict information and its location, making it easier to intuitively understand the conflicts. Specific examples of this usage are presented below.

Figure 3.9 shows conflicts that are numbered and color-coded on the TCP, matching the color scheme shown in Figure 3.3. This makes it easy to identify which conflicts occur in specific parts of the construction.

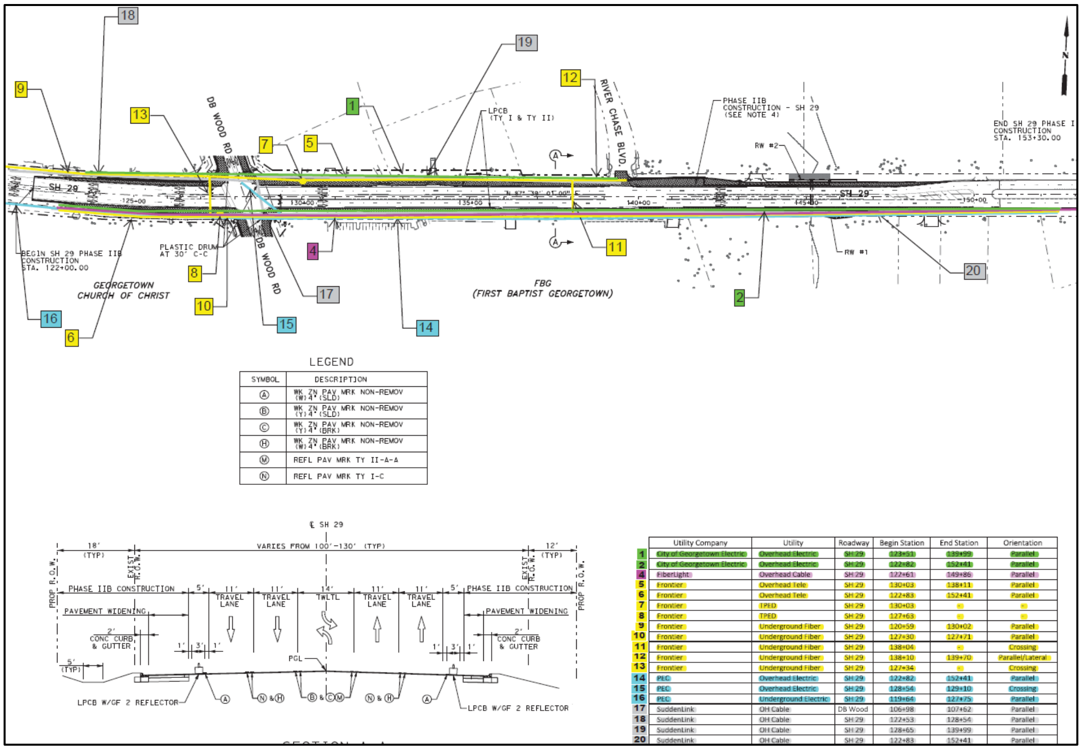


Figure 3.9 TCP and Conflict Layout with a Color Legend

3.3. Characterization of CMP Projects

This section provides a summary of the high-level analysis of all projects let in the defined research period. Key characteristics of projects with and without CMPs are reviewed to understand cost and duration differences among these projects.

3.3.1. Analysis of All Project Let Since 2019

From the time period after the implementation of CMP in FY2019 (September 2018) to September 2024, that is the research data cutoff point, a total of 4,950 projects were let in TxDOT. Of these, 255 projects (5.2%) required CMPs, while 4,695 projects (94.8%) did not and are categorized as non-CMP projects. Despite representing a small portion of the total number of projects, CMP-required projects accounted for approximately 38% of the total contract value, indicating that CMPs are predominantly associated with large-scale infrastructure projects.

The average contract amount per project was calculated by dividing the total contract value by the number of projects in each group. Projects with CMPs showed an average contract value more than 11 times higher than those without CMPs. In addition, average construction durations—measured for completed projects—were significantly longer for CMP projects than for non-CMP projects.

These findings suggest that CMP projects are not only larger in cost and duration but also more complex in nature, often involving a greater number of conflicts requiring CMPs to be identified and cleared before project execution.

Table 3.1 Comparison of Projects with CMP vs No CMP

Project Type	Total Number of Projects		Total Contract Amount		Average Contract Amount ($)	Average Construction Duration (month)
	Count	%	Dollar ($)	%		
CMP	255	5.2%	18,044,101,328	38%	70,761,182	39
Non CMP	4,695	94.8%	29,614,972,091	62%	6,307,768	22
Total	4,950	100%	47,659,073,419	100%	9,628,096	-

The graph below illustrates the distribution of projects by contract amount, grouped in $10 million intervals from $0 to $200 million. The X-axis represents the contract amount range, while the Y-axis (log scale) shows the number of projects. The distribution shows that although CMP projects are significantly fewer than non-CMP projects, they are more commonly associated with higher contract amounts, reflecting their larger scale and higher complexity. In contrast, most non-CMP projects are concentrated under the $5 million range. This trend highlights the role of CMPs in managing pre-construction risks, particularly in large-scale projects that are more likely to involve complex conflicts.

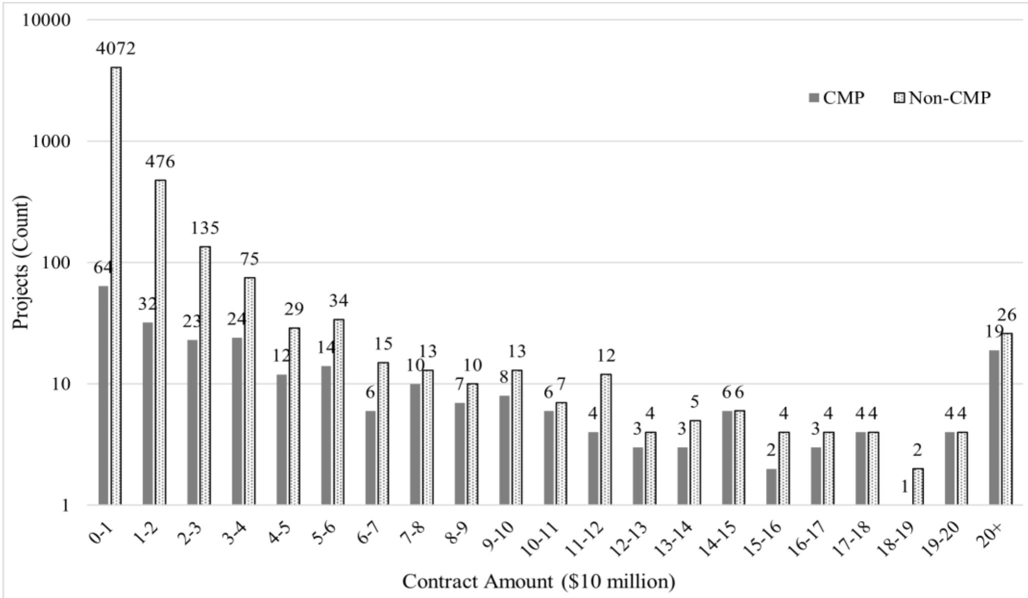


Figure 3.10 Project Distribution by Contract Amount – CMP vs Non-CMP

3.3.2. **Analysis of Completed CMP Projects**

All CMP records in PDF format issued during the target research period, from the initial implementation of CMPs in Fiscal Year 2019 (September 2018) through September 2024, were obtained and organized for this research. CMPs were categorized as either active or completed based on the status of project progress. Since data on change orders and project timelines for active projects are still subject to change, the projects are divided into two groups. This section focuses first on completed CMP projects, for which a full and finalized dataset is available. Table 3.2 presents the annual distribution of CMP projects categorized by project status by fiscal year.

Table 3.2 CMP Projects by Status

Project Start (Fiscal Year)	Project Status = Completed	Project Status = Active	Total Projects with CMP
2019	29	10	39
2020	12	31	43
2021	10	37	47
2022	6	32	38
2023	1	52	53
2024	0	35	35
Total	**58**	**197**	**255**

Among the total 255 CMP projects, 58 projects have been completed, while 197 projects remain active. The CMP project data were systematically analyzed across several key dimensions, including project information, conflict information, and conflict clearance dates. This multi-faceted analysis was conducted to understand the distribution, characteristics, and notable trends within the CMP dataset. These insights form the foundational basis for the data processing and analytical components of this study.

3.3.2.1. **Completed CMP Project Information**

Table 3.3 presents basic project information organized by CSJ (Project ID), including let dates, completion dates, and contract amounts. The projects are listed in chronological order based on their let dates, beginning with the first CMP-implemented project. The actual completion dates were sourced from TxDOT's project data. The planned completion dates were extracted from CMP documents and the conflict clearance dataset. These expected dates were established during the PS&E phase and formally recorded when CMPs were reviewed and approved. In this context, the planned completion date represents the anticipated project end date at the time of initial planning, while the actual completion date reflects when the project was truly completed.

To assess deviations from the original schedule, the metric "Actual – Planned Completion Date" was calculated by subtracting the planned completion date from the actual completion date. Discrepancies between actual and planned completion dates can arise from various factors, including changes in project scope, modifications to execution strategies, and the issuance of change orders. Additionally, conflict clearance issues identified in CMPs may also contribute to such delays.

In summary, the findings presented in this chapter suggest that project completion timelines are shaped not only by broad changes in project scope but also by factors related to CMP development and conflict resolution.

Table 3.3 Project Information – Completed CMP Projects

No	District	Original Contract Amount ($)	Actual Let Date	Actual Completion Date (a)	Planned Completion Date (b)	Actual – Planned Completion Date (a-b in Days)
1	El Paso	32,640,631	10/3/2018	1/27/2023	-	-
2	Brownwood	9,089,126	11/6/2018	5/14/2020	8/12/2019	276
3	El Paso	91,166,598	11/6/2018	12/21/2023	4/15/2022	615
4	Austin	34,428,168	11/7/2018	4/3/2023	2/5/2021	787

No	District	Original Contract Amount ($)	Actual Let Date	Actual Completion Date (a)	Planned Completion Date (b)	Actual – Planned Completion Date (a-b in Days)
5	Yoakum	2,898,132	12/6/2018	2/8/2021	1/30/2020	375
6	Austin	18,681,315	12/6/2018	8/25/2022	9/4/2020	720
7	Houston	2,789,053	1/8/2019	9/1/2021	4/30/2020	489
8	Yoakum	34,757,445	1/8/2019	8/5/2024	10/21/2021	1019
9	Amarillo	45,797,691	1/9/2019	9/28/2023	3/29/2022	548
10	Lubbock	18,836,295	2/5/2019	4/28/2022	8/22/2022	-116
11	Beaumont	35,023,919	2/5/2019	3/20/2023	5/29/2020	1025
12	Houston	43,751,963	3/5/2019	3/25/2024	2/11/2022	773
13	Austin	28,375,954	3/6/2019	8/16/2022	6/4/2021	438
14	Dallas	4,599,653	4/2/2019	5/27/2022	2/10/2021	471
15	Austin	24,590,929	4/2/2019	2/19/2024	12/14/2020	1162
16	Laredo	23,429,429	4/3/2019	7/21/2022	11/1/2021	262
17	Odessa	48,936,556	4/3/2019	9/24/2024	4/17/2023	526
18	Houston	6,676,661	5/7/2019	3/11/2022	6/29/2020	620
19	Houston	2,849,524	5/8/2019	5/23/2022	1/29/2021	479
20	Childress	6,581,608	5/8/2019	8/11/2022	11/15/2020	634
21	Austin	50,359,853	5/8/2019	12/13/2023	8/11/2022	489
22	Fort Worth	23,361,070	5/8/2019	3/18/2024	12/30/2021	809
23	Corpus Christi	8,996,759	7/9/2019	8/30/2022	2/10/2021	566
24	Houston	15,109,139	7/9/2019	3/20/2024	11/30/2020	1206
25	Houston	13,891,860	7/10/2019	2/8/2022	4/30/2021	284
26	Houston	10,994,230	7/10/2019	11/14/2023	10/31/2020	1109
27	Austin	15,507,841	7/10/2019	9/9/2024	12/31/2020	1348
28	Houston	2,399,432	8/6/2019	12/14/2022	7/10/2020	887
29	Austin	27,468,704	8/6/2019	8/16/2024	11/5/2019	1746
30	Austin	1,519,610	9/6/2019	1/14/2023	4/30/2020	989
31	Dallas	33,684,844	11/5/2019	8/16/2024	11/25/2022	630
32	Abilene	8,259,120	1/9/2020	7/16/2022	8/29/2022	-44
33	San Angelo	16,563,814	3/5/2020	3/3/2022	1/31/2022	31
34	Austin	17,392,024	3/5/2020	3/13/2023	11/30/2021	468
35	Houston	5,499,460	5/7/2020	10/25/2022	7/6/2021	476
36	Lufkin	4,885,972	5/7/2020	11/10/2022	11/17/2021	358
37	Houston	20,384,047	5/8/2020	8/2/2024	6/5/2022	789
38	Austin	1,850,412	6/5/2020	12/20/2022	4/6/2021	623
39	Bryan	1,198,244	6/5/2020	8/16/2024	10/31/2021	1020
40	Odessa	54,467,579	8/6/2020	5/24/2023	1/31/2023	113
41	Austin	5,548,288	8/6/2020	1/11/2024	5/10/2022	611
42	Dallas	28,053,073	9/4/2020	3/15/2024	4/4/2023	346

No	District	Original Contract Amount ($)	Actual Let Date	Actual Completion Date (a)	Planned Completion Date (b)	Actual – Planned Completion Date (a-b in Days)
43	Fort Worth	1,053,948	10/1/2020	4/6/2022	6/30/2021	280
44	Atlanta	5,634,658	1/7/2021	1/29/2024	4/1/2023	303
45	Austin	5,959,526	3/5/2021	7/27/2023	8/2/2022	359
46	Beaumont	388,842	5/6/2021	10/20/2023	1/1/2022	657
47	Pharr	1,147,081	6/4/2021	9/18/2023	5/25/2022	481
48	San Antonio	4,316,413	6/4/2021	11/15/2023	6/1/2022	532
49	Austin	9,323,423	8/4/2021	5/9/2024	6/30/2023	314
50	Austin	5,760,579	8/4/2021	9/11/2024	4/14/2023	516
51	Austin	6,598,036	8/5/2021	7/18/2023	9/27/2022	294
52	Houston	3,272,347	10/8/2021	4/25/2023	11/3/2022	173
53	Austin	6,654,422	11/4/2021	10/17/2023	9/30/2023	17
54	Austin	36,556,400	11/4/2021	7/3/2024	12/31/2023	185
55	Austin	9,387,686	1/6/2022	10/18/2023	4/1/2023	200
56	Austin	12,252,580	4/7/2022	9/25/2024	12/15/2023	285
57	Fort Worth	2,285,805	8/4/2022	8/9/2023	7/31/2023	9
58	Corpus Christi	1,589,267	2/2/2023	6/17/2024	4/10/2024	68

3.3.2.2. **Conflict Information from Completed CMP Projects**

The conflicts identified in the CMP are classified into three types: Right-of-Way Acquisition (ROW), Railroad Agreement (RR), and Utility Relocation (UTL). The conflict clearance certificate in a CMP details the owners of ROW, RR, and UTL, their precise locations with drawings, and expected clearance dates, among other information.

Utility conflicts, which constitute the majority of conflicts in CMPs due to their varied types and ownerships, were further categorized by utility type—water, sewer, telecommunications, electricity, power poles, and gas/oil pipelines. Expected clearance dates for each conflict were certified in the CMP, while actual clearance dates were recorded only at the final clearance stage by ROW, RR, and UTL categories. The difference between planned and actual clearance dates was calculated as Actual – Planned Clearance Date, with the actual clearance date reflecting the resolution of the last conflict in the project. If the actual clearance date exceeded the planned date, the delay period was calculated, and a clearance delay flag was assigned.

An example of CMP projects and their conflict data is presented in Table 2.3. Among the 58 completed projects with CMP, there were a total of 1,018 conflicts, with utility issues being the most common, totaling 942 cases. The breakdown of utility conflicts by type is as follows: telecommunications 364, electricity 316, gas 131, water 90, power pole 24, and sewer 17.

It is noteworthy that CMPs started including buffer time for projects let after 2021. The research team observed no instances of CMPs that reported buffer information where the difference between the actual and expected clearance dates exceeded the buffer time. This indicates that, even when conflict clearances did not meet the expected schedule, they were resolved within the buffer time, thereby not affecting the construction schedule. The inclusion of buffer time has proven effective, demonstrating that conflicts do not impact the construction timeline when adequate buffer time is allocated.

Table 3.4 CMP Conflict and Clearance Data from Completed CMP Projects

No	District	Conflicts: Total Count	ROW (Right-of-way Acquisition): ROW Total Conflict Count	ROW: Expected ROW Clearance Date	ROW: Actual ROW Clearance Date	RR (Railroad Agreement): RR Total Conflict Count	RR: Expected RR Clearance Date	RR: Actual RR Clearance Date	UTL (Utility Relocation): UTL Total Conflict Count	UTL Conflict Count by Type: Water	Sewer	Tele com	Electric	Power Pole	Gas/Oil	Expected UTL Clearance Date	Actual UTL Clearance Date	Buffer Time Shown in the CMP (Month)	Actual – Expected Clearance Date: ROW	RR	UTL
1	El Paso	12	6	2/25/2019	9/30/2019	1			5			4	1			4/30/2019	2/25/2019		217	0	-64
2	Brownwood	1				1	4/30/2019	11/30/2018	0											-151	
3	El Paso	22	3	3/31/2019	4/24/2019	1	2/28/2019	8/12/2019	18	10		3			5	5/1/2019	2/15/2021		24	165	656
4	Austin	27							27			3	23		1	4/30/2019	11/20/2019				204
5	Yoakum	4							4			4				4/30/2019	6/13/2019				44
6	Austin	21							21	5		7	8		1	3/31/2019	10/1/2019				184
7	Houston	82	3	7/1/2019	8/1/2019				79			79							31		
8	Yoakum	4							4				4			8/1/2019	2/20/2020				203
9	Amarillo	37	3	5/1/2019	1/16/2020				34	2	3	17	7		5	2/8/2020	1/16/2020		260		-23
10	Lubbock	51	1				2/28/2019	4/9/2019	50	5		20	20		5	4/30/2019	12/9/2019			40	223
11	Beaumont	2							2			1	1			9/15/2019	3/7/2020				174
12	Houston	92	7	4/30/2019	12/1/2022				85	2	3	26	28		26	7/31/2019	12/1/2021		1311		854
13	Austin	89						1/22/2019	89	6		19	59		5	8/23/2019	7/21/2020				333
14	Dallas	7				1			6			3	2		1	8/31/2019	6/1/2021				640
15	Austin	2							2				1		1	8/23/2019	7/7/2020				319
16	Laredo	13							13		7	6				12/14/2020	12/13/2020				-1
17	Odessa	3	3	3/1/2021	2/28/2021				0										-1		
18	Houston	8							8	3		1		4		11/30/2019	11/30/2019				
19	Houston	5	2	8/31/2019	9/5/2019				3				3			11/30/2019	10/1/2019		5		-60
20	Childress	1							1	1						10/12/2019	6/15/2020				247
21	Austin	2				1	3/31/2020	3/30/2020	1	1						6/30/2019	8/15/2019			-1	46
22	Fort Worth	28	22	5/31/2020	12/30/2019				6			2		2	2	10/31/2020	6/1/2021		-153		213
23	Corpus Christi	4							4	2	1		1			12/1/2019	2/7/2020				68
24	Houston	53							53			13	14	1	25	2/14/2020	2/1/2020				-13
25	Houston	21							21			10		3	8	12/31/2019	10/1/2019				-91
26	Houston	44							44	17		6	7		14	10/31/2019	10/1/2019				-30
27	Austin	32							32			13	17	2		12/22/2019	4/14/2021				479
28	Houston	2							2			2				12/31/2019	12/1/2019				-30
29	Austin	40					4/1/2020	5/27/2020	40			9	26	5		9/15/2019	10/15/2019			56	30

No	District	Conflicts																Buffer Time Shown in the CMP (Month)	Actual – Expected Clearance Date		
		Total Count	ROW (Right-of-way Acquisition)			RR (Railroad Agreement)			UTL (Utility Relocation)												
			ROW Total Conflict Count	Expected ROW Clearance Date	Actual ROW Clearance Date	RR Total Conflict Count	Expected RR Clearance Date	Actual RR Clearance Date	UTL Total Conflict Count	UTL Conflict Count by Type						Expected UTL Clearance Date	Actual UTL Clearance Date				
										Water	Sewer	Tele com	Electric	Power Pole	Gas/Oil				ROW	RR	UTL
30	Austin	1				1	2/29/2020	6/29/2021	0											486	
31	Dallas	3				1			2				2			3/1/2020	3/1/2020				
32	Abilene	5							5	1		2	1		1	6/29/2020	7/28/2020				29
33	San Angelo	14							14	2		11			1	7/19/2020	7/31/2020				12
34	Austin	34							34			30			4	10/31/2020	10/31/2020				
35	Houston	16							16			10		1	5	12/31/2020	12/3/2020				-28
36	Lufkin	5							5			5				9/15/2020	9/1/2020				-14
37	Houston	9	2	1/2/2021	11/4/2021				7			2	4	1		11/30/2020	12/31/2020		306		31
38	Austin	7							7			7				12/1/2020	4/13/2021				133
39	Bryan	7							7	3	1	2	1			8/9/2021	5/21/2021				-80
40	Odessa	17							17			2	13		2	12/31/2021	12/16/2021				-15
41	Austin	20							20			14	6			1/18/2021	7/26/2021				189
42	Dallas	16							16	4	1	6	1	1	3	12/1/2020	5/15/2021				165
43	Fort Worth	1							1	1						3/31/2021	3/31/2021				
44	Atlanta	4				1	10/1/2021	8/11/2021	3	1		1		1		2/1/2021	10/5/2021			-51	246
45	Austin	12	3	4/30/2021	9/1/2021				9			3	3		3	10/4/2021	4/13/2022	6.5	124		191
46	Beaumont	7	6	9/27/2021	5/1/2021				1			1				9/27/2021	10/1/2021	1	-149		4
47	Pharr	3							3		1		1		1	9/28/2021	12/1/2021	4.5			64
48	San Antonio	9							9						9	9/28/2021	8/6/2021	5			-53
49	Austin	1				1	8/30/2022	11/6/2021	0											-297	
50	Austin	6							6	2			4			9/1/2022	1/31/2023				152
51	Austin	17							17	1		12	2		2	10/31/2021	3/15/2022				135
52	Houston	4							4			1		2	1	2/28/2022	3/15/2022	7			15
53	Austin	3							3	2		1				5/18/2022	1/31/2023				258
54	Austin	4	2	12/1/2021	12/30/2021	1	12/31/2021	1/31/2022	1					1		12/1/2021	1/1/2022		29	31	31
55	Austin	15				1	6/20/2022	2/17/2022	14	14						1/31/2022	4/29/2022	11		-123	88
56	Austin	54							54				54			7/29/2022	1/30/2024	3			550
57	Fort Worth	12							12	5		5	2			3/27/2023	6/20/2023	7			85
58	Atlanta	4				1	10/1/2021	8/11/2021	3	1		1		1		2/1/2021	10/5/2021			-51	246
	Total	**1,018**	**65**	**-**	**-**	**11**	**-**	**-**	**942**	**90**	**17**	**364**	**316**	**24**	**131**						

3.3.3. Analysis of Active CMP Projects

In a target research period, a total of 197 CMP projects remained ongoing. Since certain data elements, such as actual completion dates and finalized change order details, can only be determined upon project completion, they are excluded from this section.

3.3.3.1. Active CMP Project Information

Table 3.5 presents basic project information for active CMP projects, including contract amounts and letting dates. The structure and content of this information are consistent with that of completed projects. However, actual completion dates are not included, as these projects have not yet been finalized. Only planned completion dates are provided, as they were defined at the time the CMP was issued and are still subject to change.

Table 3.5 Project Information - Active CMP Projects

No	District	Original Contract Amount ($)	Actual Let Date	Planned Completion Date
1	Houston	116,922,668	9/6/2018	7/7/2022
2	Beaumont	102,144,835	9/7/2018	3/17/2022
3	El Paso	144,207,911	10/3/2018	N/A
4	Yoakum	34,757,445	1/8/2019	11/9/2020
5	Odessa	48,936,556	4/3/2019	5/4/2023
6	Houston	17,999,505	4/3/2019	7/31/2023
7	Lufkin	37,447,955	6/5/2019	5/31/2022
8	Lufkin	86,198,369	7/9/2019	11/15/2021
9	San Antonio	77,332,883	7/9/2019	1/13/2023
10	Houston	25,495,057	7/9/2019	9/14/2024
11	Austin	15,507,841	7/10/2019	1/14/2024
12	Austin	27,468,704	8/6/2019	12/30/2022
13	Houston	65,322,057	8/6/2019	3/10/2022
14	Houston	165,825,007	8/7/2019	3/30/2022
15	Houston	75,955,686	9/5/2019	10/15/2024
16	Houston	81,760,171	9/6/2019	5/1/2026
17	Houston	42,315,989	9/6/2019	2/1/2024
18	Houston	12,691,073	9/6/2019	11/30/2022
19	Corpus Christi	78,425,430	10/2/2019	7/31/2024
20	Dallas	33,684,844	11/5/2019	11/22/2023
21	Yoakum	151,401,690	11/5/2019	1/9/2023
22	Paris	31,389,823	11/6/2019	3/31/2025
23	Dallas	78,665,971	12/3/2019	11/28/2023

No	District	Original Contract Amount ($)	Actual Let Date	Planned Completion Date
24	Lufkin	140,865,929	12/4/2019	3/5/2024
25	Yoakum	168,669,295	1/10/2020	6/1/2024
26	Amarillo	50,032,708	2/6/2020	9/11/2023
27	Yoakum	12,487,777	2/7/2020	8/31/2024
28	Dallas	301,097,341	5/7/2020	10/4/2023
29	Lubbock	23,982,637	5/8/2020	3/31/2026
30	Corpus Christi	55,237,175	5/8/2020	5/30/2024
31	Atlanta	88,870,749	5/8/2020	1/31/2022
32	Houston	20,384,047	5/8/2020	10/12/2023
33	Laredo	114,884,944	6/4/2020	1/2/2023
34	Fort Worth	103,766,994	6/4/2020	7/31/2024
35	Houston	36,717,603	6/4/2020	3/11/2024
36	Beaumont	52,363,934	6/5/2020	3/28/2025
37	Bryan	1,198,244	6/5/2020	4/8/2022
38	Fort Worth	98,999,997	6/5/2020	7/30/2024
39	Fort Worth	22,988,076	7/8/2020	7/26/2026
40	Fort Worth	31,553,079	7/8/2020	2/28/2023
41	Houston	29,787,408	7/8/2020	12/31/2025
42	Houston	58,199,301	7/8/2020	10/27/2023
43	El Paso	75,428,369	7/8/2020	11/13/2023
44	San Antonio	149,200,124	7/9/2020	8/31/2024
45	Bryan	4,509,032	7/9/2020	6/1/2023
46	Pharr	5,394,454	8/5/2020	5/31/2024
47	Houston	225,845,814	8/5/2020	11/21/2024
48	Tyler	13,220,500	8/5/2020	4/22/2022
49	Houston	103,251,457	8/6/2020	8/31/2023
50	Austin	60,525,748	9/3/2020	11/3/2021
51	Fort Worth	20,892,293	9/3/2020	2/17/2022
52	Houston	70,042,726	9/4/2020	7/15/2024
53	Bryan	45,254,645	9/4/2020	3/25/2022
54	Dallas	91,386,585	10/1/2020	11/1/2023
55	Fort Worth	38,841,809	10/1/2020	12/12/2023
56	Odessa	15,760,358	10/1/2020	1/17/2026
57	Fort Worth	30,387,611	10/2/2020	12/31/2024
58	Bryan	2,432,739	10/2/2020	10/23/2024
59	Laredo	6,359,706	11/4/2020	12/14/2023
60	San Angelo	24,497,111	11/5/2020	10/22/2024
61	Pharr	4,728,316	11/5/2020	2/18/2025
62	San Angelo	26,934,935	1/7/2021	7/10/2025

No	District	Original Contract Amount ($)	Actual Let Date	Planned Completion Date
63	San Antonio	15,523,367	1/7/2021	6/30/2022
64	Odessa	36,305,216	2/4/2021	6/16/2025
65	Wichita Falls	209,999,113	2/5/2021	10/5/2026
66	Dallas	142,404,495	3/4/2021	6/27/2022
67	San Antonio	100,202,671	3/5/2021	1/3/2025
68	San Antonio	6,974,797	4/7/2021	7/28/2025
69	San Antonio	148,073,104	4/7/2021	3/31/2025
70	Austin	81,218,267	4/8/2021	2/6/2025
71	El Paso	5,350,903	6/3/2021	8/31/2026
72	San Antonio	243,941,845	6/3/2021	8/28/2023
73	San Antonio	5,145,675	6/4/2021	4/15/2024
74	San Antonio	39,295,624	6/4/2021	3/30/2022
75	Lubbock	154,873,365	6/4/2021	7/31/2025
76	Wichita Falls	48,462,414	7/1/2021	9/30/2023
77	Austin	9,323,423	8/4/2021	7/1/2024
78	Bryan	18,052,622	8/4/2021	3/31/2025
79	Dallas	135,873,393	8/4/2021	5/31/2023
80	Fort Worth	30,738,904	8/4/2021	7/10/2025
81	Houston	96,532,489	8/4/2021	6/30/2027
82	Houston	108,363,935	8/4/2021	7/13/2022
83	Austin	5,760,579	8/4/2021	4/9/2026
84	Houston	16,095,271	8/4/2021	4/30/2025
85	Beaumont	24,884,247	8/5/2021	8/22/2024
86	Beaumont	7,063,406	8/5/2021	8/21/2023
87	Waco	54,894,543	8/5/2021	10/31/2025
88	Houston	48,285,564	8/5/2021	3/25/2027
89	Houston	54,799,230	8/5/2021	9/1/2027
90	Waco	29,180,209	8/5/2021	5/30/2024
91	Paris	9,300,300	9/2/2021	8/1/2024
92	Beaumont	70,021,319	9/2/2021	12/9/2023
93	Bryan	198,146,415	9/2/2021	2/19/2026
94	Austin	8,953,610	9/2/2021	1/4/2028
95	San Antonio	125,021,001	11/3/2021	1/2/2029
96	Austin	36,556,400	11/4/2021	9/29/2023
97	Austin	71,330,416	12/1/2021	6/1/2023
98	Pharr	24,806,299	12/2/2021	6/29/2027
99	Lufkin	2,490,125	1/7/2022	10/28/2024
100	El Paso	174,305,265	2/4/2022	12/12/2024
101	Corpus Christi	176,703,809	3/3/2022	2/29/2024

No	District	Original Contract Amount ($)	Actual Let Date	Planned Completion Date
102	Beaumont	307,243,558	3/3/2022	3/25/2025
103	Houston	14,685,048	3/3/2022	6/28/2024
104	Dallas	15,839,362	3/4/2022	7/13/2026
105	Austin	12,252,580	4/7/2022	9/27/2024
106	Houston	7,143,864	5/4/2022	6/30/2025
107	El Paso	137,955,531	5/4/2022	10/16/2023
108	Odessa	68,497,620	5/5/2022	5/22/2026
109	Austin	547,603,210	5/5/2022	10/31/2025
110	Lufkin	172,799,108	5/5/2022	8/28/2023
111	Houston	8,553,523	5/5/2022	6/30/2024
112	Dallas	4,570,585	5/5/2022	7/31/2026
113	San Antonio	418,111,026	6/1/2022	12/5/2026
114	Bryan	17,531,350	6/2/2022	6/18/2024
115	Lufkin	31,995,094	6/2/2022	5/26/2026
116	Dallas	31,480,213	6/29/2022	10/26/2026
117	Tyler	55,487,305	6/30/2022	5/20/2024
118	Bryan	14,087,278	6/30/2022	10/2/2023
119	Houston	113,599,269	8/3/2022	6/30/2027
120	Tyler	44,362,527	8/3/2022	12/10/2025
121	Houston	57,486,751	8/3/2022	4/5/2027
122	Fort Worth	4,410,629	8/3/2022	2/1/2025
123	Houston	51,803,008	8/4/2022	5/1/2023
124	Odessa	36,740,467	8/4/2022	11/13/2026
125	Austin	3,199,567	8/4/2022	8/29/2025
126	Atlanta	29,546,263	9/7/2022	10/31/2025
127	Paris	128,075,439	10/6/2022	12/11/2024
128	Houston	107,298,495	10/6/2022	10/7/2026
129	Houston	88,477,391	10/7/2022	2/23/2028
130	Houston	10,942,905	11/2/2022	2/20/2025
131	Bryan	35,901,732	12/1/2022	3/6/2026
132	Amarillo	133,890,000	12/1/2022	8/1/2025
133	Pharr	1,753,094	1/5/2023	4/28/2028
134	Brownwood	1,073,352	1/5/2023	4/1/2027
135	Atlanta	11,920,528	1/5/2023	7/29/2027
136	Houston	90,916,060	1/5/2023	10/17/2024
137	San Antonio	97,802,917	1/6/2023	2/27/2027
138	Pharr	15,880,158	2/1/2023	3/29/2029
139	Brownwood	10,684,355	2/2/2023	11/30/2024
140	Corpus Christi	1,589,267	2/2/2023	1/29/2027

No	District	Original Contract Amount ($)	Actual Let Date	Planned Completion Date
141	Houston	93,945,777	3/7/2023	9/27/2029
142	Odessa	49,428,879	3/8/2023	10/1/2026
143	Austin	22,834,261	3/8/2023	1/3/2025
144	Houston	12,079,143	4/4/2023	10/20/2025
145	Tyler	69,493,846	4/4/2023	9/15/2025
146	Houston	85,589,531	4/4/2023	3/19/2026
147	El Paso	17,835,786	4/4/2023	12/30/2025
148	Houston	99,699,465	4/5/2023	10/23/2028
149	Dallas	46,333,942	4/5/2023	2/20/2025
150	Fort Worth	4,830,946	5/4/2023	9/26/2025
151	Atlanta	53,799,919	5/4/2023	11/24/2025
152	San Antonio	48,503,887	5/4/2023	9/15/2024
153	Pharr	33,170,887	5/5/2023	10/14/2030
154	Austin	2,331,672	5/5/2023	12/31/2025
155	Houston	197,855,402	5/5/2023	11/16/2027
156	San Antonio	245,194,039	6/1/2023	12/23/2027
157	Austin	12,041,546	6/2/2023	4/15/2029
158	Houston	62,500,910	6/27/2023	5/17/2028
159	Lufkin	189,820,654	6/27/2023	4/30/2028
160	Houston	33,795,218	6/27/2023	10/1/2024
161	Austin	2,578,219	6/27/2023	3/28/2025
162	Pharr	20,955,781	6/27/2023	5/31/2026
163	Houston	16,604,494	6/27/2023	1/28/2025
164	El Paso	36,413,140	6/27/2023	9/21/2027
165	Houston	28,674,823	6/27/2023	6/10/2026
166	Yoakum	364,820,500	6/28/2023	1/31/2025
167	San Antonio	5,064,945	6/28/2023	6/23/2028
168	Bryan	9,980,814	6/28/2023	2/7/2028
169	Abilene	16,096,056	6/28/2023	5/1/2025
170	Austin	5,205,669	6/28/2023	4/17/2025
171	Laredo	344,030,535	8/2/2023	6/21/2027
172	Yoakum	55,933,078	8/2/2023	6/1/2028
173	San Antonio	68,941,542	8/2/2023	11/16/2028
174	Paris	179,987,605	8/3/2023	2/10/2026
175	Houston	144,686,970	8/3/2023	12/8/2028
176	Tyler	66,711,336	8/3/2023	6/24/2027
177	Yoakum	74,026,222	8/3/2023	4/16/2025
178	Laredo	7,207,235	8/3/2023	11/30/2025
179	Abilene	8,867,739	8/3/2023	5/15/2026

No	District	Original Contract Amount ($)	Actual Let Date	Planned Completion Date
180	Houston	27,298,741	8/3/2023	8/28/2026
181	Houston	1,998,146	9/6/2023	10/27/2029
182	Beaumont	205,416,130	9/6/2023	2/28/2027
183	Houston	3,799,247	9/7/2023	5/10/2029
184	Austin	5,546,235	9/7/2023	12/15/2027
185	Tyler	167,154,897	10/5/2023	3/22/2029
186	San Antonio	72,780,035	10/5/2023	10/6/2026
187	Austin	4,715,510	10/5/2023	3/31/2027
188	San Antonio	1,244,334	10/6/2023	5/20/2025
189	San Antonio	192,940,023	10/6/2023	12/17/2027
190	Odessa	237,861,190	11/2/2023	10/31/2027
191	Pharr	190,998,296	12/5/2023	9/30/2028
192	Yoakum	342,707,535	12/6/2023	12/21/2029
193	Houston	15,447,120	1/4/2024	2/13/2029
194	Amarillo	312,507,981	2/1/2024	1/6/2027
195	Waco	53,775,775	2/2/2024	7/10/2031
196	San Antonio	2,399,238	3/5/2024	11/5/2032
197	Amarillo	73,856,678	3/5/2024	8/4/2026

3.3.3.2. **Conflict Information from Active CMP Projects**

In the same format, conflict information for active CMP projects is presented in Appendix A. Similar to the completed projects, the table displays the total number of conflicts by type along with their planned clearance dates. However, information on actual clearance dates is not included, as it is not yet available for projects that are still ongoing.

The total number of conflicts from 197 active projects is 6,220, consisting of 711 ROW conflicts, 59 RR conflicts, and 4,670 utility-related conflicts. Among UTL, same as completed CMP projects, 2,307 electricity and 1,431 telecom conflicts are the majority, followed by 718 power pole conflicts, 466 water, 264 oil and gas, and 51 sewer conflicts.

Chapter 4. Analysis of Change Orders

4.1. Introduction

Change orders occur in many state highway construction projects. They represent modifications to the original scope of work agreed upon in the contract or changes due to new developments that occurred during project execution. These changes can arise from various causes, including unforeseen site conditions, design modifications, regulatory changes, and stakeholder requests. Proper management of change orders is crucial to ensuring project success, maintaining budget and schedule baselines, and mitigating risks. To this end, TxDOT provides statewide guidelines for managing and recording change order data, utilizing an in-house management system named "SiteManager." CMP also aims to mitigate change orders related to unclear conflicts. To verify the effectiveness of CMPs in preventing change orders, it is essential to analyze change orders from projects that have a CMP and also from projects that don't have one.

In this regard, Task 4 of this research project involves:

- Collecting and analyzing data on project change orders.
- Classifying change orders based on significant project attributes, including project amount, reason codes, project type, and districts.
- Identifying and verifying relationships between change orders and CMPs.
- Identifying and categorizing change orders in relation to conflict types of Right-of-way, Railroad, and Utilities.

4.2. Data Collection

This research task was conducted using change order data stored in SiteManager, which TxDOT employs to manage and store primary project information and change orders. Other specific activities such as utility relocation management, right-of-way acquisition, and the review and approval of drawings may utilize other specialized systems.

From SiteManager, reports summarizing change orders by project and detailed reports describing each change order were generated. Initially, text data were extracted and analyzed based on basic information, including reason codes. Subsequently, an in-depth forensic analysis was conducted to determine the association with the CMP and identify other potential conflicts. This classification served as the foundation for a comprehensive analysis, categorizing change orders in the context of the CMP to uncover significant findings.

The research team acquired access to SiteManager, enabling the exploration of its system, functions, and the types of stored documents and data. Through this exploration, two primary reports were identified as the main sources of change order information: the Change Order Summary Report and the Change Order Report. These reports were extracted and organized by projects in the data collection step for the following analysis step.

4.2.1.1. **Change Order Summary Report**

The Change Order Summary Report lists all change orders that have occurred in a project. As shown in Figure 4.1, at the top of the report, project information such as CSJ number, the original contract amount, district, and other major details are provided. Below this section, change orders are listed sequentially by change order number, starting from No. 1. Each entry includes the title of the change order, the corresponding change order amount, and any time adjustments in days, if applicable.

SiteManager
Construction Management Software

CHANGE ORDER SUMMARY REPORT

REPORT DATE: **03/28/24**

CONTRACT ID:	**026504062**	HIGHWAY:	**SH 21**
PROJECT:	**NH 2019(613)**	DISTRICT:	**14**
CONTRACT:	**05193201**	COUNTY:	**BASTROP**
AWARD AMOUNT:	**$50,359,853.46**	AREA ENGINEER:	[redacted]
PROJECTED AMOUNT:	**$51,270,304.44**	AREA NUMBER.:	**050**
CONTRACTOR:	**CAPITAL EXCAVATION COMPANY**		

Total Non-Participating Amount:	**0.00**
Total Non-Participating Days:	**0**

CO NUMBER	CO TYPE	STATUS	APPROVAL DATE	CONTRACT TIME ADJUSTMENT	MILESTONE TIME ADJUSTMENT	3RD PARTY PARTICIPATION	CO AMOUNT ($)	APPROVED CO AMOUNT $
001	PART	Approved	11/30/2019			$0.00	$7,456.78	$7,456.78
	Description:	Potholing, Gabion relocate, RW AF, add revised plan sheets						
002	PART	Approved	03/27/2020			$0.00	$37,623.68	$37,623.68
	Description:	straddle shaft concrete/CTB/slotted rail/PCP/added rip rap						
003	PART	Approved	03/30/2020			$0.00	$48,232.19	$48,232.19
	Description:	C221 rail at Water St						
004	PART	Approved	09/25/2020			$0.00	$171,225.60	$171,225.60
	Description:	Storm sewer/COSS move/C221 Rail/RWAA/ELC SRV/RR Flagger						
005	PART	Approved	05/07/2020			$0.00	$-463,667.00	$-463,667.00
	Description:	Frontage road Bent #8 and ML Bent #12 modifications						
006	SNPT	Approved	11/05/2020			$0.00	$14,763.93	$14,763.93
	Description:	3rd party damage						
007	PART	Approved	11/19/2020			$0.00	$32,282.28	$32,282.28
	Description:	Permanent casing/UPRR illumination/shear keys/SP506-005						
008	PART	Approved	01/21/2021			$0.00	$11,984.62	$11,984.62
	Description:	Electrical service fees/PCP on FRT RD bridges/Mailboxes						
009	PART	Approved	07/27/2021			$0.00	$-24,946.52	$-24,946.52
	Description:	Wall AF construction/WBFR base/ML bearing seat elev/Rev. TCP						
010	PART	Approved	10/04/2021			$0.00	$28,927.58	$28,927.58
	Description:	C2 curb/backfill at SSTR & Wall BH/illumin/C221 metal rail						
011	PART	Approved	10/04/2021			$0.00	$87,688.86	$87,688.86
	Description:	MASH crash cushion						
012	PART	Approved	11/30/2021	5		$0.00	$44,418.94	$44,418.94
	Description:	UPRR Bridge Demo/MKL culvert & wingwall/Striping items						
013	PART	Approved	05/26/2022			$0.00	$182,193.70	$182,193.70
	Description:	Hasler pothole/soil test/unsuitable materials/bridge drain						
014	PART	Approved	07/07/2022			$0.00	$105,238.13	$105,238.13
	Description:	Wall BB revision/Special Rip Rap/Revised Plan Sheets						

Figure 4.1 Change Order Summary Report Sample

4.2.1.2. **Change Order Report**

Each change order has a separate report detailing all aspects of the change order, including reason codes, change order amounts, time adjustments, change order items, and specific descriptions. These descriptions cover the reason for the changes, the impact on the project, and the surrounding project conditions. This report is the primary source for analysis as it contains essential information for identifying the characteristics of change orders, which will be analyzed alongside CMP data.

Each change order includes a primary reason code, and occasionally one or two secondary reason codes. These codes represent the primary causes of the change orders, categorized into seven main categories, with subcategories identified by letters. To enable accurate categorization, the reason codes were systematically extracted from each change order. The description sections provide detailed information on the change orders, including the context and causes of each change, the impact on the project, and any significant overruns or underruns in contract items. Figure 4.2 shows an example of a Change Order Report.

SiteManager Construction Management Software

CHANGE ORDER NBR. 8

REPORT DATE: **3/28/2024 1:29:49PM**

CONTRACT ID:	026504062	**HIGHWAY:**	SH 21
PROJECT:	NH 2019(613)	**DISTRICT:**	14
CONTRACT:	05193201	**COUNTY:**	BASTROP
AWARD AMOUNT:	$50,359,853.46	**AREA ENGINEER:**	[redacted]
PROJECTED AMOUNT:	$51,270,304.44	**AREA NUMBER:**	050
ADJ PROJECTED AMT:	$52,548,041.31		
PEND ADJ PROJ AMT:	$52,719,266.91	**DESCRIPTION:**	Electrical service fees/PCP on FRT RD bridges/Mailboxes
CONTRACTOR:	CAPITAL EXCAVATION COMPANY	**REASON:**	5B - 5B-CONTR REQUEST CHANGE MATL OR METHOD
CO AMOUNT:	$11,984.62	**SECONDARY REASON(S):**	003R - 3R-TXDOT DIRECTED OBSL
CO TYPE:	FEDERAL PARTICIPATING		
3RD PARTY AMOUNT:	$0.00		
APPRV LEVEL:	AREAENGR		

Functions:
- ☑ Extra Work
- ☐ Zero Dollar
- ☐ Overrun/Underrun
- ☐ Time Adjustment
- ☐ Stock Account
- ☐ Force Account
- ☐ Final Quantity
- ☐ Change Project Limits
- ☐ Delete/Add CSJ

DESCRIBE THE REASON FOR THE CHANGE ORDER AND WHAT IS BEING CHANGED. WHEN NECESSARY, INCLUDE EXCEPTIONS TO THIS AGREEMENT:

Due to the requirements of Bastrop Power & Light Company, the electric service to be provided is being changed from overhead to underground. Unique line number 3367 is being added for fees associated with the underground electrical connection.

Plans sheets 428A, 435A, 455B and 492A will replace plans sheets 428, 435, 455A and 492. They have been revised to allow the use of PCPs in the top tension flange area on the steel girders of the frontage road bridges. No time or money will be associated with the use of this contractor-requested alternate design.

This change order adds ITEM 560-6011 MAILBOX INSTALL-S (TWW-POST) TY 4, ITEM 560-6012 MAILBOX INSTALL-D (TWW-POST) TY 4 and ITEM 560-6013 MAILBOX INSTALL-M (TWW-POST) TY 4 for the temporary relocation and permanent installation of mailboxes on the frontage roads east of the river.

Plan sheet 501B replaces plan sheet 501A to update the table of deflections.

ADDITIONAL TIME NOT NEEDED

"By signing this change order, the contractor agrees to waive any and all claims for additional compensation due to any and all other expenses; additional changes for time, overhead and profit; or loss of compensation as a result of this change and that this agreement is made in accordance Item 4 and the Contract. Exceptions should be noted in explanation above."

THE CONTRACTOR

BY: ____________________ **DATE**

TYPED/PRINTED NAME: ____________________ **DATE**

TYPED/PRINTED TITLE: ____________________ **DATE**

AREA ENGINEER: ____________________ **DATE**

AREA ENGINEER'S SEAL:

DISTRICT ENGINEER: ____________________ **DATE**

DIRECTOR, CONSTRUCTION DIVISION: ____________________ **DATE**

DEPUTY EXECUTIVE DIRECTOR: ____________________ **DATE**

FHWA: ____________________ **DATE**

Figure 4.2 Change Order Report Sample

4.3. **Change Orders from All Projects**

To analyze all change orders, this study used data from SiteManager, a system originally developed by AASHTO (2019) and customized by state DOTs to manage change order information. The dataset consists of highway and roadway construction projects let by TxDOT between January 1, 2010, and September 30, 2024**,** along with all change orders issued for these projects during the same period.

To ensure consistency in monetary values, all dollar amounts were adjusted to their 2024 Q1 value to account for inflation. Adjustments were made using the National Highway Construction Cost Index (NHCCI) provided by the Federal Highway Administration (FHWA, 2024). This quarterly index allowed for inflation-adjusted calculations from 2010 Q1 to 2024 Q3.

An initial analysis was conducted to examine the overall distribution of projects and change orders. Among the projects let during the study period, a total of 9,871 projects were completed. Categorizing projects based on CMP implementation points, 6,979 projects were let before CMP with a total contract value of $64,377,493,233, and 2,892 projects were executed after CMP with a total contract value of $19,623,344,809.

Change orders were analyzed by comparing the number of change orders, total contract amounts ($), and total change order amounts ($) before and after CMP implementation. The project cost variation rate due to change orders (%) was calculated as the total change order amount divided by the total contract amount for each group. Before CMP, there were 35,510 change orders totaling $3,305,372,140, whereas after CMP implementation, there were 9,822 change orders totaling $529,296,638. The cost variation rate after CMP implementation was lower than before, decreasing from 5.13% to 2.70%**,** suggesting a notable reduction in change order costs.

Table 4.1 Project Change Orders Before and After the CMP

CMP Implementation	Total Number of Projects (count)	Total Number of Change Orders (count)	Total Contract Amount	Total Change Order Amount	Project Cost Variation due to Change Orders (%)
			(a)	(b)	b/a
Before	6,979	35,510	64,377,493,233	3,305,372,140	5.13%
After	2,892	9,822	19,623,344,809	529,296,638	2.70%
Total	**9,871**	**45,332**	**84,000,838,042**	**3,834,668,778**	**4.57%**

The project size categorization finding is summarized in Table 4.2. Project size classification follows TxDOT's criteria: TEX-size projects have contract amounts exceeding $150 million, Large projects range from $50 million to $150 million, Medium projects range from $15 million to $50 million, and Small projects have contract amounts under $15 million.

When comparing cost variations due to change orders across different project sizes, TEX-size projects exhibited the highest cost variation, followed by Large projects, Medium projects, and finally, Small projects. This indicates that change orders in larger projects have a more pronounced impact on overall project costs, highlighting the importance of effective change order management in these high-value projects.

Table 4.2 Project Change Orders by Project Size

Category	Total Number of Projects (count)	Total Number of Change Orders (count)	Total Contract Amount ($)	Total Change Order Amount ($)	Project Cost Variation due to Change Orders (%)
TEX-size	9	1324	3,492,718,436	335,124,359	9.59%
Large	79	4,437	12,084,833,630	886,684,034	7.34%
Medium	440	8,605	20,425,643,199	938,083,521	4.59%
Small	9,343	30,966	47,997,642,779	1,674,776,864	3.49%
Total	**9,871**	**45,332**	**84,000,838,042**	**3,834,668,778**	**4.57%**

4.3.1. Analysis of Change Order Before and After The Use of CMP

Change orders were further classified based on two major categories: project sizes and reason codes to identify significant differences before and after the implementation of CMP.

4.3.1.1. Change Orders by Project Size

Change orders were categorized by project size and summarized using key change order information, highlighting how project size influenced change orders before and after the implementation of CMPs.

4.3.1.1.1. Change Orders from TEX-size Projects

There are only eight completed TEX-size projects that were let before the implementation of CMP, and only one completed TEX-size project let after CMP. Due to the limited number of completed projects during the target study period in this category, primarily because TEX-size projects are the largest and typically have longer durations, it is difficult to make a direct comparison between the before and after groups. However, it was found that among all project size categories, TEX-size projects exhibited the highest project cost variation rate.

Table 4.3 Change Orders from TEX-size Projects - Before vs After the Use of CMPs

CMP	Total Number of Projects (count)	Total Contract Amount	Total Change Order Amount	Project Cost Variation due to All Change Orders (%)	Total Change Order Amount-Reason Code 6	Project Cost Variation due to Change Orders Reason Code 6 (%)
		(a)	(b)	b/a	(c)	c/a
Before	8	2,911,330,867	288,301,120	9.90%	10,882,192	0.37%
After	1	581,387,569	46,823,238	8.05%	-	0.00%
Total	**9**	**3,492,718,436**	**335,124,359**	**9.59%**	**10,882,192**	**0.31%**

4.3.1.1.2. Change Orders from Large Projects

The Large Projects, while comprising only 1% of the total number of completed construction projects (n = 79), contribute to 14.4% of the total contract value of all analyzed projects. The total change order amount for this group accounts for 23% of the total change order amount across all projects and exhibits a project cost variation due to change orders of 7.34%. Notably, the project cost variation on completed projects let before CMP implementation was 7.75%, which is nearly double the 3.81% recorded on the completed projects let after CMP implementation. When comparing the project cost variation rates across different project sizes, Large Projects demonstrate the highest variation rate, second only to TEX-size Projects. This emphasizes that managing change orders in Large Projects has a more significant impact on overall project outcomes compared to smaller projects, underscoring the importance of effective change order management for these complex undertakings.

Table 4.4 Change Orders from Large Projects - Before vs After the Use of CMPs

CMP	Total Number of Projects (count)	Total Contract Amount	Total Change Order Amount	Project Cost Variation due to All Change Orders (%)	Total Change Order Amount-Reason Code 6	Project Cost Variation due to Change Orders Reason Code 6 (%)
		(a)	(b)	b/a	(c)	c/a
Before	68	10,809,796,296	838,072,275	7.75%	107,872,986	1.00%
After	11	1,275,037,334	48,611,759	3.81%	28,589	0.00%
Total	**79**	**12,084,833,630**	**886,684,034**	**7.34%**	**107,901,575**	**0.89%**

4.3.1.1.3. Change Orders from Medium Projects

The Medium Projects group consists of 440 projects, representing 4% of the total number of analyzed projects. Despite their smaller proportion, these projects contribute 25% of the total change order amounts, a value comparable to the total change order amounts seen in Large Projects. The project cost variation due to change orders for Medium Projects is 4.59%, placing it between the variation rates observed for Large and Small Projects. Similar to the trend observed in Large Projects, the project cost variation in Medium Projects has decreased in completed projects let after the implementation of CMPs. Specifically, the project cost variation due to all change orders declined from 5.21% before CMP implementation to 2.52% after CMP implementation. Likewise, the project cost variation associated with Reason Code 6 (typically related to CMP and right-of-way or utility conflicts) decreased slightly, from 0.43% to 0.06%, on completed projects let after the implementation of CMPs. These trends demonstrate that, while the overall project cost variation in Medium Projects is slightly lower than that of Large Projects, CMP implementation still yields a notable reduction in the financial impact of change orders.

Table 4.5 Change Orders from Medium Projects - Before vs After the Use of CMPs

CMP	Total Number of Projects (count)	Total Contract Amount	Total Change Order Amount	Project Cost Variation due to All Change Orders (%)	Total Change Order Amount-Reason Code 6	Project Cost Variation due to Change Orders Reason Code 6 (%)
		(a)	(b)	b/a	(c)	c/a
Before	316	5,743,947,948	820,277,973	5.21%	67,989,504	0.43%

After	124	4,681,695,251	117,805,548	2.52%	2,777,011	0.06%
Total	**440**	**20,425,643,199**	**938,083,521**	**4.59%**	**70,766,515**	**0.35%**

4.3.1.1.4. Change Orders from Small Projects

The small projects account for 95% of the total number of projects let during the designated period, 57% of the total contract amount, and 43% of the total change order amounts. The project cost variation due to change orders is 3.49% overall, with 3.89% observed before CMP implementation and 2.42% after CMP implementation. Although Small Projects make up the largest portion of values related to change orders among all project size groups, the project cost variation rate is the lowest both overall and in the periods before and after CMP implementation. This indicates that change orders from larger projects tend to have a greater impact on overall project cost variation.

Table 4.6 Change Orders from Small Projects - Before vs After the Use of CMPs

CMP	Total Number of Projects (count)	Total Contract Amount	Total Change Order Amount	Project Cost Variation due to All Change Orders (%)	Total Change Order Amount-Reason Code 6	Project Cost Variation due to Change Orders Reason Code 6 (%)
		(a)	(b)	b/a	(c)	c/a
Before	6,587	34,912,418,123	1,358,720,772	3.89%	51,566,168	0.15%
After	2,756	13,085,224,656	316,056,093	2.42%	1,742,285	0.01%
Total	**9,343**	**47,997,642,779**	**1,674,776,864**	**3.49%**	**53,308,453**	**0.11%**

4.3.1.2. **Change Orders by Month**

To investigate potential patterns or variability in change orders based on the time of year they occurred, a monthly trend analysis was conducted. This analysis focused on the average project cost variation due to change orders for each month in the target dataset. The project cost change due to change orders was calculated by dividing the total change order amount by the total corresponding contract amount for each month. The resulting graphs illustrate the average project cost variation for all change orders, as well as for change orders specifically associated with Reason Code 6**.**

For all change orders, the project cost change due to change orders ranged between **-**0.503% and 1.115%. In comparison, for change orders associated with

Reason Code 6, the project cost variation ranged from 0.02% to 0.234%. It is important to note that several peaks observed in the analysis are attributed to isolated change orders from one or two specific projects, causing localized fluctuations. Overall, there is no clear or consistent trend in the change order cost change related to specific months or seasons.

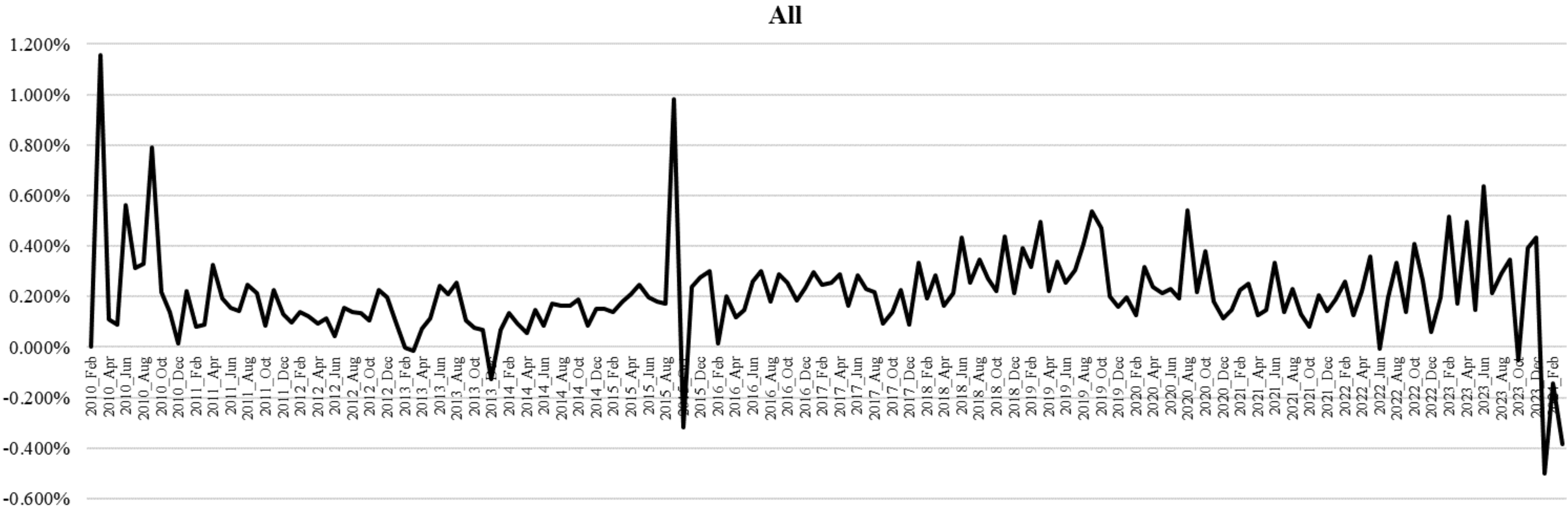


Figure 4.3 Average Monthly Project Cost Variation due to All Change Orders (%)

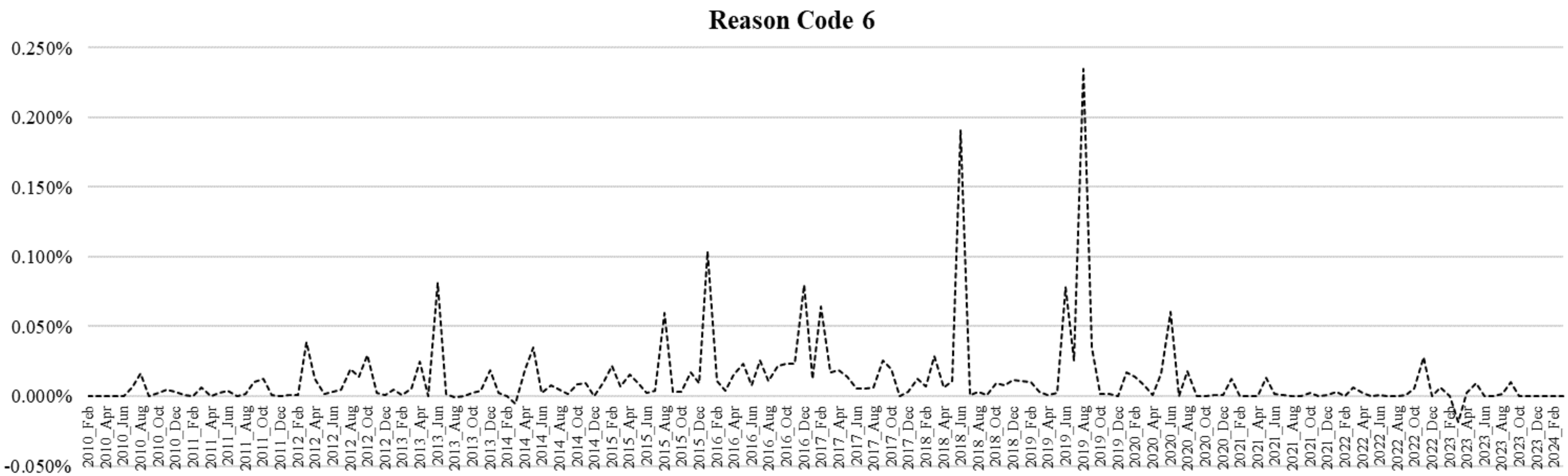


Figure 4.4 Average Monthly Project Cost Variation due to Reason Code 6 Change Orders (%)

4.3.1.3. **Change Orders by Reason Codes**

Reason codes are used to classify change orders based on their primary causes are provided by TxDOT in its publicly available manuals. These codes range from 1 to 7, with subcategories indicated by letters under each main category. The number represents the general cause of the change order, while the accompanying letter provides a more specific explanation within that category. Of particular relevance to this study is Reason Code 6 – Right-of-Way and Utility, which directly relates to conflict clearance and serves as a key focus in the analysis.

In relation to CMP implementation, before the use of CMP, Reason Code 3 – TxDOT Convenience was the most frequent cause of change orders, accounting for 66.28% of all change orders and contributing to a 3.40% increase in total contract cost. Within this category, Subcode 3F – Additional Work represented the majority of change order costs, indicating that unanticipated field adjustments were a common issue. After CMP implementation, the proportion of change orders under this category decreased to 48.14%, and the associated cost impact was significantly reduced to 1.30%. The second most common reason code was Reason Code 1 – Errors and Omissions. The proportion of change orders under this category increased from 26.76% to 39.44%, yet the associated cost impact decreased from 1.37% to 1.06%, suggesting that while errors remained frequent, their financial impact was mitigated.

Reason Code 6 – ROW and Utilities, which is directly related to CMP, showed a substantial decrease in both the number of change orders and associated costs. The proportion of change orders due to ROW and utilities dropped from 7.21% to 0.86%, while the cost impact fell from 0.37% to 0.02%.

Overall, after CMP implementation, the distribution of change order reason codes shifted**,** but more importantly, the total project cost variation rate due to change orders decreased**.** Most reason codes exhibited reduced cost impact rates, indicating a measurable decrease in cost overruns during the CMP implementation period.

Table 4.7 Change Orders by Reason Code

Reason Code	Before CMP Implementation			After CMP Implementation			Project Cost Variation Due to Change Orders (%)
	Proportion of Total Change Order Amount (%)	Total Change Order Amount ($)	Project Cost Variation Due to Change Orders (%)	Proportion of Total Change Order Amount (%)	Total Change Order Amount ($)	Project Cost Variation Due to Change Orders (%)	After - Before
1 ERRORS AND OMISSIONS	**26.76%**	**884,455,160**	**1.37%**	**39.44%**	**208,780,540**	**1.06%**	**-0.31%**
1A-INCORRECT PS&E (TxDOT DESIGN)	6.56%	216,797,899	0.34%	7.73%	40,888,786	0.21%	-0.13%
1B-INCORRECT PS&E (CONSULTANT DESIGN)	11.39%	376,415,318	0.58%	18.37%	97,220,644	0.50%	-0.09%
1C-DESIGN ERROR OR OMISSION (OTHER)	4.50%	148,874,383	0.23%	9.53%	50,428,778	0.26%	0.03%
1D-DES ERROR DELAY, REWORK, INEFF-TXDOT	1.43%	47,314,976	0.07%	1.04%	5,505,909	0.03%	-0.05%
1E-DES ERROR DELAY, REWORK, INEFF-CONSLT	2.88%	95,052,583	0.15%	2.78%	14,736,424	0.08%	-0.07%
2 DIFFERING SITE CONDITIONS (UNFORESEEABLE)	**-3.03%**	**-100,037,996**	**-0.16%**	**15.30%**	**80,978,311**	**0.41%**	**0.57%**
2A-DIFFER SITE CONDITION (UNFORESEEABLE)	-5.96%	-196,854,479	-0.31%	14.41%	76,249,092	0.39%	0.69%
2F-SITE CONDITIONS ALTERED BY ACT OF GOD	1.50%	49,588,914	0.08%	0.66%	3,491,619	0.02%	-0.06%
2G-UNADJUSTED UTILITY (UNFORSBL) OBSL	1.43%	47,227,569	0.07%	0.23%	1,237,600	0.01%	-0.07%
3 TXDOT CONVENIENCE	**66.28%**	**2,190,754,649**	**3.40%**	**48.14%**	**254,802,397**	**1.30%**	**-2.10%**
3A-DISPUTE RESOLUTION	12.25%	405,053,331	0.63%	3.25%	17,205,184	0.09%	-0.54%
3B-PUBLIC REQUEST AFTER LETTING	0.51%	17,021,480	0.03%	0.74%	3,914,155	0.02%	-0.01%
3E-REDUCTION OF FUTURE MAINTENANCE	3.32%	109,691,168	0.17%	3.41%	18,029,707	0.09%	-0.08%
3F-ADDITIONAL WORK DESIRED BY TXDOT	23.79%	786,364,154	1.22%	29.32%	155,215,507	0.79%	-0.43%
3H-COST SAVINGS OPPORTUNITY	-4.28%	-141,386,018	-0.22%	-10.33%	-54,672,687	-0.28%	-0.06%
3I-IMPLEMENT IMPROVED TECHNOLOGY/PROCESS	0.43%	14,135,122	0.02%	0.44%	2,339,325	0.01%	-0.01%
3K-ADD STK ACCT OR MATL SUPPLD BY TXDOT	0.48%	15,992,329	0.02%	1.56%	8,279,080	0.04%	0.02%
3L-REVISING SAFETY MEASURES	3.03%	100,045,284	0.16%	5.38%	28,459,076	0.15%	-0.01%
3M-TXDOT CONVENIENCE - OTHER OBSL	0.02%	520,154	0.00%	-	-	-	0.00%
3N-UPGRADE TO CURRENT STANDARDS	0.55%	18,216,109	0.03%	2.63%	13,900,672	0.07%	0.04%
3O-TIME EXTENSION	19.63%	648,684,052	1.01%	0.76%	4,041,372	0.02%	-0.99%
3P-REPAIR DUE TO 3RD PARTY DAMAGE	1.48%	49,046,123	0.08%	1.34%	7,118,411	0.04%	-0.04%
3Q-EMERGENCY DECLARATION	0.66%	21,691,039	0.03%	1.04%	5,493,547	0.03%	-0.01%
3R-TXDOT DIRECTED OBSL	4.41%	145,680,323	0.23%	8.22%	43,531,791	0.22%	0.00%
3T-ACTIVATION CORRECTIONS	-	-	-	0.37%	1,947,257	0.01%	0.01%
4 THIRD PARTY ACCOMMODATION	**3.81%**	**126,025,069**	**0.20%**	**2.34%**	**12,399,249**	**0.06%**	**-0.13%**

Reason Code	Before CMP Implementation			After CMP Implementation			Project Cost Variation Due to Change Orders (%)
	Proportion of Total Change Order Amount (%)	Total Change Order Amount ($)	Project Cost Variation Due to Change Orders (%)	Proportion of Total Change Order Amount (%)	Total Change Order Amount ($)	Project Cost Variation Due to Change Orders (%)	After - Before
4A-FAILURE 3RD PARTY TO MEET COMMITMENT	-0.09%	-2,837,155	0.00%	0.15%	794,162	0.00%	0.01%
4B-3RD PARTY REQUEST FOR ADDITIONAL WORK	3.83%	126,548,589	0.20%	1.95%	10,307,989	0.05%	-0.14%
4D-3RD PARTY ACCOMMODATION - OTHER	0.07%	2,313,635	0.00%	0.25%	1,297,098	0.01%	0.00%
5 CONTRACTOR CONVENIENCE	**-1.19%**	**-39,383,663**	**-0.06%**	**-3.27%**	**-17,333,908**	**-0.09%**	**-0.03%**
5A-CONTR REQUEST CHANGE, TCP OR SEQUENCE	-0.31%	-10,319,372	-0.02%	-0.74%	-3,902,393	-0.02%	0.00%
5B-CONTR REQUEST CHANGE MATL OR METHOD	-0.63%	-20,750,720	-0.03%	-1.50%	-7,948,438	-0.04%	-0.01%
5C-PAYMENT FOR PARTNERING WORKSHOP	0.00%	147,057	0.00%	0.00%	7,276	0.00%	0.00%
5E-CONTRACTOR CONVENIENCE - OTHER	-0.03%	-930,230	0.00%	-0.68%	-3,620,075	-0.02%	-0.02%
5F-PRICE REDUCTION	-0.23%	-7,530,398	-0.01%	-0.35%	-1,870,278	-0.01%	0.00%
6 ROW AND UTILITIES	**7.21%**	**238,310,849**	**0.37%**	**0.86%**	**4,547,885**	**0.02%**	**-0.35%**
6A-ROW NOT CLEAR - 3RD PARTY RESPONSIBLE	0.11%	3,480,534	0.01%	0.02%	104,030	0.00%	0.00%
6B-ROW NOT CLEAR - TXDOT RESPONSIBLE	0.98%	32,446,317	0.05%	0.00%	2,188	0.00%	-0.05%
6C-UTILITIES NOT CLEAR OBSL	2.84%	94,011,688	0.15%	0.41%	2,153,202	0.01%	-0.14%
6D-UNTIMELY ROW / UTILITIES - OTHER OBSL	3.27%	107,947,912	0.17%	0.22%	1,155,978	0.01%	-0.16%
6E-UNTIMELY ROW	0.00%	58,309	0.00%	0.02%	83,698	0.00%	0.00%
6F-JOINT BID UTILITIES	-	-	-	0.05%	264,767	0.00%	0.00%
6G-KNOWN UNADJUSTED UTILITIES	0.00%	21,670	0.00%	0.00%	-9,373	0.00%	0.00%
6H-UNKNOWN UNADJUSTED UTILITIES	0.01%	344,420	0.00%	0.15%	793,395	0.00%	0.00%
7 TERMINATION	**0.16%**	**5,248,071**	**0.01%**	**-2.81%**	**-14,877,836**	**-0.08%**	**-0.08%**
7A-CONTRACT TERMINATED-DESIGN ERROR TXDOT	-0.06%	-1,898,047	0.00%	-	-	-	0.00%
7B-CONTRACT TERMINATED-DSGN ERR CONSULT	-0.17%	-5,580,868	-0.01%	0.00%	22,469	0.00%	0.01%
7C-CONTRACT TERMINATED-UTILITIES	-1.75%	-57,799,298	-0.09%	0.08%	408,083	0.00%	0.09%
7D-CONTRACT TERMINATED-ROW	-0.88%	-29,038,372	-0.05%	-	-	-	0.05%
7E-CONTRACT TERMINATED-3RD PARTY	-	-	-	-1.65%	-8,714,487	-0.04%	-0.04%
7F-CONTRACT TERMINATED-ACTS OF GOD	-	-	-	-	-	-	0.00%
7G-CONTRACT TERMINATED-OTHER	3.01%	99,564,657	0.15%	-1.25%	-6,593,901	-0.03%	-0.19%
Total	**100.00%**	**3,305,372,140**	**5.13%**	**100.00%**	**529,296,638**	**2.70%**	**-2.44%**

4.3.2. Change Orders from CMP Projects

4.3.2.1. Analysis Methodology

For an in-depth analysis of change orders explicitly related to ROW, UTL, and RR conflicts listed in CMPs, a separate data processing approach was applied using change order data extracted from SiteManager. The analysis began with the extraction and review of basic text data, including reason codes. Following this, an in-depth forensic review was conducted to determine each change order's association with CMP-listed conflicts and to identify any additional conflict-related issues. This classification process formed the foundation for a broader analysis, allowing change orders to be evaluated within the context of CMP documentation to uncover meaningful patterns and relationships. A text mining technique was employed to support the identification of CMP-related change orders, enabling efficient filtering and categorization based on the content of change order descriptions from change order reports.

Text mining and information retrieval methods were applied to detect CMP-related keywords within the descriptions. ROW and RR-related change orders, due to their relatively low frequency and minimal cost or schedule impacts, were classified more easily, since ROW acquisitions and railroad agreements are typically identified before project initiation. In contrast, UTL-related change orders required more detailed classification due to their complexity and variability. These change orders were categorized into five subgroups: 1) CMP-related, 2) Unforeseen – Conflicts arising from unexpected utility conditions, 3) PS&E errors and omissions – Errors or missing information in PS&E, 4) Relocation by Joint Bid – Utility relocation work bid jointly with other construction work, and 5) Utility Service – Changes related to utility services required during the project.

To confirm whether a change order was CMP-related, the research team cross-verified the conflict description with the CMP documentation. This verification process included checking whether the conflict was listed in the CMP, whether the utility owner matched the one specified, and whether the location of the utility work aligned with the CMP record.

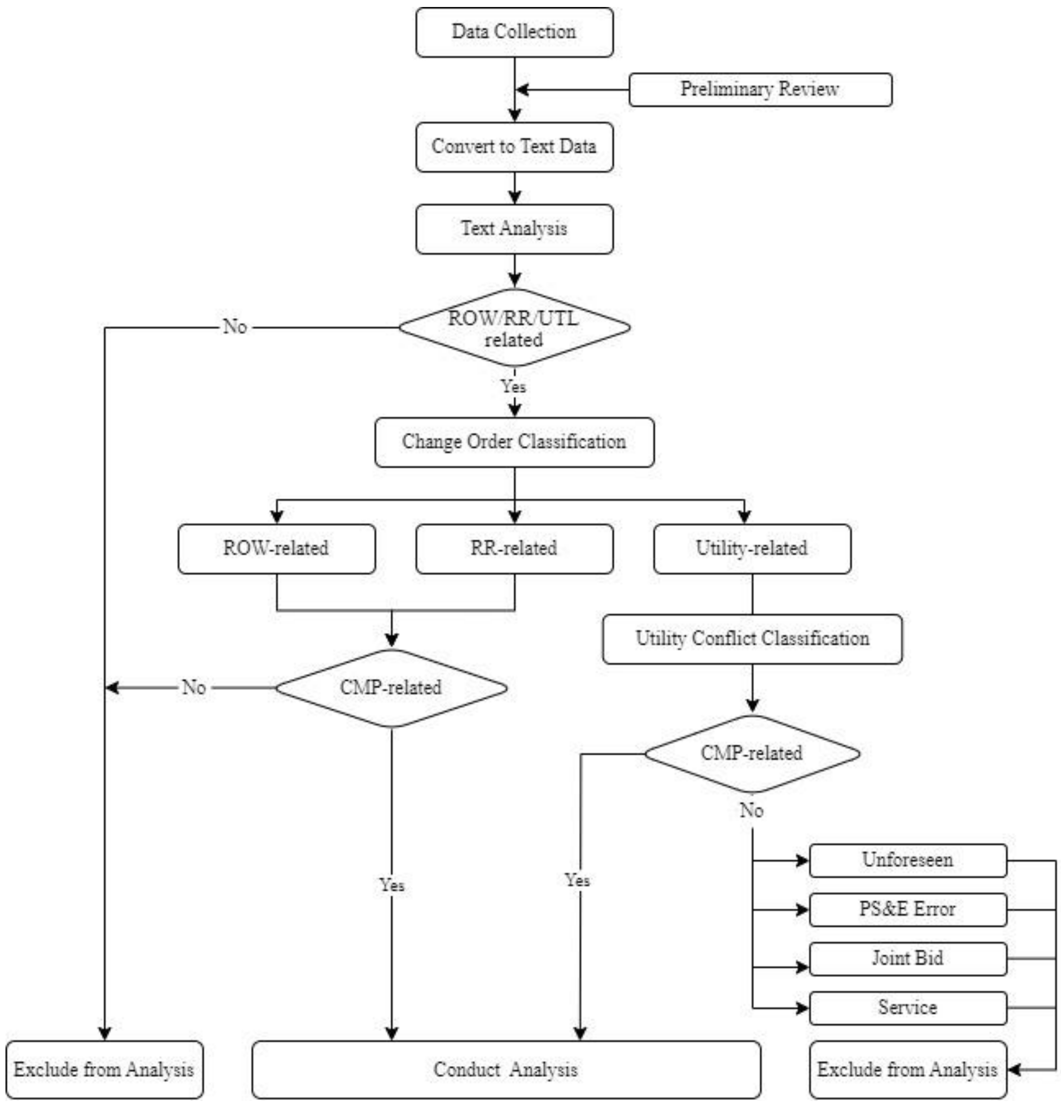


Figure 4.5 Change Order Data Classification Flowchart

4.3.2.2. **Change Orders from Completed CMP Projects**

All change orders from CMP projects were initially categorized by their status as either Completed or Active, with the initial focus on Completed projects since they will likely no longer generate additional change orders, ensuring a comprehensive data set. In completed CMP projects, each change order includes a title summarizing its description and primary reason code, along with details on cost and time adjustments. The dataset comprises 785 change orders, with the number of change orders per CSJ ranging from 1 to 67.

The analysis of all change orders on Completed CMP projects reveals that 30 change orders, or 3.82% of the total 785 change orders, are related to the CMP.

The number of projects that have CMP-related change orders is 16 out of a total of 58 projects. The project cost variation due to all change orders (%) was calculated by dividing the total sum of change order amounts from all change orders by the total contract amount from all completed CMP projects.

The total change order amount for these CMP-related orders represents only 13.55% of the total change order amount, leading to a project cost variation of just 0.65% from the original contract amount. This suggests that CMP-related change orders have a smaller financial impact on project costs compared to all change orders. The significance of CMP-related change orders will be further analyzed in subsequent sections by categorizing key project characteristics.

Table 4.8 CMP-related Change Orders – Completed CMP Projects

Category	Number of Change Orders (count)	Number of Projects (count)	Total Contract Amount ($)	Total Change Order Amount ($)	Project Cost Variation due to Change Orders (%)	Total Time Adjustment (day)
(a) All Change Orders	785	58	995,477,036	47,544,763	4.78%	2,231
(b) CMP-related Change Orders	30	16		6,441,956	0.65%	47
Proportion (b/a)	**3.82%**	**27.59%**	**-**	**13.55%**	**-**	**2.11%**

4.3.2.2.1. Change Orders by Districts

The 785 change orders from Completed CMP projects were classified by districts first. Table 4.9 is ordered by the total amount of change orders from each district in descending order. Columns represent the total number of change orders, total contract amount, and change order amount for projects conducted in each district. The project cost variation due to change orders is calculated by dividing the total change order amount by the total contract amount. The project cost variation due to change orders vary significantly across districts.

The top four districts in terms of change order amount — Austin, El Paso, Houston, and Dallas — account for 89% of the total amount of change orders on Completed CMP projects from all 21 districts. Additionally, these four districts include CMP-related change orders. These districts represent 25 out of the 30 CMP-related change orders, making up 83% of the total change order amounts.

Notably, Atlanta’s project cost variation due to change orders is as high as 26%, with the CMP-related project cost variation also reaching 6.5%. This unusually high project cost variation can be attributed to a single project where the increase was driven by a delay in the railroad agreement and the rise in material unit prices that were already under contract.

In terms of time adjustments, the majority occur in the top four districts, with districts that have fewer change orders showing little to no time adjustments. Among the projects with CMP-related change orders, only one experienced a 47-day schedule delay, which was due to the relocation of a utility line that was found to be in a different location than initially planned.

Table 4.9 Change Orders by District – Completed CMP Projects

District	Number of Projects (count)	All Change Orders					CMP-related Change Orders				
		Number of Change Order (count)	Contract Amount ($)	Change Order Amount ($)	Project Cost Variation due to Change Orders (%)	Time Adjustment (day)	Number of Change Order (count)	Contract Amount ($)	Change Order Amount ($)	Project Cost Variation due to Change Orders (%)	Time Adjustment (day)
Austin	19	263	318,215,749	14,248,820	4.5%	706	11	318,215,749	4,252,329	1.3%	
El Paso	2	83	123,807,230	13,518,071	10.9%	470	3	123,807,230	184,783	0.1%	
Houston	11	172	127,617,715	11,225,486	8.8%	598	9	127,617,715	1,194,114	0.9%	
Dallas	3	75	66,337,569	3,179,424	4.8%	0	2	66,337,569	56,068	0.1%	
Atlanta	1	8	5,634,658	1,485,137	26.4%	96	3	5,634,658	366,318	6.5%	
Odessa	2	8	103,404,135	1,326,252	1.3%	0		103,404,135		0.0%	
Fort Worth	3	63	26,700,824	1,230,330	4.6%	147	2	26,700,824	388,344	1.5%	47
Yoakum	2	9	37,655,577	1,001,599	2.7%	0		37,655,577		0.0%	
Corpus Christi	2	19	10,586,025	719,532	6.8%	0		10,586,025		0.0%	
Amarillo	1	16	45,797,691	675,267	1.5%	87		45,797,691		0.0%	
San Angelo	1	4	16,563,814	378,917	2.3%	3		16,563,814		0.0%	
San Antonio	1	7	4,316,413	347,669	8.1%	67		4,316,413		0.0%	
Childress	1	5	6,581,608	166,076	2.5%	49		6,581,608		0.0%	
Lubbock	1	6	18,836,295	129,673	0.7%	31		18,836,295		0.0%	
Pharr	1	2	1,147,081	87,839	7.7%	19		1,147,081		0.0%	
Lufkin	1	5	4,885,972	49,100	1.0%	0		4,885,972		0.0%	
Bryan	1	2	1,198,244	43,315	3.6%			1,198,244		0.0%	
Laredo	1	15	23,429,429	3,560	0.0%	-132		23,429,429		0.0%	
Abilene	1	3	8,259,120	(186,237)	-2.3%	0		8,259,120		0.0%	
Brownwood	1	4	9,089,126	(659,046)	-7.3%	5		9,089,126		0.0%	
Beaumont	2	16	35,412,760	(1,426,021)	-4.0%	85		35,412,760		0.0%	
Total	**58**	**785**	**995,477,036**	**47,544,763**	**4.8%**	**2,231**	**30**	**995,477,036**	**6,441,956**	**0.6%**	**47**

4.3.2.2.2. Change Orders by Project Classification

Each project is classified and assigned a specific project type code based on its primary function, such as new construction of freeways or bridges, freeway or non-freeway widening, restoration, maintenance, and miscellaneous construction. By categorizing change orders under these project types, it is possible to identify which types of projects experience more significant change orders compared to others.

For completed CMP projects, 13 different project classifications were identified. Change orders from these projects are listed in Table 4.10 in descending order based on the total change order amount.

Among all change orders, the largest amounts were associated with INC - Interchange projects, MSC - Miscellaneous Construction, and WNF- Widen Non-Freeway projects. These three categories account for 77% of the total change order amount. The number of change orders from these three categories totals 488, representing 62% of all change orders. Additionally, time adjustments within these three project types are 1,461 days, accounting for 65% of the total time adjustments. In terms of project cost variation due to change orders, aside from the highest project cost variation of 12.1% from Hazard Elimination & Safety. Interchange projects show a project cost variation rate of 10.5%, indicating that the top project type continues to have a significant impact.

The top three project types – INC, MSC, WNF – also account for the majority of CMP-related change orders, both in terms of total number and amount, mirroring the trends observed in all change orders, accounting for 60% of the number and 77% of the total amounts.

Table 4.10 Change Orders by Project Classification – Completed CMP Projects

Project Type		Number of Projects (count)	All Change Orders					CMP-related Change Orders				
			Number of Change Orders (count)	Contract Amount ($)	Change Order Amount ($)	Project Cost Variation due to Change Orders (%)	Time Adjustment (day)	Number of Change Orders (count)	Contract Amount ($)	Change Order Amount ($)	Project Cost Variation due to Change Orders (%)	Time Adjustment (day)
INC	Interchange (New or Reconstructed)	3	108	170,225,106	17,945,668	10.5%	509	5	170,225,106	1,053,470	0.6%	
MSC	Miscellaneous Construction	19	263	341,311,555	10,662,715	3.1%	749	10	341,311,555	3,733,584	1.1%	
WNF	Widen Non-Freeway	7	117	151,905,310	8,036,746	5.3%	203	3	151,905,310	182,062	0.1%	
NNF	New location Non-Freeway	4	66	72,899,715	4,653,556	6.4%	350	6	72,899,715	774,399	1.1%	
RER	Rehabilitation Of Existing Road	9	126	110,652,170	2,478,783	2.2%	235	3	110,652,170	405,492	0.4%	47
HES	Hazard Elimination & Safety	3	19	20,105,245	2,422,809	12.1%	0		20,105,245		0.0%	
RES	Restoration	3	31	33,145,210	1,856,236	5.6%	70	3	33,145,210	292,946	0.9%	
UPG	Upgrade to Standards Freeway	1	8	34,757,444	1,003,193	2.9%	0		34,757,444		0.0%	
BR	Bridge Replacement	5	24	9,912,167	544,101	5.5%	45		9,912,167		0.0%	
TS	Traffic Signal	1	4	4,599,652	37,623	0.8%	0		4,599,652		0.0%	
TPD	Traffic Protection Devices	1	1	1,850,411	7,101	0.4%	0		1,850,411		0.0%	
SC	Seal Coat	1	4	9,089,126	(659,046)	-7.3%	5		9,089,126		0.0%	
WF	Widen Freeway	1	14	35,023,918	(1,444,726)	-4.1%	65		35,023,918		0.0%	
Total		**58**	**785**	**95,477,036**	**47,544,763**	**4.8%**	**2,231**	**30**	**995,477,036**	**6,441,955**	**0.6%**	**47**

4.3.2.2.3. *Change Orders by Conflict Types*

CMP documents contain the most information about utility conflicts, as these are the most frequent in projects. Consequently, CMP-related change orders are also most commonly related to utilities. Similarly, change order amounts and project cost variations due to change orders tend to be higher for utility-related change orders. There are also five change orders related to railroads, all of which were due to delays in clearance from the railroad company. Notably, in completed CMP projects, there were no right-of-way-related change orders, although such issues did arise in active all-cleared projects, which will be discussed in the next section.

Table 4.11 Change Orders by Conflict Type – Completed CMP Projects

Conflict Type	Number of Change Order (count)	Contract Amount ($)	Change Order Amount ($)	Project Cost Variation due to Change Orders (%)	Time Adjustment (day)
ROW	-	995,477,036	-	-	-
RR	6		1,020,040	0.07%	-
UTL	24		5,421,915	0.54%	47
Total	**30**	995,477,036	6,441,955	0.6%	**47**

4.3.2.3. **Change Orders from Active CMP Projects**

Comparable to the analysis conducted on change orders from Completed CMP Projects, all change orders from Active All Cleared CMP Projects were analyzed. Since the implementation of CMP, there have been 118 active projects where conflicts have been cleared, and within these, 109 projects generated a total of 2,309 change orders. The combined contract amount for these projects is $7,570,420,302, with a total change order amount to date of $543,648,414, resulting in a project cost variation due to change orders of 7.18%. The total time adjustment recorded for these projects is 2,513 days.

When examining CMP-related change orders, there are 83 change orders in Active All Cleared CMP Projects, accounting for 3.59% of the total number of change orders and 30.51% of the total change order amount. The project cost variation due to these CMP-related change orders is only 0.16%, significantly lower than the project cost variation due to all change orders of 7.18%. Time adjustments for these CMP-related change orders total 68 days, making up 2.71% of the total time adjustments.

When compared to CMP-related change orders in Completed CMP Projects, it is evident that the proportion of both the number of change orders and the project cost variation due to change orders is slightly higher in Active All Cleared CMP Projects.

Table 4.12 CMP-related Change Orders – Active All Cleared CMP Projects

Category	Number of Change Orders (count)	Number of Projects (count)	Total Contract Amount ($)	Total Change Order Amount ($)	Project Cost Variation due to Change Orders (%)	Total Time Adjustment (day)
(a) All Change Orders	2,309	118	7,570,420,302	543,648,414	7.18%	2,513
(b) CMP-related Change Orders	83	36		11,740,524	0.16%	68
Proportion (b/a)	**3.59%**	**30.51%**	**-**	**2.16%**	**-**	**2.71%**

4.3.2.3.1. Change Orders by Districts

Active All Cleared CMP Projects are currently underway in 23 districts, and similar to Completed CMP Projects, the majority of change orders are concentrated in the top few districts, as shown in Table 4.13. When sorted by total change order amount in descending order, the top five districts—Houston, El Paso, Beaumont, San Antonio, and Fort Worth—account for 81% of the total change order amount. However, the combined contract amount for these projects represents only 52% of the total, resulting in a project cost variation due to change orders of 11.1%, which is higher than the overall average of 7.18%.

In particular, Houston, which has the largest share in terms of project size, number of projects, number of change orders, and change order amount, shows a project cost variation due to change orders of 14.59%. This is followed by El Paso, with a project cost variation due to change orders of 27.45%, much more than the average increase. Additionally, time adjustments show that Houston experienced a delay of 1,054 days, almost half of the total time adjustments.

Likewise, about 65% of the CMP-related change orders occurred in the Houston district. It also accounts for the largest change order amount at $7 million, with a project cost variation due to change orders of 0.05% and a time adjustment of 50 days, both being the highest values observed. The change order amounts in the top four districts represent 94% of the total, indicating that most change orders occur in districts that tend to have more large-scale projects.

Table 4.13 Change Orders by District - Active All Cleared CMP Projects

District	Number of Projects (count)	All Change Orders					CMP-related Change Orders				
		Number of Change Order (count)	Contract Amount ($)	Change Order Amount ($)	Project Cost Variation due to Change Orders (%)	Time Adjustment (day)	Number of Change Order (count)	Contract Amount ($)	Change Order Amount ($)	Project Cost Variation due to Change Orders (%)	Time Adjustment (day)
Houston	27	672	1,436,304,602	209,612,624	14.59%	1054	34	1,436,304,602	7,151,354	0.50%	50
El Paso	5	103	458,104,685	125,736,612	27.45%		1	458,104,685	-	0.00%	
Beaumont	6	152	563,721,299	35,276,870	6.26%	33	5	563,721,299	2,382,944	0.42%	3
San Antonio	7	239	,129,332,917	35,140,256	3.11%		9	1,129,332,917	1,461,727	0.13%	
Fort Worth	9	214	382,579,393	34,574,382	9.04%	326	7	382,579,393	151,617	0.04%	
Dallas	8	212	801,317,947	21,316,846	2.66%	281	3	801,317,947	-42,607	-0.01%	
Austin	7	157	232,764,948	18,720,102	8.04%	149	11	232,764,948	307,799	0.13%	15
Yoakum	4	24	450,030,285	11,055,800	2.46%	80		450,030,285		0.00%	
Corpus Christi	3	89	310,366,414	9,457,999	3.05%	316	4	310,366,414	20,783	0.01%	
Lufkin	6	68	471,796,580	8,919,070	1.89%	31	1	471,796,580	4,770	0.00%	
Odessa	2	12	52,500,825	7,450,657	14.19%			52,500,825		0.00%	
Laredo	3	46	128,451,886	4,872,007	3.79%	41		128,451,886		0.00%	
Waco	2	118	84,074,752	4,070,845	4.84%		3	84,074,752	264,398	0.31%	
Atlanta	3	26	130,337,539	3,822,515	2.93%			130,337,539		0.00%	
Bryan	6	46	94,317,129	3,506,934	3.72%		2	94,317,129	10,042	0.01%	
Pharr	5	21	52,562,321	3,428,329	6.52%	160	1	52,562,321	-	0.00%	
Amarillo	2	29	183,922,708	1,852,529	1.01%		1	183,922,708	5,880	0.00%	
Paris	2	36	40,690,123	1,227,773	3.02%	42		40,690,123		0.00%	
Wichita Falls	2	7	258,461,527	1,090,979	0.42%		1	258,461,527	21,816	0.01%	
Brownwood	2	9	11,757,708	1,052,555	8.95%			11,757,708		0.00%	
San Angelo	1	14	24,497,111	896,968	3.66%			24,497,111		0.00%	
Lubbock	2	8	178,856,002	416,979	0.23%			178,856,002		0.00%	
Total	**118**	**2309**	**7,570,420,302**	**543,648,414**	**7.18%**	**2513**	**83**	**7,570,420,302**	**11,740,524**	**0.16%**	**68**

4.3.2.3.2. Change Orders by Project Classification

A total of 15 project types were encountered among the Active All Cleared CMP Projects, with most change orders occurring in the following types: WNF - Widen Non-Freeway, MSC - Miscellaneous Construction, WF - Widen Freeway, and INC - Interchange, as shown in Table 4.14. These are the same types as those identified in the Completed CMP Project classification as major types. As expected, widening freeways tends to involve a broader scope of work compared to maintenance or replacement projects, leading to more conflicts and changes in construction items, which in turn results in a higher number of change orders. Notably, the total amount of change orders from these top four project types accounts for 89% of the overall total.

A similar trend is observed in CMP-related change orders. The WNF - Widen Non-Freeway, MSC - Miscellaneous Construction, and WF - Widen Freeway project types generated the most CMP-related change orders. This is because expanding roadways often involves extending the construction area into new territories, which frequently requires additional tasks such as right-of-way acquisition or utility relocation. As a result, there is a higher likelihood of encountering unanticipated changes in conflict clearance during construction. These issues can lead to schedule delays, particularly when conflict clearance is not completed on time. Similarly, project types that have a significant impact on change order amounts also tend to have a greater impact on the project schedule.

Table 4.14 Change Orders by Project Classification - Active All Cleared CMP Projects

Project Type		Number of Projects (count)	All Change Orders					CMP-related Change Orders				
			Number of Change Order (count)	Contract Amount ($)	Change Order Amount ($)	Project Cost Variation due to Change Orders (%)	Time Adjustment (day)	Number of Change Order (count)	Contract Amount ($)	Change Order Amount ($)	Project Cost Variation due to Change Orders (%)	Time Adjustment (day)
WNF	Widen Non-Freeway	26	630	1,373,540,710	205,668,975	14.97%	828	38	1,373,540,710	6,686,943	0.49%	50
MSC	Miscellaneous Construction	20	416	872,398,035	144,206,547	16.53%	476	11	872,398,035	1,054,686	0.12%	
WF	Widen Freeway	20	632	2,925,759,196	97,762,128	3.34%	494	15	2,925,759,196	1,381,706	0.05%	3
INC	Interchange (New or Reconstructed)	11	281	794,907,148	36,478,008	4.59%	209	8	794,907,148	98,684	0.01%	15
HES	Hazard Elimination & Safety	3	25	66,830,382	24,663,281	36.90%	0	3	66,830,382	2,302,298	3.44%	
RER	Rehabilitation of Existing Road	16	126	312,119,737	7,751,761	2.48%	480	1	312,119,737	-	0.00%	
NLF	New Location Freeway	3	35	336,653,113	7,135,605	2.12%	26		336,653,113		0.00%	
CNF	Convert Non-Freeway To Freeway	3	42	386,814,349	6,062,382	1.57%	0	3	386,814,349	57,288	0.01%	
NNF	New location Non-Freeway	3	24	57,009,848	5,086,392	8.92%	0	1	57,009,848	66,185	0.12%	
UPG	Upgrade to Standards Freeway	2	30	200,222,374	3,547,742	1.77%	0		200,222,374		0.00%	
TS	Traffic Signal	2	32	102,200,817	3,171,664	3.10%	0	3	102,200,817	92,733	0.09%	
BWR	Bridge Widening Or Rehabilitation	1	14	57,486,751	1,751,444	3.05%			57,486,751		0.00%	
BR	Bridge Replacement	6	17	49,664,435	498,310	1.00%	0		49,664,435		0.00%	
OV	Overlay	1	5	7,063,406	(135,825)	-1.92%	0		7,063,406		0.00%	
MNT	Maintenance	1		27,750,000		0.00%			27,750,000		0.00%	
Total		**118**	**2,309**	**7,570,420,302**	**543,648,414**	**7.18%**	**2513**	**83**	**7,570,420,302**	**11,740,524**	**0.16%**	**68**

4.3.2.3.3. Change Orders by Conflict Types

Categorizing the 83 CMP-related change orders into ROW/RR/UTL categories reveals that, similar to the findings from Completed CMP Projects, the majority of 73 change orders resulted from utility conflicts, as shown in Table 4.15. The corresponding change order amounts further emphasize this, with utilities representing 96% of the total, indicating that most change orders are driven by issues related to utility relocation. This outcome is anticipated because utility conflicts are the most frequently listed in CMPs and are the most common conflicts encountered during construction.

All time adjustments also occurred in utility-related issues, highlighting that right-of-way acquisition and railroad agreements are less frequently required both in the CMPs and during construction and less likely to generate change orders in comparison to utility relocations. Even when change orders arise, the overall project cost variation due to change orders for ROW and RR remains relatively modest, at $0.1 million and $0.3 million, respectively. These findings underscore the critical importance of continuously managing utility relocations throughout the project to minimize the financial and time-related impacts of change orders.

Table 4.15 Change Orders by Conflict Type – Active All Cleared CMP Projects

Conflict Type	Number of Change Order (count)	Contract Amount ($)	Change Order Amount ($)	Project Cost Variation due to Change Orders (%)	Time Adjustment (day)
ROW	6	7,570,420,302	143,731	0.00%	-
RR	4		353,263	0.00%	-
UTL	73		11,243,530	0.15%	68
Total	83	-	11,740,524	-	**68**

4.3.2.4. **Utility-Related Change Orders from CMP Projects**

Utility-related change orders are broader than CMP-related change orders. Even if a change order is related to a utility conflict, it is classified as utility-related if it is not listed in the CMP or lacks sufficient evidence to establish a direct connection. For example, if the conflict type or the owner's name is not mentioned, the change order is categorized as utility-related. Additionally, Reason Code 6F – Joint Bid Utility specifically represents change orders caused by conflicts from joint bid parties. The classification result is provided in Table 4.16.

The most common reason for utility-related change orders is unforeseen conditions. These conflicts, often discovered in the field, are challenging to identify prior to construction, especially when utilities are buried underground or when outdated utility drawings are the only reference available. Similarly, unforeseen change orders related to other aspects of projects are also the most frequent type of change orders. This trend underscores the commonality of unforeseen issues in construction projects, particularly when the conditions cannot be fully anticipated during the planning phase.

Table 4.16 Utility-related Change Order Classification

Category	CMP-related	Utility-related			
		Unforeseen	PS&E	Joint Bid	Service
Completed	30	28	12	-	4
Active Cleared	83	75	38	10	8
Total	**113**	**103**	**50**	**10**	**12**

The total number of CMP-related change orders is 113, representing 3.65% of the 3,094 total all change orders from CMP projects. Additionally, the total number of utility-related change orders across all subcategories is 175, accounting for 5.66% of all change orders. To sum up, 9.31% of all change orders from CMP projects are related to utility conflicts, regardless of whether they were explicitly indicated in the CMP.

In terms of total change order amounts, CMP-related change orders account for 3.08% of the total change order amounts, while utility-related change orders represent 2.50%. Among utility-related change orders, PS&E accounts for the largest proportion at 1.21%, followed by unforeseen conditions at 2.50%, joint bids at 0.41%, and utility service at 0.04%.

The project cost variation rates due to change orders by classification were calculated by dividing the total sum of change order amounts by the total contract amount. The overall rate for all change orders is 6.90%, while CMP-related change orders account for 0.21%, and utility-related change orders contribute 0.17%.

In summary, although the number of CMP-related change orders is smaller than that of utility-related change orders, their cost impact on projects is greater. This may be because CMP-related change orders are often more complex, potentially involving major conflicts that should or could have been identified earlier in the project planning stage. In contrast, utility-related change orders are often tied to the discovery of unforeseen conflicts during construction or minor errors in drawings, resulting in a comparatively smaller financial impact.

Table 4.17 CMP- and Utility-related Change Order Analysis

Category	Number of Change Orders (count)	Proportion of Total Number of Change Orders (%)	Total Contract Amount ($)	Total Change Order Amount ($)	Proportion of Total Change Order Amount (%)	Project Cost Variation due to Change Orders (%)
All	3,094	100.00%	8,565,897,339	591,193,177	100.00%	6.90%
CMP-related	113	3.65%		18,182,480	3.08%	0.21%
Utility-related	175	5.66%		14,771,487	2.50%	0.17%
Unforeseen	103	3.33%		5,468,854	0.93%	0.06%
PS&E	50	1.62%		6,645,132	1.12%	0.08%
Joint Bid	10	0.32%		2,433,155	0.41%	0.03%
Service	12	0.39%		224,345	0.04%	0.00%

Chapter 5. Statistical Analyses of Project Cost Variations Due to Change Order Before and After the Use of CMPs

5.1. Introduction

The analysis provided a fundamental understanding of the project cost variation due to change orders before and after the implementation of CMPs. It builds on these findings by conducting a more rigorous and detailed statistical analysis to assess whether the observed changes in project cost variation due to change orders on projects let before and after CMP implementation are statistically significant. The goal of this task is to quantitatively evaluate if the use of CMPs had an impact on project change orders and claims.

The scope of this chapter includes the following key activities:

- Classifying change orders based on significant project attributes, such as project size and reason codes
- Conducting statistical tests to identify statistically significant differences in project cost variation due to change orders on projects let before and after CMP implementation
- Classifying CMP-related change orders by analyzing their root causes

5.2. Analysis Methodology

Building on the previously collected and classified data categorized by project characteristics and CMP implementation status, this analysis focuses on identifying statistically significant differences before and after the use of CMPs. The analysis begins with descriptive statistics, including mean, median, standard deviation, and minimum and maximum values of project cost variation rate due to change orders (%) to provide an overview of change order trends in relation to the use of CMP.

Distribution analysis was conducted to examine the spread and patterns of change order data. Given the significant variation observed in project cost growth rates, the Interquartile Range (IQR) method was applied to detect and remove outliers for both before-CMP and after-CMP groups. The IQR was computed as the difference between the first quartile (Q1, 25th percentile) and third quartile (Q3, 75th percentile). The lower bound was determined as Q1 - 1.5 × IQR, and the upper bound was Q3 + 1.5 × IQR. Any data points falling outside these bounds were classified as outliers and excluded from further analysis to ensure robust statistical results (Aguinis, 2013; Smiti, 2020; Freund, 2022).

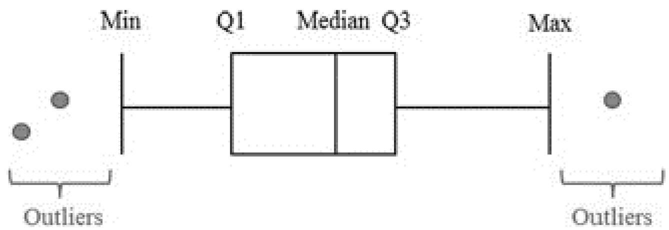


Figure 5.1 IQR Outlier Detection (Smiti, 2020)

Afterward, appropriate statistical tests were selected to evaluate whether there is a statistically significant difference in change order cost growth rates between before- and after-CMP implementation. Although t-tests are commonly used for comparing two independent groups, change order cost growth rates were primarily concentrated between -10% and 10% due to strict project cost management. As a result, the data was considered not to follow a normal distribution. To determine the appropriate statistical test, normality tests were performed using the Kolmogorov-Smirnov test and Shapiro-Wilk test (Ghasemi, 2021). As expected, the normality of the data was not satisfied; the non-parametric Mann-Whitney U test was conducted instead. The Mann-Whitney U test assesses whether the distributions of two independent groups are significantly different. If the mean ranks of change order cost growth rates are significantly different between before-CMP and after-CMP groups, and the test results yield a p-value less than the significant level of 0.05, it indicates that the difference between the two groups is statistically significant.

5.3. Change Orders from All Projects

Change order data was divided into two groups—before and after CMP implementation—to analyze project-level cost variation rate by statistical testing. These analyses focused on change order metrics within each project to determine whether significant differences existed before and after the introduction of CMPs.

One key aspect of this analysis is that project-level cost variation rates were calculated individually for each project. The cost variation rate was determined by dividing the sum of the change order amount in a project by the project's original contract value. These individual project rates were then used as the dataset for statistical analysis, meaning the statistical tests evaluated the distribution of variation rates across projects rather than relying on a single aggregated rate.

Table 5.1 presents descriptive statistics for all projects in each group. In the Before group, which includes 6,979 projects, the mean project cost variation due to change orders is 3.57%, with a standard deviation of 12.26. In contrast, the After group, based on 2,892 projects, shows a lower mean project cost variation of 2.87%, with a standard deviation of 11.23. The data ranges also differ, with the Before group spanning from -10.25% to 235.2%, whereas the After group ranges from -98.2% to 127.9%, indicating that the After group exhibits a narrower range of change order rates.

Table 5.1 Descriptive Statistics of Change Orders with Outliers

Statistics (%)	Before	After
Count	6,979	2,892
Mean	3.57	2.87
Standard Deviation	12.26	11.23
Maximum	235.2	127.9
Median (50%)	1.00	0.50
Minimum	-102.5	-98.2

The distribution of project cost variation rates was examined, and the histograms below visually illustrate the frequency and spread of the data. The analysis indicates that the data does not follow a normal distribution. Instead, most project cost variations resulting from change orders are concentrated within a narrow range of 0% to 10%. This distribution pattern is primarily influenced by the relatively low cost of change orders, which are typically maintained within controlled limits. Significant cost variations occur only in rare and exceptional cases, often due to unforeseen site conditions or additional work requested by the owner or other stakeholders.

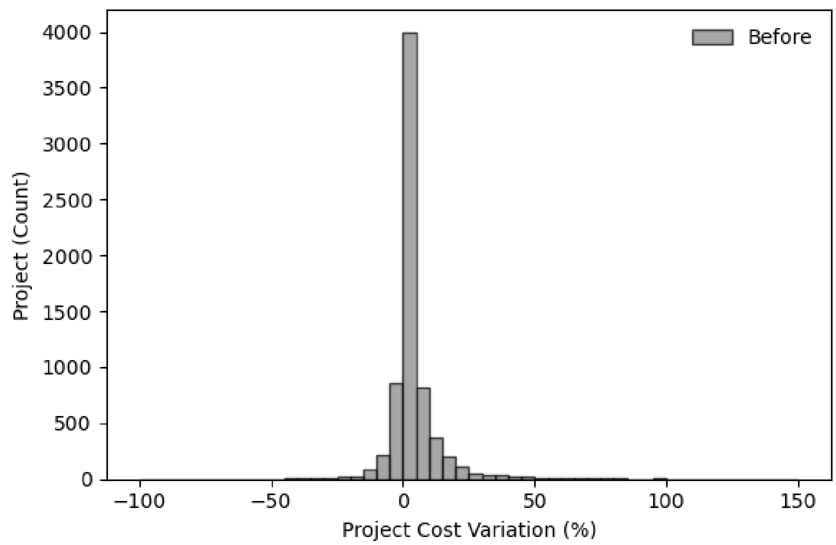


Figure 5.2 Histogram of Project Cost Variation (%) – Projects Let Before CMP

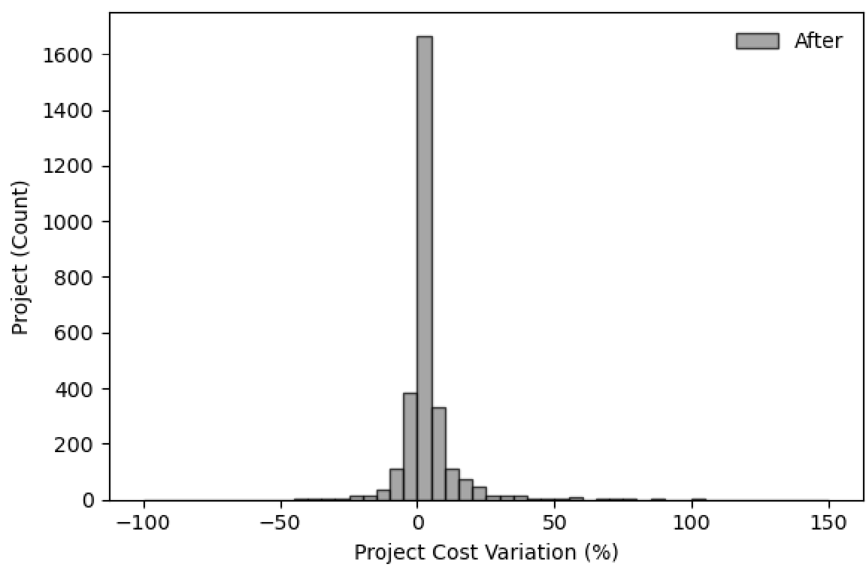


Figure 5.3 Histogram of Project Cost Variation (%) – Projects Let After CMP

Since the data does not follow a normal distribution, as confirmed by the Kolmogorov-Smirnov Test with a low p-value, a non-parametric statistical test was chosen to compare the datasets. Specifically, the Mann-Whitney U Test was applied, as it is suitable for analyzing data that does not meet normality assumptions, ensuring the robustness and reliability of the results.

The Mann-Whitney U Test produced a U statistic value of 10,739,154 and a p-value of 4.54×10^{-7}, which is significantly below the 0.05 significance level. This result indicates a statistically significant difference in project cost variation due to change orders between the two groups. The extremely low p-value confirms that the observed differences are unlikely to be due to random chance, further reinforcing the conclusion that project cost variations due to change orders are lower in projects executed after the implementation of CMP.

Table 5.2 Mann-Whitney U-Test Results with Outliers

U statistics	10,739,154
p-value	4.54×10^{-7}

Given the significant variance and widespread distribution observed in project cost variation data, the IQR method was applied to identify and remove outliers in both the Before and After groups. This approach ensured a more robust and reliable dataset by minimizing the influence of extreme values, allowing for more accurate statistical analysis. (Aguinis, 2013; Smiti, 2020; Freund, 2022).

As a result of outlier removal, the statistics presented in Table 5.3 are lower than those in Table 5.1, reflecting a more refined dataset. The maximum and minimum values, along with the overall range of cost variations, were adjusted to more reasonable levels for both groups. Additionally, the standard deviation decreased, indicating reduced variability in the dataset. By filtering out extreme values, the analysis provides a clearer and more reliable representation of changes in cost variation rates.

When comparing the two groups after removing outliers, the mean project cost variation due to change orders decreased from 1.81% in the Before group to 1.40% in the After group. The standard deviation was also reduced from 3.43% to 3.00%, indicating less variability in cost variations. The maximum cost variation dropped from 12.2% to 10.2%, while the median value declined significantly from 0.8% to 0.3%. The range of minimum values also narrowed slightly, from -7.3% in the Before group to -6.1% in the After group.

Table 5.3 Descriptive Statistics of Change Orders without Outliers

Statistics (%)	Before	After
Count	6,000	2,429
Mean	1.81	1.40
Standard Deviation	3.43	3.00
Maximum	12.2	10.2
Median (50%)	0.8	0.3
Minimum	-7.3	-6.1

These differences are visually represented in the box plot in Figure 5.4, which illustrates a lower median, a reduced range, and a more concentrated distribution after outlier removal. This visualization further highlights the impact of eliminating extreme values, reinforcing the statistical analysis findings.

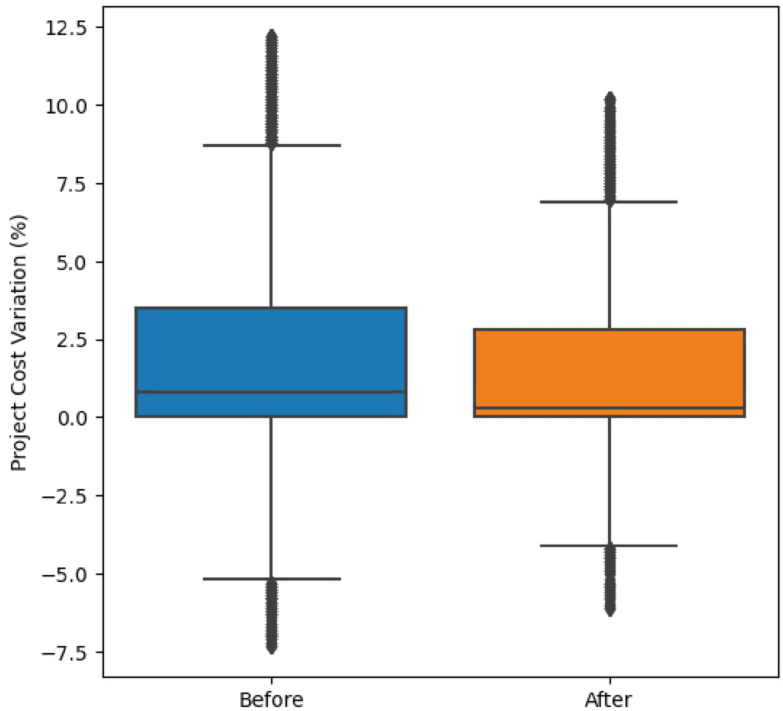


Figure 5.4 Box Plots of Project Cost Variation Rate without Outliers (%)

As with the test conducted on all project data, the Mann-Whitney U Test was also performed on the interquartile range data. The test yielded a U statistic of 7,795,315 and a p-value of 4.29×10^{-5}, which remains significantly below the 0.05 threshold. These results confirm that, even after eliminating extreme values, the difference in project cost variation rates between the Before and After groups remains statistically significant.

Table 5.4 Mann-Whitney U-Test Results without Outliers

U statistics	7,795,315
p-value	4.29×10^{-5}

5.4. Change Orders by Project Size

Projects were categorized into distinct groups to analyze the impact of change orders across different project sizes. The same statistical testing procedures were applied to each group, both with and without outliers. However, due to the limited availability of data for TEX-size projects, statistical tests were only conducted for the Large, Medium, and Small project groups.

As part of the process, the Kolmogorov-Smirnov Test was performed to assess the normality of the data within each size group. The results confirmed that none of the groups followed a normal distribution, aligning with the overall dataset analysis, which also indicated deviations from normality. Given this non-normal distribution, the Mann-Whitney U Test was used to compare project cost variation rates across the different size categories.

To further enhance the reliability of the analysis, the IQR method was applied to reduce the influence of outliers in each project size group. Before conducting statistical tests, box plots were generated for each category to visually assess data distributions. As shown in Figure 5.5, these box plots provided a clear representation of the range, median, and presence of outliers within each project size group, offering valuable insights into the differences in cost variation trends across project sizes.

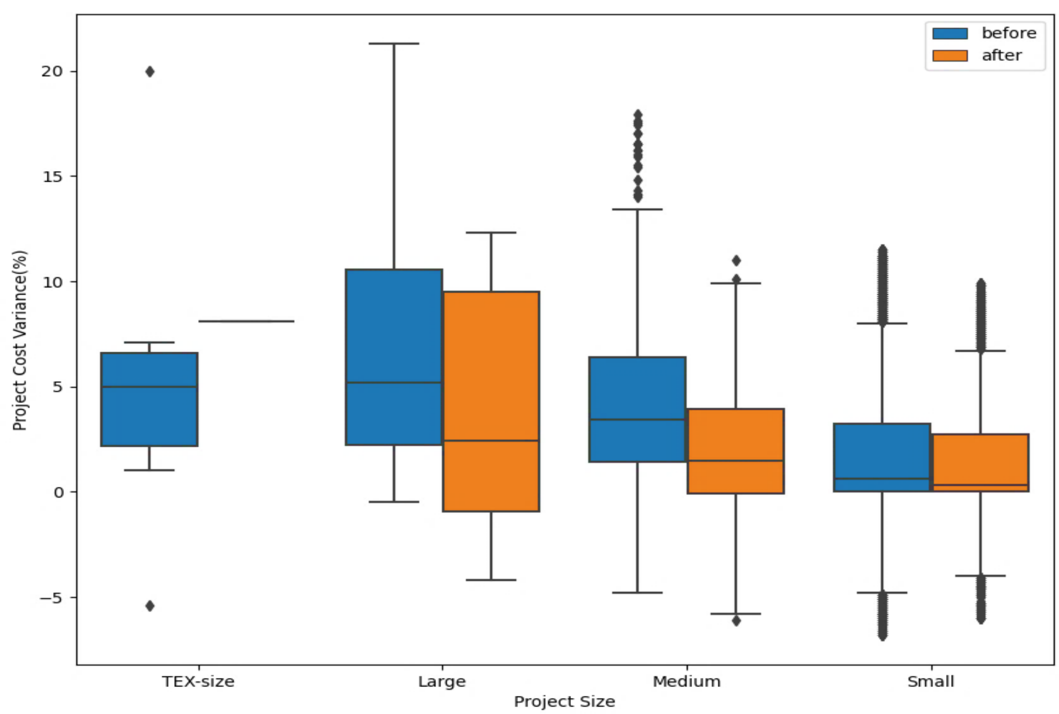


Figure 5.5 Box Plots of Project Cost Variation Rate without Outliers (%) by Project Size

5.4.1.1. **Change Orders from TEX-size Projects**

The TEX-size projects group contains only eight completed projects left before the CMP implementation and one completed project left after CMP. Therefore, hypothesis testing is not available in this group.

5.4.1.2. **Change Orders from Large Projects**

The statistical analysis was performed on Large Projects after removing outliers. The Before group consisted of 66 projects, and the After group included 11 projects. A comparison with Table 5.5 shows that the mean cost variation rate in the Before group decreased from 6.81% to 3.89% in the After group, reinforcing the trend of lower cost variation in projects let after CMP implementation. The standard deviations were nearly identical, with 5.87% in the Before group and 5.94% in the After group. Additionally, the maximum cost variation rate dropped from 21.3% in the Before group to 12.3% in the After group, suggesting a decrease in extreme cost fluctuations.

Table 5.5 Descriptive Statistics of Change Orders Without Outliers – Large Project

Statistics (%)	Before	After
Count	66	11
Mean	6.81	3.89
Standard Deviation	5.87	5.94
Maximum	21.3	12.3
Median (50%)	5.2	2.4
Minimum	-0.5	-4.2

However, from a Mann-Whitney U Test, the U statistic was calculated as 461.5, and the p-value was 0.1536, greater than the 0.05 significance level. This indicates that while the descriptive statistics show a reduction in cost variation, the statistical test did not find a significant difference between the Before and After groups.

Table 5.6 Mann-Whitney U-Test Results Without Outliers – Large Project

U statistics	461.5
p-value	0.1536

5.4.1.3. **Change Orders from Medium Projects**

The Before group included 292 projects, while the After group consisted of 114 projects. As presented in Table 5.7, the mean cost variation rate decreased from 4.71% in the Before group to 1.91% in the After group, indicating a notable reduction in cost variation following CMP implementation. The standard deviation dropped from 4.90% to 3.35%, suggesting reduced variability in cost changes. The maximum cost variation rate declined from 17.9% to 11.0%, reflecting fewer extreme cost fluctuations. The median cost variation rate fell from 3.4% to 1.5%, further supporting a downward trend. The minimum cost variation rate shifted from -4.8% to -6.1%, indicating a slight increase in the range of negative cost changes.

Table 5.7 Descriptive Statistics of Change Orders Without Outliers – Medium Project

Statistics (%)	Before	After
Count	292	114
Mean	4.71	1.91
Standard Deviation	4.90	3.35
Maximum	17.9	11.0
Median (50%)	3.4	1.5
Minimum	-4.8	-6.1

Results from the Mann-Whitney U Test in Table 5.8 confirm these findings. The test produced a U statistic of 22,167.5 and a p-value of 2.012×10^{-7}, which is well below the 0.05 significance level. This strongly supports the conclusion that the difference in cost variation rates between the Before and After groups is statistically significant after outlier removal.

Table 5.8 Mann-Whitney U-Test Results Without Outliers – Medium Project

U statistics	22,167.5
p-value	$2.012 \text{ x } 10^{-7}$

5.4.1.4. **Change Orders from Small Projects**

After removing outliers from the small project group, the Before group consisted of 5,614 projects, while the After group included 2,292 projects. As shown in Table 5.9, the average cost variation rate declined from 1.67% in the Before group to 1.33% in the After group, indicating a reduction in cost fluctuations. The standard deviation also slightly decreased from 3.26% to 2.91%, suggesting lower variability in cost variations. Additionally, the maximum cost variation rate dropped from 11.5% to 9.9%, while the median cost variation rate decreased from 0.6% to 0.3%. The minimum cost variation rate changed slightly from -6.8% to -6.0%, showing a marginal shift in the range of negative cost variations.

Table 5.9 Descriptive Statistics of Change Orders Without Outliers – Small Projects

Statistics (%)	Before	After
Count	5,614	2,292
Mean	1.67	1.33
Standard Deviation	3.26	2.91
Maximum	11.5	9.9
Median (50%)	0.6	0.3

Minimum	-6.8	-6.0

The Mann-Whitney U Test yielded a U statistic of 6,810,013.5 and a p-value of 3.817×10^{-5}, which is far below the 0.05 significance level. This result confirms that the difference in cost variation rates between the Before and After groups is statistically significant. This further supports the conclusion that CMP implementation has had a measurable impact on reducing project cost variations in Small Projects, supporting the effectiveness of structured change order management in improving cost control.

Table 5.10 Mann-Whitney U-Test Results Without Outliers – Small Projects

U statistics	6,810,013.5
p-value	3.817×10^{-5}

5.5. Change Orders with Reason Code 6

A statistical analysis was conducted to evaluate changes in cost variation due to Reason Code 6 change orders, which are the most closely associated with CMP implementation. The dataset was filtered to include only change orders categorized under Reason Code 6, and projects containing these change orders were identified. For each selected project, the project cost variation rate was calculated by dividing the total Reason Code 6 change order amount by the original contract amount. Using this refined dataset, statistical tests were performed following the same methodology as in previous analyses to determine whether significant differences existed between the Before and After groups.

To examine the distribution of the data, visual representations, such as histograms and box plots, were generated to compare the Before and After groups, as shown in Figures 5.6 and 5.7. Similar to the overall change order distribution, the project cost variation rates caused by Reason Code 6 change orders were highly concentrated around 0%, with a slight increase near 0.1%, suggesting that the data does not follow a normal distribution. The Kolmogorov-Smirnov Test was performed to assess normality numerically to confirm it. The test results produced p-values significantly smaller than the significance level for both the Before and After groups, reinforcing the conclusion that the data deviates from a normal distribution. Given these findings, descriptive statistics were calculated, and a non-parametric Mann-Whitney U Test was conducted to evaluate differences in cost variation rates between the two groups.

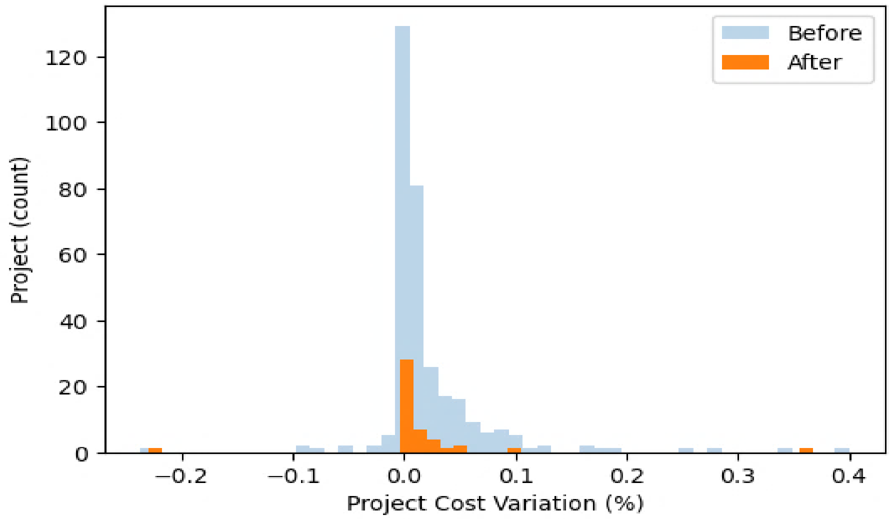


Figure 5.6 Histogram of Project Cost Variation of Reason Code 6 (%)

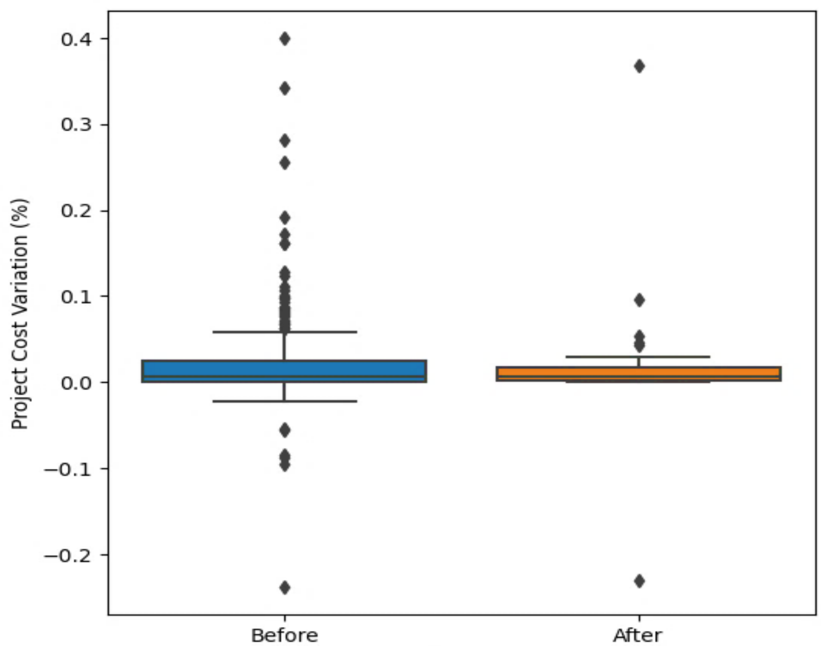


Figure 5.7 Box Plots of Project Cost Variation of Reason Code 6 (%)

The Before group consisted of 320 projects, while the After group included 45 projects. As shown in Table 5.11, the mean cost variation rate decreased slightly from 2.07% in the Before group to 1.51% in the After group. However, the standard deviation increased from 4.96% to 6.73%, indicating that while the average cost variation was slightly lower after CMP implementation, the variability of cost changes became more pronounced. The maximum cost variation rates were similar between the two groups, with the Before group reaching 40.01% and the After group slightly lower at 36.79%. The median cost variation rate remained unchanged at 0.6%, suggesting that the central tendency of the data remained consistent. The minimum cost variation rates were also comparable, at -23.74% in the Before group and -23.03% in the After group.

To determine whether these differences were statistically significant, a Mann-Whitney U Test was conducted, with results summarized in Table 5.12. The test yielded a U statistic of 7,305.0 and a p-value of 0.875. Since the p-value is much greater than the 0.05 significance level, the results indicate that there is no statistically significant difference in project cost variation rates caused by Reason Code 6 change orders between the Before and After groups.

Table 5.11 Descriptive Statistics of Change Orders – Reason Code 6

Statistics (%)	Before	After
Count	320	45
Mean	2.07%	1.51%
Standard Deviation	4.96%	6.73%
Maximum	40.01%	36.79%
Median (50%)	0.63%	0.59%
Minimum	-23.74%	-23.03%

Table 5.12 Mann-Whitney U-Test Results – Reason Code 6

U statistics	7,305.0
p-value	0.875

In summary, while the descriptive statistics suggest minor differences in the average cost variation rates and increased variability after CMP implementation, the statistical test confirms that these differences are not significant. This suggests that, for projects involving Reason Code 6 change orders, the implementation of CMPs did not lead to a statistically meaningful reduction in cost variation.

Chapter 6. Analyses of Potential Correlations Between Conflict Clearance Delays and Project Change Orders

6.1. Introduction

Delays in clearing conflicts can significantly impact project outcomes, often resulting in change orders that may lead to cost overruns or schedule delays. Task 6 focused on analyzing potential correlations between delays in conflict clearance and the occurrence of project change orders. The objective was to provide insights into how delayed conflict resolution may influence change order frequency and magnitude, thereby highlighting the critical role of effective conflict management in project delivery.

To conduct this analysis, project data were collected from CMP documents and the SiteManager system. Key variables were identified and examined using correlation coefficient analysis to explore potential relationships between conflict clearance delays and change order trends.

Task 6 included the following key activities:

- Collect and categorize ROW, RR, and UTL conflict information included in CMP documents from projects and corresponding change orders.
- Conduct correlation analysis to identify potential relationships between conflict clearance delays and project change orders by major project categories, both from CMP projects and non-CMP projects that had their conflicts cleared more than 90 days from their letting date.

6.2. Analysis Methodology

6.2.1. Project Data Description

Data was collected from CMP documents, project information records, and change orders retrieved from the SiteManager system. All CMP project-related documents were provided by TxDOT for analysis. Conflict information, including conflict types, proposed clearance dates, and buffer times (if available), were extracted using Optical Character Recognition (OCR) techniques and text recognition from PDF format files.

Additionally, project information and conflict clearance date data were obtained as spreadsheets from TxDOT's internal database. Further data updates were requested from TxDOT to enhance previously collected research data. The project dataset covers CMP projects from September 1, 2018, to September 30, 2024, encompassing the period from the first implementation of CMPs to the most recent data request. This ensures consistency with other datasets collected during the same period, including change orders and project letting information. Additionally, consistent with previous research tasks, the analysis includes only completed projects and active projects in which all conflicts have been cleared.

To conduct the correlation analysis, the extracted data was integrated and preprocessed. During this process, unique project codes (CSJ) were used to link project information, change order data, and conflict clearance dates. These datasets were further classified by project status (completed or active) and conflict clearance status (cleared or not cleared). Each dataset was assigned as an attribute, and additional attributes were generated for analysis.

For instance, the clearance dataset included both planned and actual clearance dates for the three conflict categories: UTL, ROW, and RR. Planned versus actual clearance dates were compared to calculate potential conflict clearance delays. If the actual clearance dates exceeded the planned dates, the delay period was calculated, and a clearance delay flag was added.

Additionally, change order information obtained in previous tasks, including the occurrence of change orders and project cost variation due to change orders, were integrated. Some attributes were also added as binary data. For example, projects with delays in conflict clearance (calculated as the difference between planned and actual clearance dates) were marked with a binary flag: "1" for the occurrence of conflict clearance delays and "0" for no delay. These binary markers allowed quantification of the coefficients for correlation analysis.

As a result, the final dataset consisted of 175 CMP projects (rows) and 48 attributes (columns). This comprehensive dataset was analyzed using statistical methods to identify correlations between significant variables.

6.2.2. Correlation Analysis Methods

To further explore the relationship between change orders and CMP-related conflict clearance data, correlation analysis was performed on individual variables. Correlation analysis is a widely used methodology for examining the relationships between variables (Asuero, 2006; NAC, 2021). The choice of correlation test depends on the type of data and the research objective. In this research, three correlation methods were used:

1. Pearson Correlation Coefficient – Applied when both variables are continuous numerical data, such as measuring the linear relationship between conflict clearance delay days and change order cost growth rates.

2. Point-Biserial Correlation – Used when one variable is binary (e.g., clearance delay occurs or not) and the other is numerical.

3. Chi-Square Test of Independence – Conducted for categorical variables, such as assessing whether change order occurrence is significantly associated with the delay occurrence.

The choice of correlation analysis method was based on the data type of each variable. A significance level of 0.05 was applied across all analyses, with results yielding p-values below this threshold considered statistically significant, thereby indicating a meaningful correlation. For analyses involving Pearson and Point-Biserial correlation methods, correlation coefficients were calculated and included in the results.

This analysis was first conducted on all projects and the associated change orders. Further analyses were then performed by categorizing projects based on size, classification, and district to determine if correlations varied according to project group characteristics.

Among the CMP projects analyzed, some experienced change orders while others did not; therefore, the projects with change orders were categorized as binary data (Yes/No). For projects with change orders, the dataset included two primary variables: the number of change orders and the project cost variation due to these orders, which is measured as a percentage of the original contract amount.

The correlation analysis focused on three variables related to change orders:

1. Occurrence of change orders (Yes/No)

2. Number of change orders (count)

3. Project cost variation rate due to change orders (percentage)

Conflict clearance variables were categorized into two groups:

1. Conflict Clearance Delays: For the ROW, RR, and UTL categories, each project had both planned and actual clearance dates. These variables were used to compute delays or early completions by comparing the two dates.

The extent of any observed delay (in days) was recorded. If a delay was noted in any of the three categories, the project was flagged with a binary delay indicator (Yes/No).

2. Conflict Counts by Type: This variable documented the number of conflicts within each category (ROW, RR, and UTL).

Using these variables, the analyses were conducted to explore their relationships with change orders, utilizing methods appropriate for the respective data types. While correlation analyses were performed on both variable categories, the primary focus of this task is to examine the relationship between conflict clearance delays and change orders, as detailed analysis of this correlation is presented in the following sections. A summary of the results of the correlation analysis between conflict counts by type and change orders are provided separately in Appendix B.

6.3. Correlation Analysis of CMP Projects

The correlation analysis was initially conducted using completed and active conflict-all-cleared CMP projects and their associated change orders. Subsequent analyses were performed by grouping projects according to their size, classification, and district to assess whether the relationships varied based on project characteristics.

6.3.1. Change Orders from All CMP Projects

In the first stage of analysis, all completed and active all-cleared CMP projects and their change orders were considered. The occurrence of change orders was treated as a binary variable, and its relationship with conflict clearance delay occurrence was analyzed. Additionally, the number of clearance delay days in each conflict category of ROW/UTL/RR was included to assess whether delays in specific categories were associated with the likelihood of change orders. Further, correlation analyses were conducted using continuous variables, such as the number of change orders and the project cost variation rate due to change orders, to determine whether a statistical relationship existed between them and conflict clearance delays.

The results in Tables 6.1, 6.2, and 6.3 indicate that while there was no statistically significant correlation between the occurrence of conflict clearance delays and the occurrence of change orders (binary-to-binary relationship), moderate positive correlations were observed between the number of change orders and clearance delay days in both ROW and UTL categories. Moreover, a positive correlation was found between clearance delays across all three conflict categories and the project cost variation rate attributable to change orders.

These findings suggest that delays in conflict clearance are associated with an increased number of change orders and a higher rate of cost variation at the project level. This highlights the importance of timely conflict resolution, as clearance delays can lead to scope changes, additional work requirements, resource reallocation, and extended project schedules, all of which contribute to increased costs.

Table 6.1 Correlation Analysis Results from CMP Projects – Change Order Occurrence vs Conflict Clearance Delay

Variable 1	Variable 2	p-value	Correlation Coefficient	Result
Change Order Occurrence (Y/N)	Occurrence of Conflict Clearance Delays (Y/N)	0.319	0.993	No Significant Correlation
	ROW Conflict Clearance Delay (In Days)	0.215	0.176	No Significant Correlation
	RR Conflict Clearance Delay (In Days)	0.143	0.270	No Significant Correlation
	UTL Conflict Clearance Delay (In Days)	0.095	0.131	No Significant Correlation

Table 6.2 Correlation Analysis Results from CMP Projects – Number of Change Orders vs Conflict Clearance Delay

Variable 1	Variable 2	p-value	Correlation Coefficient	Result
Number of Change Orders	Occurrence of Conflict Clearance Delays (Y/N)	0.113	0.123	No Significant Correlation
	ROW Conflict Clearance Delay (In Days)	0.043	0.300	**Moderate Positive**
	RR Conflict Clearance Delay (In Days)	0.583	0.108	No Significant Correlation
	UTL Conflict Clearance Delay (In Days)	0.000	0.339	**Moderate Positive**

Table 6.3 Correlation Analysis Results from CMP Projects – Project Cost Variation due to Change Orders (In %) vs Conflict Clearance Delay

Variable 1	Variable 2	p-value	Correlation Coefficient	Result
Project Cost Variation due to Change Orders (In %)	Occurrence of Conflict Clearance Delays (Y/N)	0.649	-0.360	No Significant Correlation
	ROW Conflict Clearance Delay (In Days)	0.009	0.382	**Moderate Positive**
	RR Conflict Clearance Delay (In Days)	0.003	0.534	**Moderate Positive**

	UTL Conflict Clearance Delay (In Days)	0.000	0.321	**Moderate Positive**

6.3.2. Change Orders by Project Characteristics

The same set of correlation analyses was applied to completed CMP projects and their associated change orders grouped by project characteristics, including project size, project classification, and district.

Project size categories followed the TxDOT criteria utilized in previous chapters: TEX-size, Large, Medium, and Small, based on the contract dollar amount. For project classification and district, only categories with a sufficient number of change orders (at least 30) were selected to ensure meaningful and reliable statistical results. Based on this threshold, three project classifications were included: WNF - Widen Non-Freeway, MSC - Miscellaneous Construction, and WF - Widen Freeway. For district-level analysis, the Houston, Austin, and San Antonio districts were selected as they met the minimum data requirement among TxDOT district groups.

6.3.2.1. Change Orders by Project Size

For projects classified as TEX-size, the dataset contained an insufficient number of observations to support meaningful statistical analysis. As a result, correlation analyses for TEX-size projects were marked as N/A. Similarly, if the other sample size within a project size group was too small to establish statistical significance, the analysis results were marked as N/A.

The correlation analyses between conflict clearance delays and change order occurrence, grouped by project size, revealed that none of the correlations are statistically significant, as shown in Table 6.4.

Table 6.4 Change Order Occurrence vs Conflict Clearance Delay – by Project Size

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
TEX-size	Change Order Occurrence (Y/N)	Occurrence of Conflict Clearance Delays (Y/N)	N/A	N/A	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.652	0.277	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.526	-0.382	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.540	0.187	No Significant Correlation
Large	Change Order	Occurrence of Conflict Clearance Delays (Y/N)	0.553	0.352	No Significant Correlation

	Occurrence (Y/N)	ROW Conflict Clearance Delay (In Days)	0.872	-0.048	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.857	-0.085	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.717	0.058	No Significant Correlation
Medium	Change Order Occurrence (Y/N)	Occurrence of Conflict Clearance Delays (Y/N)	0.792	0.069	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.696	0.091	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.160	0.548	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.131	0.210	No Significant Correlation
Small	Change Order Occurrence (Y/N)	Occurrence of Conflict Clearance Delays (Y/N)	0.141	2.172	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.413	0.275	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.328	0.326	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.133	0.205	No Significant Correlation

When examining the relationship between conflict clearance delay days and the number of change orders, grouped by project size, both the Large and Medium project size groups showed a moderate positive correlation with Utility clearance delay days.

Table 6.5 Number of Change Orders vs Conflict Clearance Delay – by Project Size

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
TEX-size	Number of Change Orders	Occurrence of Conflict Clearance Delays (Y/N)	N/A	N/A	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.289	0.596	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.624	0.300	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.473	0.219	No Significant Correlation
Large	Number of Change Orders	Occurrence of Conflict Clearance Delays (Y/N)	0.194	0.204	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.066	0.524	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.631	-0.223	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.021	0.360	**Moderate Positive**
Medium		Occurrence of Conflict Clearance Delays (Y/N)	0.566	0.081	No Significant Correlation

	Number of Change Orders	ROW Conflict Clearance Delay (In Days)	0.282	0.260	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.099	0.672	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.015	0.338	**Moderate Positive**
Small	Number of Change Orders	Occurrence of Conflict Clearance Delays (Y/N)	0.583	-0.074	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.737	-0.131	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.080	0.612	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.858	-0.026	No Significant Correlation

In relation to the project cost variation due to change orders, in the Large group, there were relatively strong positive correlations with both ROW and utility clearance delay days, indicating that longer ROW and utility delays are associated with higher cost increases. On top of that, a relatively strong positive correlation between railroad clearance delay days and project cost variation rates suggests that delays in railroad clearance contributed significantly to cost increases in smaller projects.

Table 6.6 Project Cost Variation due to Change Orders (In %) vs Conflict Clearance Delay – by Project Size

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
TEX-size	Project Cost Variation due to Change Orders (In %)	Occurrence of Conflict Clearance Delays (Y/N)	N/A	N/A	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.421	-0.473	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.452	-0.446	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.979	-0.008	No Significant Correlation
Large	Project Cost Variation due to Change Orders (In %)	Occurrence of Conflict Clearance Delays (Y/N)	0.299	0.164	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.024	0.620	**Strong Positive**
		RR Conflict Clearance Delay (In Days)	0.960	0.024	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.000	0.606	**Strong Positive**
Medium	Project Cost Variation due to Change	Occurrence of Conflict Clearance Delays (Y/N)	0.176	-0.189	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.410	0.201	No Significant Correlation

	Orders (In %)	RR Conflict Clearance Delay (In Days)	0.137	0.620	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.628	0.069	No Significant Correlation
Small	Project Cost Variation due to Change Orders (In %)	Delay Occurrence	0.729	-0.047	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.537	-0.238	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.044	0.680	**Strong Positive**
		UTL Conflict Clearance Delay (In Days)	0.824	0.032	No Significant Correlation

6.3.2.2. **Change Orders by Project Classification**

When analyzing change order occurrence within the three primary project classifications, no statistically significant correlation was found with conflict clearance delays. This indicates that the type of project does not have a substantial influence on the likelihood of change orders resulting from delays in conflict resolution. Moreover, after dividing subgroups, WF project classification only contains a YES value in change order occurrence, which results in N/A as the data point is not sufficient to analyze the relationship.

Table 6.7 Change Order Occurrence vs Conflict Clearance Delay – by Project Class

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
WNF	Change Order Occurrence (Y/N)	Occurrence of Conflict Clearance Delays (Y/N)	N/A	N/A	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.117	0.477	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.569	0.105	No Significant Correlation
MSC	Change Order Occurrence (Y/N)	Occurrence of Conflict Clearance Delays (Y/N)	N/A	N/A	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.006	0.793	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.195	0.231	No Significant Correlation
WF	Change Order Occurrence (Y/N)	Occurrence of Conflict Clearance Delays (Y/N)	N/A	N/A	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation

		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation

When examining the relationship between the number of change orders and conflict clearance delays across different project classifications, as illustrated in Table 6.8, in both the WNF and MSC categories, delays in utility conflict clearance showed a moderate positive correlation with the number of change orders. Additionally, in the MSC category, delays in ROW conflict clearance demonstrated a relatively strong positive correlation with the number of change orders. These findings suggest that unresolved utility and ROW conflicts contributed to an increase in change orders.

Table 6.8 Number of Change Orders vs Conflict Clearance Delay – by Project Classification

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
WNF	Number of Change Orders	Occurrence of Conflict Clearance Delays (Y/N)	0.792	0.048	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.706	0.129	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.024	0.405	**Moderate Positive**
MSC	Number of Change Orders	Occurrence of Conflict Clearance Delays (Y/N)	0.487	0.116	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.006	0.691	**Strong Positive**
		RR Conflict Clearance Delay (In Days)	0.514	-0.252	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.010	0.448	**Moderate Positive**
WF	Number of Change Orders	Occurrence of Conflict Clearance Delays (Y/N)	0.583	0.127	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.110	0.608	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.998	-0.002	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.332	0.229	No Significant Correlation

The correlation analysis between cost variation rate due to change orders and conflict clearance delays yielded similar results to the analysis of change order counts. In both the WNF and MSC categories, delays in utility conflict clearance showed a positive correlation with cost variation rates. Furthermore, in the MSC category, delays in ROW conflict clearance exhibited a strong positive correlation with cost variation rates. These results indicate that delays in resolving these conflicts significantly impacted cost increases. Notably, the two most common project classifications, WNF and MSC, both demonstrated statistically significant correlations.

Table 6.9 Project Cost Variation due to Change Orders (In %) vs Conflict Clearance Delay – by Project Classification

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
WNF	Project Cost Variation due to Change Orders (In %)	Occurrence of Conflict Clearance Delays (Y/N)	0.278	0.198	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.231	0.394	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.003	0.522	**Moderate Positive**
MSC	Project Cost Variation due to Change Orders (In %)	Occurrence of Conflict Clearance Delays (Y/N)	0.898	-0.021	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.013	0.646	**Strong Positive**
		RR Conflict Clearance Delay (In Days)	0.094	0.591	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.000	0.632	**Strong Positive**
WF	Project Cost Variation due to Change Orders (In %)	Occurrence of Conflict Clearance Delays (Y/N)	0.621	-0.115	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.106	-0.613	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.723	0.220	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.576	-0.133	No Significant Correlation

6.3.2.3. **Change Orders by District**

When grouping projects by district, the dataset became highly fragmented, resulting in insufficient data for analysis in many cases. Additionally, no statistically significant correlation was observed between change order occurrence and conflict clearance delays. This suggests that project location did not play a significant role in influencing whether change orders occurred.

Table 6.10 Change Order Occurrence vs Conflict Clearance Delay – by District

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result

Houston	Change Order Occurrence (Y/N)	Occurrence of Conflict Clearance Delays (Y/N)	0.948	0.004	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.147	0.346	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.215	0.671	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.140	0.251	No Significant Correlation
Austin	Change Order Occurrence (Y/N)	Occurrence of Conflict Clearance Delays (Y/N)	N/A	N/A	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
San Antonio	Change Order Occurrence (Y/N)	Occurrence of Conflict Clearance Delays (Y/N)	N/A	N/A	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation

The correlation analyses revealed a moderate positive relationship between the number of utility conflicts and the number of change orders in projects located in Houston. When considering all other project groups, the number of change orders generally showed a positive correlation with delays in utility conflict clearance, indicating that prolonged utility conflict resolution is associated with an increase in change orders.

Table 6.11 Number of Change Orders vs Conflict Clearance Delay – by District

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
Houston	Number of Change Orders	Occurrence of Conflict Clearance Delays (Y/N)	0.465	0.130	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.301	0.267	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.262	-0.916	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.002	0.519	**Moderate Positive**
Austin	Number of Change Orders	Occurrence of Conflict Clearance Delays (Y/N)	0.327	0.200	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.585	-0.332	No Significant Correlation

		RR Conflict Clearance Delay (In Days)	0.502	0.346	**Moderate Positive**
		UTL Conflict Clearance Delay (In Days)	0.588	0.119	No Significant Correlation
San Antonio	Number of Change Orders	Occurrence of Conflict Clearance Delays (Y/N)	0.417	0.335	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.379	0.361	No Significant Correlation

The correlation analyses between change order-related cost variation rates and conflict clearance delays showed a very strong positive correlation between railroad clearance delays and the number of change orders in Austin. However, this finding is based on only six data points, making it susceptible to distortion due to the small sample size.

Table 6.12 Project Cost Variation due to Change Orders (In %) vs Conflict Clearance Delay – by District

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
Houston	Project Cost Variation due to Change Orders (In %)	Occurrence of Conflict Clearance Delays (Y/N)	0.741	-0.059	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.652	0.118	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.686	-0.474	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.060	0.331	No Significant Correlation
Austin	Project Cost Variation due to Change Orders (In %)	Occurrence of Conflict Clearance Delays (Y/N)	0.762	0.062	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	0.221	-0.664	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.005	0.943	**Very Strong Positive**
		UTL Conflict Clearance Delay (In Days)	0.262	0.244	No Significant Correlation
San Antonio	Project Cost Variation due to Change Orders (In %)	Occurrence of Conflict Clearance Delays (Y/N)	0.786	-0.115	No Significant Correlation
		ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.953	0.025	No Significant Correlation

6.4. **Correlation Analysis of Non-CMP Projects**

The non-CMP projects analyzed in this section include those in which conflict clearance was completed more than 90 days after the letting date during the target research period. At the time of the PS&E review, these projects were not flagged to apply CMP because their conflicts were anticipated to be cleared within 90 days of letting. However, delays ultimately occurred in at least one of the three conflict categories of ROW/UTL/RR, resulting in a total of 181 projects included in this dataset.

The same variables analyzed for the CMP projects were applied to this group to enable direct comparison. Notably, unlike CMP projects, non-CMP projects are predominantly Medium and Small in size, as CMP requirements are typically triggered by larger and more complex projects with a higher likelihood of pre-construction conflicts.

6.4.1. **Change Orders from All Projects**

Among the analyses, only one weak negative correlation was observed between the occurrence of change orders and utility conflict clearance delay days. No other statistically significant correlations were found between conflict clearance variables and either the number of change orders or the project cost variation rate. These results in Table 6.13 to 6.15 contrast with the findings from CMP projects, where multiple moderate to strong positive correlations were identified, indicating a more defined relationship between conflict delays and project changes in those cases.

Table 6.13 Correlation Analysis Results from Non-CMP Projects – Change Order Occurrence vs Conflict Clearance Delay

Variable 1	Variable 2	p-value	Correlation Coefficient	Result
Change Order Occurrence (Y/N)	ROW Conflict Clearance Delay (In Days)	0.732	-0.078	No Significant Correlation
	RR Conflict Clearance Delay (In Days)	0.835	0.059	No Significant Correlation
	UTL Conflict Clearance Delay (In Days)	0.020	-0.184	**Weak Negative**

Table 6.14 Correlation Analysis Results from Non-CMP Projects – Number of Change Orders vs Conflict Clearance Delay

Variable 1	Variable 2	p-value	Correlation Coefficient	Result
	ROW Conflict Clearance Delay (In Days)	0.027	0.661	No Significant Correlation

Number of Change Orders	RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
	UTL Conflict Clearance Delay (In Days)	0.939	0.011	No Significant Correlation

Table 6.15 Correlation Analysis Results from Non-CMP Projects – Project Cost Variation due to Change Orders (In %) vs Conflict Clearance Delay

Variable 1	Variable 2	p-value	Correlation Coefficient	Result
Project Cost Variation due to Change Orders (In %)	ROW Conflict Clearance Delay (In Days)	0.633	-0.163	No Significant Correlation
	RR Conflict Clearance Delay (In Days)	0.749	-0.251	No Significant Correlation
	UTL Conflict Clearance Delay (In Days)	0.773	0.041	No Significant Correlation

6.4.2. Change Orders by Project Characteristics

Correlation analyses by project characteristics, including project size, classification, and district, were also conducted for non-CMP projects. Given that non-CMP projects are generally smaller in scope, the dataset is composed mainly of Medium and Small projects. There were insufficient data points for TEX-size and Large projects; therefore, those categories were excluded from the analysis.

Unlike the CMP project group, where the dominant classifications were WNF (Widen Non-Freeway), MSC (Miscellaneous Construction), and WF (Widen Freeway), the most common project types among non-CMP projects were RER (Rehabilitation of Existing Roads) followed by MSC and WNF. This distribution reflects the overall nature and scale of non-CMP projects. Dallas, Houston, and Austin were the top three districts with the highest number of non-CMP projects.

6.4.2.1. Change Orders by Project Sizes

These non-CMP projects tend to be smaller in size compared to CMP projects, as CMP is primarily used to mitigate multiple conflict delays, which are more common in larger and more complex projects. In other words, non-CMP projects are generally smaller in scale. Accordingly, in the dataset, most projects fall into the medium and small size categories, while TEX-size and large projects lack sufficient data for correlation analysis. Therefore, the analysis results are only available for the medium and small project categories.

From the analysis, in small projects, there is a weak negative correlation between utility conflict clearance delays and change order occurrence. This trend is consistent with the correlation results observed across all non-CMP projects.

However, except for this, no significant correlation was observed in non-CMP projects by size group.

Table 6.16 Change Order Occurrence vs Conflict Clearance Delay in non-CMP projects – by Project Size

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
TEX-size	Change Order Occurrence (Y/N)	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
Large	Change Order Occurrence (Y/N)	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
Medium	Change Order Occurrence (Y/N)	ROW Conflict Clearance Delay (In Days)	0.660	0.510	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.968	-0.007	No Significant Correlation
Small	Change Order Occurrence (Y/N)	ROW Conflict Clearance Delay (In Days)	0.425	-0.200	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.833	-0.077	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.026	-0.216	**Weak Negative**

Table 6.17 Number of Change Orders vs Conflict Clearance Delay in non-CMP projects – by Project Size

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
TEX-size	Number of Change Orders	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
Large	Number of Change Orders	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation

Medium	Number of Change Orders	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.201	-0.505	No Significant Correlation
Small	Number of Change Orders	ROW Conflict Clearance Delay (In Days)	0.646	-0.179	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.077	0.273	No Significant Correlation

Table 6.18 Project Cost Variation due to Change Orders (In %) vs Conflict Clearance Delay in non-CMP projects – by Project Size

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
TEX-size	Project Cost Variation due to Change Orders (In %)	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
Large	Project Cost Variation due to Change Orders (In %)	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
Medium	Project Cost Variation due to Change Orders (In %)	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.774	-0.121	No Significant Correlation
Small	Project Cost Variation due to Change Orders (In %)	ROW Conflict Clearance Delay (In Days)	0.498	-0.261	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	0.749	-0.251	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.573	0.088	No Significant Correlation

6.4.2.2. **Change Orders by Project Classification**

Three major classifications, RER, MSC, and WNF are relatively smaller projects, that is expected as projects that typically do not require CMPs tend to involve small-scale roadway improvement projects. Correlation analysis was conducted based on these three major project classifications.

In all three categories, ROW and RR conflict clearance data did not have sufficient data points for analysis, whereas utility conflict data did. This is because most conflicts in these projects are related to utilities. However, none of the three major project classifications showed any statistically significant correlation with change order occurrence. All the same trends are observed in analyses between other change order metrics and clearance variables.

Table 6.19 Change Order Occurrence vs Conflict Clearance Delay in non-CMP projects – by Project Classification

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
RER	Change Order Occurrence (Y/N)	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.106	-0.286	No Significant Correlation
MSC	Change Order Occurrence (Y/N)	ROW Conflict Clearance Delay (In Days)	0.034	-0.745	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.609	0.103	No Significant Correlation
WNF	Change Order Occurrence (Y/N)	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.356	-0.185	No Significant Correlation

Table 6.20 Number of Change Orders vs Conflict Clearance Delay in non-CMP projects – by Project Classification

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
RER	Number of Change Orders	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.257	-0.356	No Significant Correlation
MSC	Number of Change Orders	ROW Conflict Clearance Delay (In Days)	0.613	-0.234	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.644	0.149	No Significant Correlation

WNF	Number of Change Orders	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.520	0.332	No Significant Correlation

Table 6.21 Project Cost Variation due to Change Orders (In %) vs Conflict Clearance Delay in non-CMP project – by Project Classification

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
RER	Project Cost Variation due to Change Orders (In %)	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.140	-0.452	No Significant Correlation
MSC	Project Cost Variation due to Change Orders (In %)	ROW Conflict Clearance Delay (In Days)	0.503	-0.307	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.353	-0.294	No Significant Correlation
WNF	Project Cost Variation due to Change Orders (In %)	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.182	-0.627	No Significant Correlation

6.4.2.3. **Change Orders by Districts**

To identify significant regional characteristics, the research task grouped the data by districts for analysis. Among the three major district groups of Dallas, Houston, and Austin, only one correlation is significant, which is the negative correlation between change order occurrence and utility conflict clearance delay, which was observed only in Dallas.

Table 6.22 Change Order Occurrence vs Conflict Clearance Delay in non-CMP projects – by District

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
Dallas	Change Order Occurrence (Y/N)	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.019	-0.427	**Moderate Negative**

Houston	Change Order Occurrence (Y/N)	ROW Conflict Clearance Delay (In Days)	0.283	-0.602	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.124	-0.365	No Significant Correlation
Austin	Change Order Occurrence (Y/N)	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.965	-0.014	No Significant Correlation

Table 6.23 Number of Change Orders vs Conflict Clearance Delay Delay in non-CMP projects – by District

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
Dallas	Number of Change Orders	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.325	-0.328	No Significant Correlation
Houston	Number of Change Orders	ROW Conflict Clearance Delay (In Days)	0.159	0.969	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.804	-0.131	No Significant Correlation
Austin	Number of Change Orders	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.338	0.362	No Significant Correlation

Table 6.24 Project Cost Variation due to Change Orders (In %) vs Conflict Clearance Delay Delay in non-CMP projects – by District

Group	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
Dallas	Project Cost Variation due to Change Orders (In %)	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.668	0.146	No Significant Correlation
Houston	Project Cost Variation	ROW Conflict Clearance Delay (In Days)	0.562	-0.635	No Significant Correlation

	due to Change Orders (In %)	RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.895	0.070	No Significant Correlation
Austin	Project Cost Variation due to Change Orders (In %)	ROW Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		RR Conflict Clearance Delay (In Days)	N/A	N/A	No Significant Correlation
		UTL Conflict Clearance Delay (In Days)	0.279	0.406	No Significant Correlation

6.5. Findings from Correlation Analysis

The correlation analyses and their comparison between CMP and non-CMP projects reveal a notable distinction in the relationship between conflict clearance delays and change orders. Table 6.25 summarizes the correlation results in CMP projects, presenting only the relationships that were found to be statistically significant. It demonstrated multiple clear and consistent positive correlations, particularly between delays in utility and right-of-way clearance and both the frequency and cost impact of change orders, providing evidence that conflict clearance delays contribute to the occurrence and cost impact of project change orders.

On the other hand, only a little or no meaningful statistical correlation between conflict clearance delays and change orders was found in non-CMP projects (Table 6.26), suggesting that conflict clearance delays did not directly influence change orders.

Table 6.25 Correlation Analysis Results from CMP Projects

Groups of Projects	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
All	Number of Change Orders	ROW Conflict Clearance Delay (In Days)	0.043	0.3	Moderate Positive
All	Number of Change Orders	UTL Conflict Clearance Delay (In Days)	0.000	0.339	Moderate Positive
All	Project Cost Variation due to Change Orders (In %)	ROW Conflict Clearance Delay (In Days)	0.009	0.382	Moderate Positive
All	Project Cost Variation due to Change Orders (In %)	RR Conflict Clearance Delay (In Days)	0.003	0.534	Moderate Positive
All	Project Cost Variation due to Change Orders (In %)	UTL Conflict Clearance Delay (In Days)	0.000	0.321	Moderate Positive

Large	Number of Change Orders	UTL Conflict Clearance Delay (In Days)	0.021	0.36	Moderate Positive
Medium	Number of Change Orders	UTL Conflict Clearance Delay (In Days)	0.015	0.338	Moderate Positive
Large	Project Cost Variation due to Change Orders (In %)	ROW Conflict Clearance Delay (In Days)	0.024	0.62	Strong Positive
Large	Project Cost Variation due to Change Orders (In %)	UTL Conflict Clearance Delay (In Days)	0.000	0.606	Strong Positive
Small	Project Cost Variation due to Change Orders (In %)	RR Conflict Clearance Delay (In Days)	0.044	0.68	Strong Positive
WNF	Number of Change Orders	UTL Conflict Clearance Delay (In Days)	0.024	0.405	Moderate Positive
MSC	Number of Change Orders	Occurrence of Conflict Clearance Delays (Y/N)	0.487	0.116	Strong Positive
MSC	Number of Change Orders	Occurrence of Conflict Clearance Delays (Y/N)	0.487	0.116	Moderate Positive
WNF	Project Cost Variation due to Change Orders (In %)	UTL Conflict Clearance Delay (In Days)	0.003	0.522	Moderate Positive
MSC	Project Cost Variation due to Change Orders (In %)	ROW Conflict Clearance Delay (In Days)	0.013	0.646	Strong Positive
MSC	Project Cost Variation due to Change Orders (In %)	UTL Conflict Clearance Delay (In Days)	0.000	0.632	Strong Positive
Houston	Number of Change Orders	UTL Conflict Clearance Delay (In Days)	0.002	0.519	Moderate Positive
Austin	Number of Change Orders	RR Conflict Clearance Delay (In Days)	0.502	0.346	Moderate Positive
Austin	Project Cost Variation due to Change Orders (In %)	RR Conflict Clearance Delay (In Days)	0.005	0.943	Strong Positive

Table 6.26 Correlation Analysis Results from Non-CMP Projects

Groups of Projects	Variable 1	Variable 2	p-value	Correlation Coefficient	Result
All	Change Order Occurrence (Y/N)	UTL Conflict Clearance Delay (In Days)	0.002	-0.184	Weak Negative

Small	Change Order Occurrence (Y/N)	UTL Conflict Clearance Delay (In Days)	0.026	-0.216	Weak Negative
Dallas	Change Order Occurrence (Y/N)	UTL Conflict Clearance Delay (In Days)	0.019	-0.427	Moderate Negative

Chapter 7. Analysis of Change Orders on CMP Projects due to Delays in Environmental Permits

7.1. Introduction

In public highway construction projects, environmental permit approval is a critical process aimed at minimizing environmental impacts throughout the project life cycle. This process can have a significant impact on project timelines, making early consideration of environmental factors crucial in project development. However, despite these efforts, delays in environmental permit approvals can sometimes lead to change orders, potentially affecting both project cost and schedule. Therefore, in order to address it, Task 7 focuses on change orders resulting from delays in environmental permit approvals within CMP projects, including the following key activities:

- Collecting and analyzing change orders caused by delays on environmental permits from the CMP projects.
- Conducting an analysis of change orders in relation to project characteristics.

7.2. Analysis Methodology

As in previous tasks, the analysis of change orders was conducted using project-specific change order summaries and individual change order descriptions extracted from SiteManager. However, unlike conflict clearance, which may be conditionally managed after project execution, environmental permit approvals are subject to stricter regulations and oversight before construction begins, requiring rigorous compliance with established guidelines.

As a result, change orders arising from delays in environmental permit approvals are significantly fewer than those caused by conflict clearance-related delays, such as right-of-way, railroad, and utility conflicts, which are explicitly listed in the CMP.

To identify change orders related to environmental permit delays, keyword-based searches were applied for initial screening. The list of keywords includes: “environmental, permit, compliance, clearance, regulation, easement, issue, impact, delay, violation, coordination, approval, ecosystem, preservation, protection, protected area, wetland, floodplain, waterbody, wildlife, habitat, fence, endangered species, vegetation, tree removal, land use, access restriction, USACE (U.S. Army Corps of Engineers), DEQC (Department of Environmental Quality and Compliance), TCEQ (Texas Commission on Environmental Quality), EPA (Environmental Protection Agency), 404 permits, water act" etc. Following this process, the research team conducted a detailed review of the project circumstances and change order summaries to determine whether the identified change orders were genuinely caused by environmental permit delays. Based on the finalized dataset, a similar comprehensive analysis was conducted to examine project-wide trends and change order characteristics.

7.3. **Analysis Results**

7.3.1. **Key Findings**

The analysis of environmental permit-related change orders identified a total of 25 change orders across six projects in three districts: Houston, Beaumont, and Fort Worth. Among these, Houston accounted for the majority, with three projects experiencing 21 out of the 25 change orders.

A particularly notable finding is that these change orders were heavily concentrated in a single project (CSJ 0188-02-036 in Houston), which recorded 10 change orders. The primary reason for this was a delayed environmental permit approval from the United States Army Corps of Engineers (USACE), which affected the entire project timeline, leading to multiple change orders. This project also experienced the largest cost impact, with $7.96 million in change order costs, resulting in an 18.8% increase in the total project cost. Additionally, this project required a time adjustment of 54 days, indicating that delays in environmental permits impacted both cost and schedule.

Following this project, the second and third-most affected projects were also in Houston (CSJ 0188-03-019 and CSJ 0188-02-029), which recorded six and five change orders, respectively. However, the cost impact was relatively lower, with increase rates of 2.7% and 2.3%, respectively.

In contrast, projects in Beaumont and Fort Worth experienced fewer change orders and significantly lower cost impacts. This suggests that while environmental permit-related change orders can be substantial, their impact varies based on project characteristics, permitting procedures, and contract management strategies.

Additionally, the analysis confirms that change orders due to environmental permit delays are less frequent than those related to ROW, utility, or railroad conflicts, which are among the primary delay sources identified in CMP projects. Moreover, the financial impact of environmental permit-related change orders appears to be significantly lower compared to other conflict-related delays, reinforcing the notion that while environmental permitting may cause delays, its overall impact on cost escalation is relatively limited.

Table 7.1 A Summary of Projects that Have Environmental Permit Related Change Orders

CSJ	District	The Number of Change Orders (count)	Original Contract Amount ($)	Change Order Amount ($)	Project Cost Change Rate due to Change Order (%)	Time Adjustment (day)
0188-02-036	Houston	10	42,315,989	7,958,682	18.8%	54
0188-03-019	Houston	6	75,955,686	2,060,921	2.7%	
0188-02-029	Houston	5	81,760,171	1,859,643	2.3%	
0177-03-096	Beaumont	2	102,144,835	793,745	0.8%	
0258-02-059	Fort Worth	1	30,387,611	4,873	0.0%	27
0028-14-091	Beaumont	1	52,363,934	-	0.0%	
Total		**25**	**84,928,227**	**12,677,864**	**3.3%**	**81**

Chapter 8. Analyses of the Impact of CMP Factors on Project Performance and Change Orders

8.1. Introduction

Building on previous research tasks, Task 8 draws from the complete dataset and key findings to identify the major factors within CMPs that affect project performance. This task includes a comprehensive statistical analysis to reveal and summarize significant CMP variables, providing insights into the direct effectiveness of CMP implementation.

Task 8 includes the following key activities:

- Identify key variables from CMP projects, as well as their project performance metrics, including cost growth, schedule growth, and change orders.
- Develop a heatmap and data visualizations to explore the relationships between CMP factors, conflict clearance, and project performance.
- Conduct statistical analyses to determine significant CMP factors influencing project performance.

8.2. Introducing Statistical Analysis Methodologies and CMP Impact Factors

8.2.1. Analysis Methodology

In order to identify key factors within CMP projects that influence project performance, a combination of statistical methods, including explainable artificial intelligence (XAI) techniques, was employed.

First, correlation heatmaps were used as an exploratory tool to visualize the strength and direction of correlations among target variables. Heatmaps provide an intuitive overview of potential clusters of highly correlated variables and help identify meaningful predictors early in the analysis process (Tolosi & Lengauer, 2011).

Moreover, Exploratory Factor Analysis (EFA) has been widely utilized in construction management research to reveal critical factors impacting project outcomes (Fabrigar & Wegener, 2012). However, given the increasing complexity and dimensionality of datasets, traditional approaches alone are often insufficient to capture the non-linear and high-dimensional relationships among project variables. To address these challenges, explainable artificial intelligence (XAI) techniques were incorporated. XAI methods aim to improve the interpretability of complex "black-box" machine learning models, providing transparency and trust in high-stakes decision-making environments such as construction planning and risk management (Arrieta et al., 2020; Gunning et al., 2021).

In this study, the Random Forest algorithm was selected due to its robust predictive performance with high-dimensional and non-linear datasets (Breiman, 2001). Random Forest models also provide built-in measures of feature importance, evaluating the contribution of each input variable based on impurity reduction. However, traditional impurity-based feature importance scores can be biased toward continuous or high-cardinality categorical variables. To enhance interpretability and mitigate these biases, SHAP (SHapley Additive exPlanations) values were additionally computed. Grounded in cooperative game theory, SHAP assigns each feature a fair contribution value to individual predictions, thereby enabling a more detailed understanding of the model's decision process (Lundberg & Lee, 2017).

A Random Forest model was developed to predict three key project performance outcomes: the number of change orders, cost growth, and schedule growth. The dataset was split into training and testing subsets to validate model performance and avoid overfitting. After model training, feature importance scores were extracted to identify the most influential CMP-related factors for each outcome. SHAP values were then computed for each model to further clarify how individual features contributed to specific predictions. SHAP summary plots were generated to visually present the distribution and magnitude of each feature's impact across all observations.

8.2.2. **Key Variables Used in Analysis**

8.2.2.1. **Variables of CMP Project and Project Performance**

A comprehensive dataset was constructed by integrating variables from previous research tasks, including CMP documentation, change order records, and project performance data. Particular attention was given to variables defined during the CMP review phase and those directly associated with documented conflict clearance data. Therefore, a total of 24 variables were used in the analyses listed in Table 8.1.

The variables used in the analysis were categorized into two main groups: CMP project-specific characteristics and project performance metrics. The CMP project-specific characteristics variables were further subdivided into four groups: Project Information, Project Cost, Project Schedule, and Conflict Information.

- Project Information: This group included basic project details determined before project execution, such as the project's district, classification, and size. These variables were previously identified as key characteristics affecting conflict clearance and change orders in earlier research tasks.

- Project Cost: This group encompassed key financial indicators, including the original contract amount (i.e., the original bid amount at project award) and the total change order amount (i.e., the cumulative cost of all change orders associated with a project). The final cost was defined as the sum of the original contract amount and the total change order amount.

- Project Schedule: Schedule-related variables were included to provide a time-based perspective on project execution. The actual duration was calculated as the number of days between the actual let date and the actual completion date. The planned duration was determined based on the actual let date and the planned completion date as recorded during the CMP review. From these two durations, the schedule delay (in days) was computed as the difference between the actual and planned durations.

- Conflict Information: This group included the number of ROW, UTL, and RR conflicts, as well as the number of conflicts by utility type. These variables, extracted directly from CMP documentation, captured the number and types of conflicts encountered in each project, along with the delays in clearing ROW, UTL, and RR.

On the other hand, the dependent variables representing project performance metrics were selected as follows:

- The number of change orders issued throughout the project lifecycle, treated as a direct measure of project disruption and scope deviation.

- Cost growth, calculated as the ratio of the final project cost, including change orders, to the original contract amount. Values greater than 1.0 indicate cost overruns.

- Schedule growth, defined as the ratio of actual duration to planned duration. Values greater than 1.0 indicate schedule delays.

All variables were collected from CMP projects implemented from the first adoption of CMPs in fiscal year 2019 until 09/30/2024, totaling 255 projects. For the factor impact analysis, only projects with a complete set of project performance metrics, that is, those with available final cost and actual completion date, were included, resulting in 58 completed projects being used in the analysis.

Table 8.1 Variables Used in CMP Impact Factor Analysis

Variable Group		Variable Name	Definition
CMP Project Characteristic	Project Information	no	Project numbering
		district	District
		proj_class	Project classification
		size	Project size group by contract amount (TEX-size, Large, Medium, Small)
	Project Cost	contract_amount	Original contract amount
		co_amount	Total change order amount
	Project Schedule	actual_duration	Actual project duration (Actual end date - Actual let date)
		planned_duration	Planned project duration (Planned end date - Actual let date)
		schedule_delay_days	Schedule delay in days
	Conflict Information	row_conflict_num	Total number of ROW conflicts
		rr_conflict_num	Total number of RR conflicts
		utl_conflict_num	Total number of UTL conflicts
		water_conflict_num	Total number of water conflicts
		sewer_conflict_num	Total number of sewer conflicts
		telecom_conflict_num	Total number of telecom conflicts
		electricity_conflict_num	Total number of electricity conflicts
		power_pole_conflict_num	Total number of power pole conflicts
		gas_conflict_num	Total number of gas conflicts
		row_delay	ROW clearance delay in days
		rr_delay	RR clearance delay in days
		utl_delay	UTL clearance delay in days
Project Performance		schedule_growth	schedule delay rate (actual_duration / planned_duration)
		cost_growth	cost growth rate (contrat_amount + co_amount / contract_amount)
		co_num	Total number of change orders

8.2.3. **Relationships Between Variables**

Before conducting the factor analysis, a correlation analysis was performed using all available numerical variables in the dataset, with the results visualized through a heatmap. This exploratory analysis provided a comprehensive overview of potential correlations between variables and served as a basis for selecting meaningful predictors for subsequent statistical analysis and modeling. Following this initial assessment, a refined heatmap was created by excluding variables with missing values and emphasizing those showing strong associations with project performance. The results of this focused correlation analysis are presented in Figure 8.1.

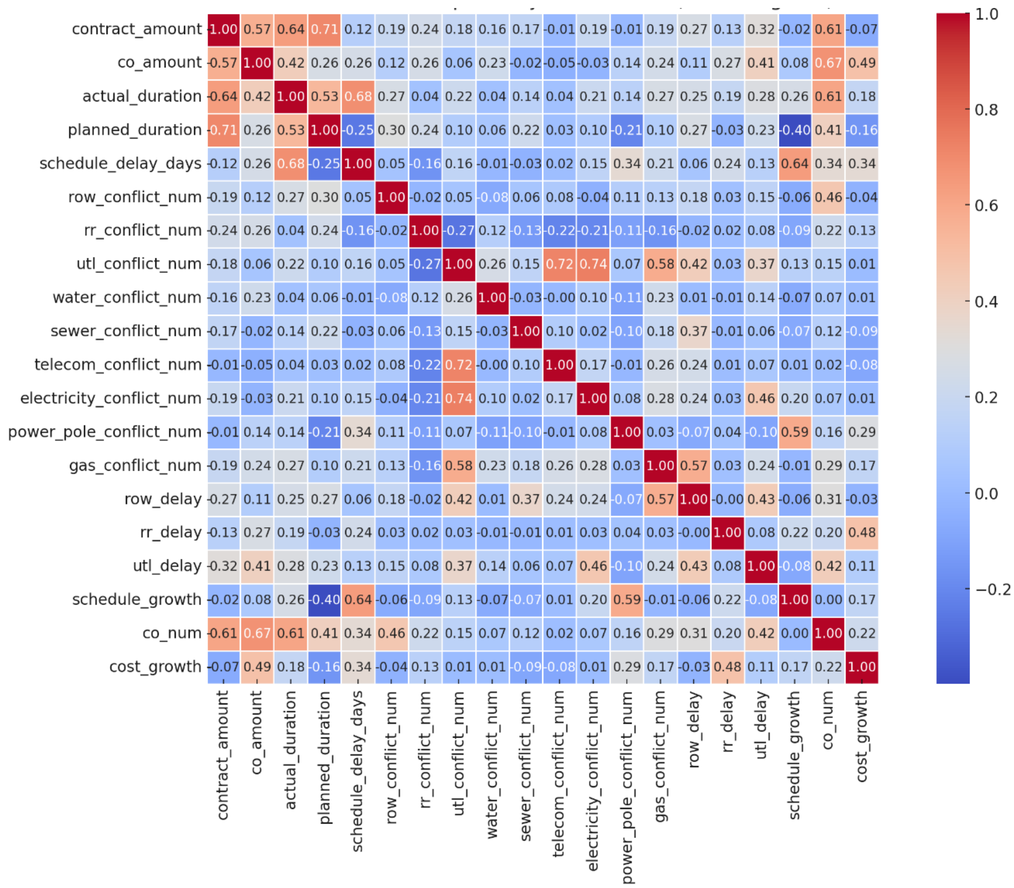


Figure 8.1 A Correlation Heatmap of Key Variables

For interpretation, variable pairs with a Pearson correlation coefficient greater than 0.4 or less than -0.4, generally considered to represent moderate to strong linear relationships, were addressed.

The analysis revealed some meaningful insights into the influence of CMP-related factors on project outcomes. The number of ROW conflicts exhibited a moderate positive correlation with the number of change orders (0.46), suggesting that challenges related to land acquisition and clearance frequently result in contractual modifications during projects. Similarly, delays in utility conflict clearance were moderately correlated with the number of change orders (0.42). Furthermore, delays associated with railroad conflict clearance showed a moderate positive correlation with cost growth (0.48), implying that extended coordination or permitting processes with railroad authorities may lead to substantial financial impacts.

Beyond these patterns, several correlations were observed among general project information variables. For example, the number of utility conflicts (utl_conflict_num) showed a strong correlation with the number of electricity conflicts (electricity_conflict_num), with a coefficient of 0.74, suggesting that electrical infrastructure issues constitute a substantial portion of utility-related conflicts. Similarly, telecom conflicts (telecom_conflict_num) were strongly correlated with utility conflicts (0.72), likely reflecting the frequent colocation of electrical and telecom systems, leading to concurrent disruptions during construction activities.

A strong relationship was also identified between the contract amount and the planned project duration (0.71), indicating that larger-scale projects tend to have both higher budgets and longer planned schedules. Also, the contract amount can generate more change orders, as shown by a strong positive correlation between the two variables (0.61). Moreover, actual duration was positively correlated with schedule delay days (0.68), implying that projects experiencing significant delays also tend to have extended overall durations.

Interestingly, a moderate negative correlation (-0.40) was found between planned duration and schedule growth. This suggests that projects with longer planned durations are, on average, less likely to experience severe schedule overruns (as a percentage of its total duration). In other words, projects allocated more generous timelines at the outset may better adhere to their schedules, possibly due to more realistic planning or reduced schedule compression.

In summary, the correlation analysis confirmed that utility, ROW, and railroad conflicts have significant relationships with key project performance indicators, including cost growth, schedule delays, and change order frequency. These findings underscore the importance of early conflict identification and mitigation strategies within the CMP process to improve overall project delivery outcomes.

8.3. The Rank of the CMP Project Factors that Affect Project Performance

8.3.1. Feature Importance of the CMP Project Factors

The feature importance derived from the Random Forest model reveals the variables that most significantly affect each dependent variable, ranking them from the most to the least influential. Three project performance outcomes - the number of change orders, cost growth, and schedule growth are individually analyzed and interpreted based on the model results.

8.3.1.1. **The Number of Change Orders**

The SHAP analysis applied to the prediction model for the number of change orders (co_num) highlights that, among all input variables, schedule_delay_days (mean absolute SHAP value: 3.083) and planned_duration (2.609) emerged as the two most dominant predictors.

In this context, the mean absolute SHAP value reflects how much each variable shifts the predicted number of change orders. For example, a SHAP value of 3.083 for schedule_delay_days means that it can either increase the predicted number of change orders by about three orders compared to the model's average prediction. Similarly, planned_duration typically shifts the prediction by about 2.6 change orders.

These time-related factors underscore the crucial role that both the extent of schedule delays and the initial project scheduling play in influencing the frequency of change orders.

The results suggest that projects that either experience significant schedule delays or are insufficiently planned at the outset are more likely to undergo frequent design modifications, scope changes, or construction adjustments, ultimately leading to a higher number of change orders.

In addition, utl_delay (1.867) and row_delay (0.971) also demonstrated strong predictive power in the model. These variables highlight that delays associated with utility relocations and right-of-way clearances are major contributors to the generation of change orders. Such delays often create unforeseen field conditions that necessitate rework, design modifications, or contractual renegotiations, all of which are formalized through change orders.

Figure 8.2 presents the mean SHAP values for all variables included in the change order prediction model, providing a visual summary of their relative contributions to model performance.

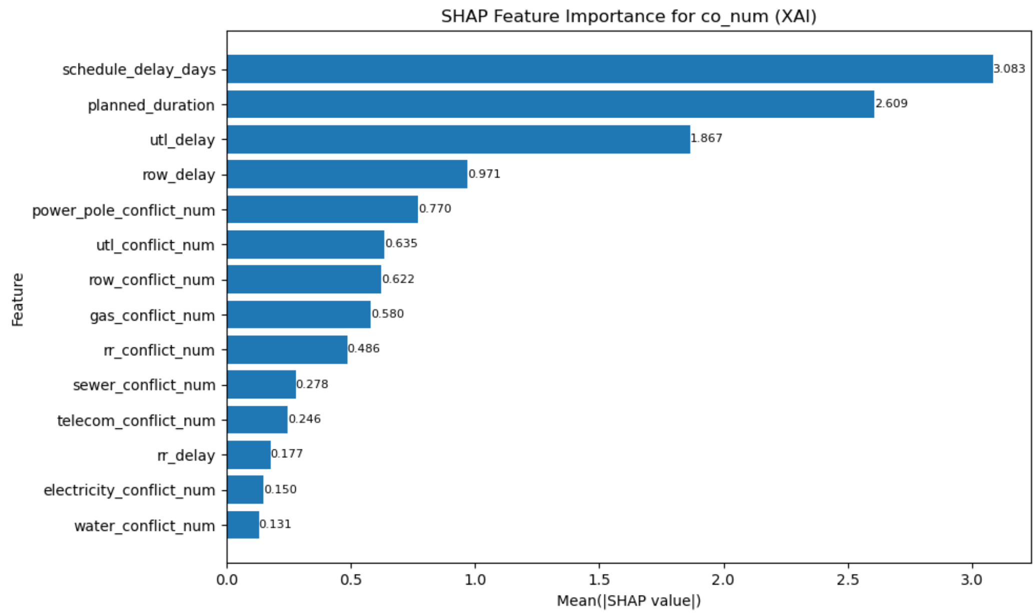


Figure 8.2 SHAP-based Feature Importance Plot – The Number of Change Orders

8.3.1.2. **Cost Growth**

The analysis of the cost growth model identified power_pole_conflict_num (0.013) and schedule_delay_days (0.013) as the two most influential predictors. This finding suggests that conflicts involving overhead utility structures, such as power poles, along with schedule delays, are strongly correlated with increased project costs. Overhead utility conflicts often require significant design revisions, additional coordination efforts, and complex construction activities, all of which contribute to cost escalation.

Furthermore, utl_delay and rr_delay were also found to have a notable influence on cost growth. Delays associated with utility relocation and railroad coordination disrupt the planned construction sequence, impact critical path activities, and frequently necessitate additional work or scope modifications. These disruptions are typically formalized through change orders, thereby driving up overall project costs. The relative importance of all input variables in predicting cost growth is visually summarized in Figure 8.3.

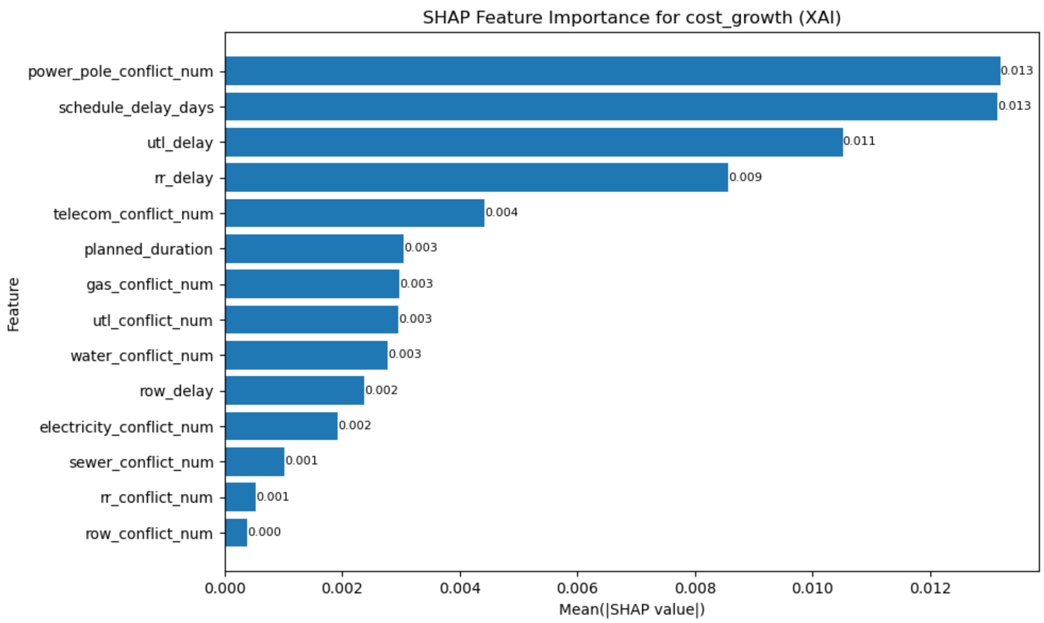


Figure 8.3 SHAP-based Feature Importance Plot – Cost Growth

8.3.1.3. **Schedule Growth**

For schedule growth prediction, the SHAP analysis revealed that power_pole_conflict_num was once again the most influential predictor, with a mean absolute SHAP value of 0.555. This consistent finding across both cost and schedule models emphasizes the critical impact of overhead utility conflicts on project delivery timelines. The mean absolute SHAP value of 0.555 indicates that the number of power pole conflicts shifts the predicted schedule growth by approximately 0.555. Given that schedule growth is defined as the ratio of actual to planned durations (actual_duration / planned_duration), and a value greater than 1.0 represents a project delay, a shift of 0.555 suggests a substantial extension of project duration. In other words, projects affected by overhead utility conflicts are expected to experience approximately 55.5% longer durations compared to the original plan.

The second and third most influential variables were contract_amount (0.196) and co_amount (0.112), respectively. On average, variations in contract amount can shift the predicted schedule growth by approximately 19.6%, indicating that projects with higher contract amounts are more likely to experience notable schedule extensions. Similarly, change order amounts are prone to greater schedule deviations by 11.2%. These results suggest that larger projects with higher initial contract values and greater cumulative change order costs tend to be more vulnerable to schedule deviations. Projects of this scale often involve a broader range of subcontractors, more complex scopes of work, and greater design variability, all of which increase the likelihood of coordination challenges and subsequent delays.

Moreover, rr_delay and utl_delay consistently ranked among the top predictors across all three models (change orders, cost growth, and schedule growth). This reinforces the conclusion that delays in conflict clearance activities, particularly those involving railroad authorities and utility providers, have a significant and persistent impact on project outcomes.

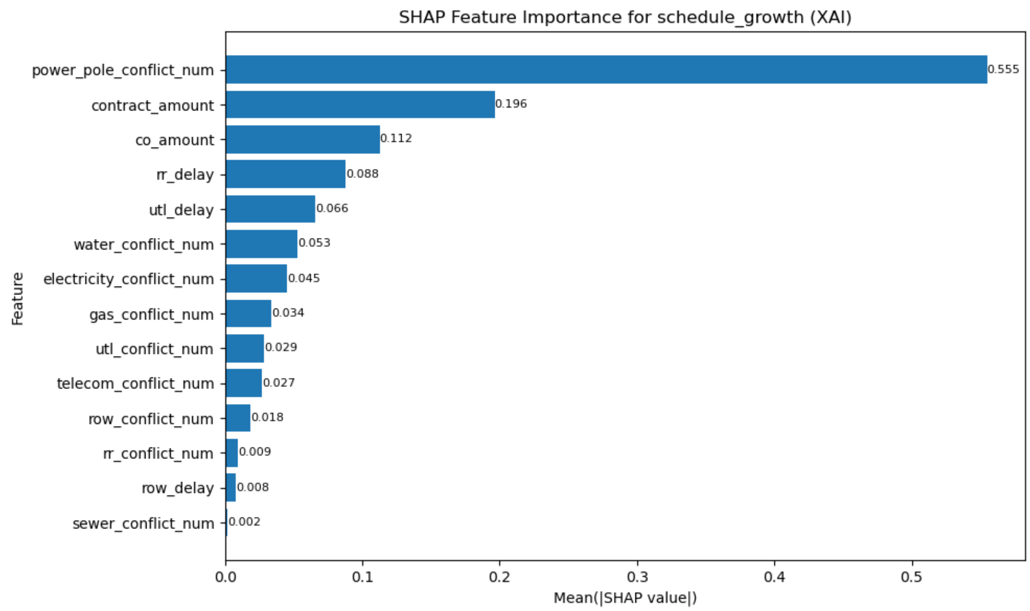


Figure 8.4 SHAP-based Feature Importance Plot - Schedule Growth

Overall, the SHAP analysis provided an interpretable and quantitative understanding of the key drivers behind project performance metrics. The findings not only validate intuitive expectations based on industry experience but also offer a data-driven ranking of critical factors. This data-driven insight supports more informed and proactive decision-making in the use of CMP, particularly in the early identification and mitigation of conflict risks during project planning and execution.

Chapter 9. Recommendations for Improving the Effectiveness of CMPs

9.1. Introduction

Drawing on findings from previous research tasks, Task 9 identifies opportunities to enhance CMP structure and implementation strategies. It provides key lessons learned from the use of CMPs and offers research-based recommendations for improving its effectiveness in three major categories: CMP format review, data-driven recommendations, and lessons learned from CMP-related change orders analysis.

9.2. Lessons Learned and Recommendations from CMP Format, Structures, and Components

9.2.1. Lessons Learned and Recommendations from Chapter 3 CMP Analysis

In Chapter 3, the research team conducted a detailed review of the CMP format, components, and structure to identify opportunities for improvement in standardization and practical application. Many of these recommendations were later incorporated into the TxDOT CMP SOP, which formalized key elements such as conflict narrative requirements, standardized templates, and detailed certifications organized by conflict type. The SOP's adoption of table-based formats and structured documentation reflects strong alignment with the earlier recommendations and provides a solid foundation for more effective CMP implementation. This section summarizes the original recommendations previously proposed by the research team, with a markup of adopted items.

Memo/Cover Page:

- Highlight the main conflicts and items deserving more attention (adopted).

Exhibit A. Certification

- Standardize Conflict Information Table (adopted).
- List each conflict individually based on its location and group by type and owner to facilitate its identification.
- Include columns in the Conflict Information Table for each distinctive conflict information, including owner, type, location, status, estimated

clearance date, buffer time, phases impacted, and effects on construction (adopted).

- Have columns for estimated clearance date, buffer time, and phases impacted, since these enhance the ability to control and manage these conflicts during construction (adopted).
- Label right-of-way parcels and utility with unique identifiers to help identify and manage each conflict, as well as to facilitate cross-reference of conflict information across different documents (adopted).

Exhibit B. Project Schedule

- Provide guidelines on how to include conflict-related activities in the project schedule to not only facilitate the preparation of initial plans but also conflict clearance control during execution (adopted).
- Include the conflict clearance schedule showing the conflict clearance activities that will occur before and after project letting in the overall project schedule.
- Have separate conflict clearance schedules with critical paths to improve conflict control to ensure they will be cleared by the estimated clearance dates.
- Add notes on the schedule to highlight major project milestones such as project letting, construction start, conflict clearance dates, and construction completion. This provides a better understanding of the key components of the project schedule.

Exhibit C. Traffic Control Plan

- Standardize the notations, identification/coloring schemes, and legends used to show conflicts in the TCP.
- Use colored notations to represent various owners, types, and components, since it is more effective to identify conflicts using visual aids.
- Mark conflict locations clearly on the TCP to pinpoint specific areas that are impacted by the conflicts.
- Match the colors of conflicts in the TCP with those in the Conflict Information Table, as well as using unique identifiers, can ensure consistency and clarity for conflict management and resolution.

9.2.2. **Lessons Learned and Recommendations from The Recent CMPs**

Building upon the foundation established in previous research tasks and the CMP SOP, this chapter proposes additional enhancements to strengthen the role of CMPs as proactive risk management tools. These recommendations are informed by recent CMPs approved after Fiscal Year 2024, and include further guidance and structural improvements to support system-level data integration, long-term conflict tracking, and enhanced project performance analysis.

- **Introduce a CMP Risk Rating System**
  The current CMP format lacks a formalized method to assess the overall risk level or completeness of a plan. Introducing a risk rating system (e.g., Low, Medium, High) based on factors such as the number of unresolved conflicts, the duration of delays, the number of agencies involved in clearance, and ROW litigation status would provide a quick reference for TxDOT Administration. This system could help prioritize CMP reviews, allocate oversight resources more effectively, and promote early identification of high-risk projects. The risk rating note is recommended to be put on the first page of certificates. Figure 9.1 shows an example of a Risk Management Matrix.

Risk Management Matrix

<table>
<tr><td>Potential Risk: ROW Acquisition Delays</td><td>Risk Consequence: Delay to project schedule</td></tr>
<tr><td>Likelihood of Risk before Mitigation: High
Likelihood of Risk after Mitigation: Low</td><td>Risk Location: IH 35 reconstruction from Holly to Woodward</td></tr>
<tr><td colspan="2">Mitigation Strategy:
1. The ROW acquisition schedule has been synchronized with the overarching CapEx-Central program and the construction sequencing of the CapEx-C Lady Bird Lake project.
2. The ROW acquisition schedule includes a minimum 4-month buffer for all parcels from the required clear for no schedule impacts.</td></tr>
</table>

Figure 9.1 Example - Risk Rating Note (CSJ 0015-13-428)

- **Specify Systemic Data Storage for Conflict Tracking and Analysis**
  Although conflict data is organized by type in the certification forms, the SOP does not define where or how this data should be stored for long-term analysis. To ensure conflicts are tracked beyond letting and utilized for broader and future project management analyses, conflict-related data should be stored systematically within a TxDOT's central database. This would enable better tracking of clearance progress over time and support

data-driven evaluation of project performance, schedule delays, and change order trends.

- **Standardize Conflict Location Documentation**
  While the CMP template provides standardized formats for conflict types, it does not clearly specify how to consistently document the location of each conflict. To improve clarity and comparability across projects, the SOP should include a standard method for noting conflict locations, such as stationing, GIS coordinates, or referencing specific plan sheets. This will facilitate accurate mapping, field verification, and tracking of conflict zones. Figures 9.2 to 9.4 show examples of conflict location documentation.

Parcel # and Owner	Location	Phase Impacted	Estimated Acquisition Date	Phase Start Critical Date*	Buffer	Utility Impacted UID #	Description of Construction
P00064602 City of Austin - Norwood Dog Park	IH 35 ML, STA 3342+34.35RT to 3345+98.38RT	Phase 1 Step 1B through Phase 4 Step 1	01/02/2025	8/16/2025	7-month buffer		Riverside construction Impacts SB SUP Bridge Construction
P00066425.001 LADY BIRD LAKE (Waller Beach) - CITY OF AUSTIN	IH35ML STA 3335+04.91RT to 3336+34.54RT	Phase 1 Step 2A	04/10/2025	12/03/2025	8-month buffer		LBL Bridge construction
P00066412 CITY OF AUSTIN	FR035NB403_1A, STA 1005+49.19LT to 1007+00.91LT	Phase 1 Step 2A	05/15/2025	12/03/2025	7-month buffer		NBFR construction Holly to LBL
P00064560.001 APTCO RIVERVIEW LLC (Berkshire Riverside Apt)	IH35ML, STA 3345+06.53LT to 3350+29.00LT	Phase 1 Step 2A	05/17/2025	12/03/2025	7-month buffer		NBFR Riverside Ramp bridge construction
P00064560.002 APTCO RIVERVIEW LLC (Berkshire Riverside Apt)	IH35ML, STA 3345+06.53LT to 3350+29.00LT	Phase 1 Step 2A	06/04/2025	12/03/2025	6-month buffer		Riverside Blvd Joint Bid Utility Construction

Figure 9.2 Example 1 - Clear Conflict Location and Description

UTILITY INFORMATION					
Utility Owner	Description / Location	Estimated Clearance Date	Phase Impacted	Phase Start Date	Effect on Construction
City of Hereford Steve Bartels 806-363-7100 steve@go-herd.com	Underground Water Line Crossing STA 698+90 – STA 699+30 Water Line E – crossing at Progressive	5/13/24	SEGMENT 1, PHASE 1	8/5/24	Conflicts with proposed roadway pavement. 3 month buffer.
City of Hereford Steve Bartels 806-363-7100 steve@go-herd.com	Underground Water Line Crossing STA 744+60 – STA 745+35 Water line C-1 Crossing at Rd GD/Whittier	5/13/24	SEGMENT 1, PHASE 1	8/5/24	Conflicts with proposed roadway pavement. 3 month buffer.
City of Hereford Steve Bartels 806-363-7100 steve@go-herd.com	Underground Water Line Crossing STA 829+49 – STA 829+81	5/13/24	SEGMENT 3, PHASE 1	9/4/24	Conflicts with proposed roadway pavement. 4 month buffer.
City of Hereford Steve Bartels 806-363-7100 steve@go-herd.com	Underground Water Line Longitudinal STA 825+50 – STA 827+90	5/13/24	SEGMENT 3, PHASE 1	9/4/24	Conflicts with proposed roadway pavement. 4 month buffer.

Figure 9.3 Example 2 - Clear Conflict Location and Description

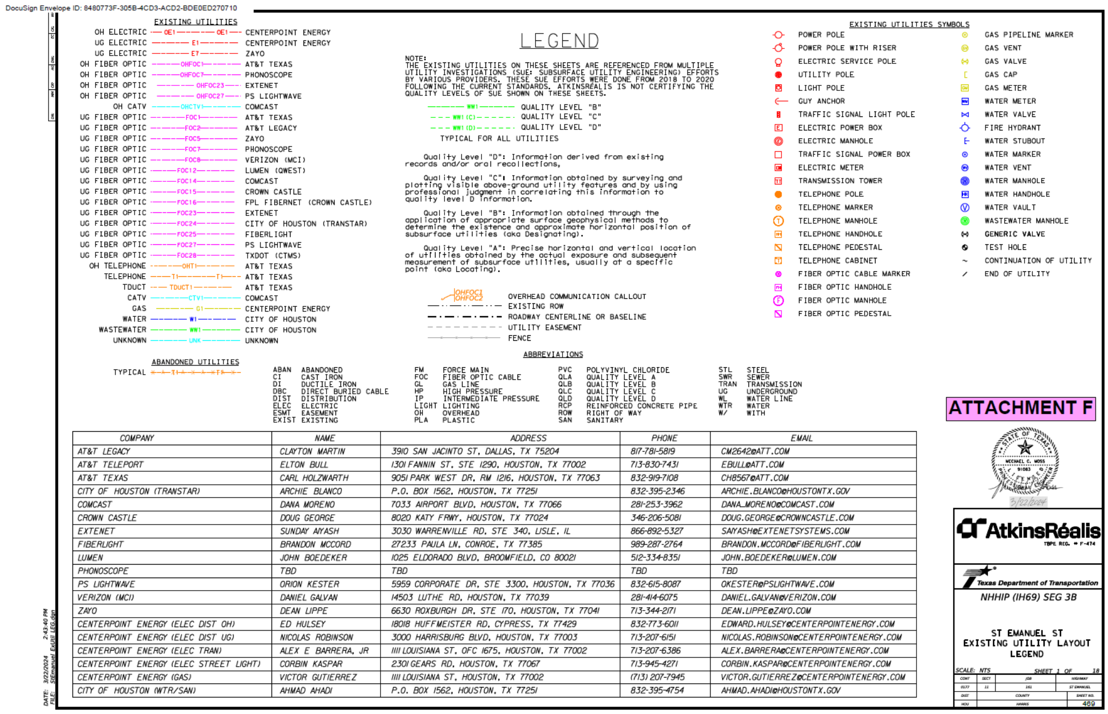
UTILITY OWNER	LOCATION FROM STATION	LOCATION TO STATION	ESTIMATED CLEARANCE DATE	TCP PHASE IMPACTED AND DATES	EFFECT ON CONSTRUCTION
AT&T Texas	Alabama St 62+38	63+04	1/30/2025	**Phase 2A** – 11/29/2025	Buffer 10 months.
CenterPoint Electric Distribution	Alabama St 62+38	63+04	12/31/2024		Buffer 11 months.
CenterPoint Gas	IH69 SBML 1059+39	116+15	8/1/2025		Buffer 4 months.
Comcast	Alabama St 62+38	63+04	1/30/2025		Buffer 10 months.
Verizon Wireless	Alabama St 62+38		12/1/2024		Buffer 12 months.

Figure 9.4 Example 3 - Unclear Conflict Location and Description

- **Document Buffer Rationale and Risk Scenarios**
  Although buffer time is defined in the SOP as the difference between the estimated clearance date and the construction phase start date, there is no requirement to explain how the buffer was determined or to account for possible delays. The SOP should require a brief justification for each buffer (e.g., historical delays from specific utilities or environmental agencies). Optionally, risk scenarios can be included to assess how project schedules would be impacted if conflicts are not cleared as expected.

- **Expand Conflict Layout Sheets to Identify Potential Risk Zones**
  The conflict layout sheet currently shows known conflicts and their estimated clearance dates but does not highlight areas that may pose a higher risk of potential unforeseen issues. Incorporating visual markups, such as color-coded high-risk zones or shading areas where unexpected conflicts historically arise (e.g., telecom corridors, railroad crossings), would help internal reviewers or contractors better anticipate and mitigate potential delays in conflict clearance and construction schedules.

- **Standardize Legends for Conflicts with Owner Information**
  To improve clarity and consistency in CMP conflict layout sheets, a standardized legend is suggested to be adopted across all districts. This legend should include defined symbols and distinctive line types for each conflict category (e.g., utility, ROW, railroad), with the display of conflict owner information. A unified legend format will help ensure that contractors, designers, and internal reviewers can easily interpret the layout regardless of the project or district. Figure 9.5 shows an example of a legend for conflicts.



COMPANY	NAME	ADDRESS	PHONE	EMAIL
AT&T LEGACY	CLAYTON MARTIN	3910 SAN JACINTO ST, DALLAS, TX 75204	817-781-5819	CM2642@ATT.COM
AT&T TELEPORT	ELTON BULL	1301 FANNIN ST, STE 1290, HOUSTON, TX 77002	713-830-7431	EBULL@ATT.COM
AT&T TEXAS	CARL HOLZWARTH	9051 PARK WEST DR, RM 1216, HOUSTON, TX 77063	832-919-7108	CH8567@ATT.COM
CITY OF HOUSTON (TRANSTAR)	ARCHIE BLANCO	P.O. BOX 1562, HOUSTON, TX 77251	832-395-2346	ARCHIE.BLANCO@HOUSTONTX.GOV
COMCAST	DANA MORENO	7033 AIRPORT BLVD, HOUSTON, TX 77066	281-253-3962	DANA_MORENO@COMCAST.COM
CROWN CASTLE	DOUG GEORGE	8020 KATY FRWY, HOUSTON, TX 77024	346-206-5081	DOUG.GEORGE@CROWNCASTLE.COM
EXTENET	SUNDAY AYASH	3030 WARRENVILLE RD, STE 340, LISLE, IL	866-892-5327	SAYASH@EXTENETSYSTEMS.COM
FIBERLIGHT	BRANDON MCCORD	27233 PAULA LN, CONROE, TX 77385	989-287-2764	BRANDON.MCCORD@FIBERLIGHT.COM
LUMEN	JOHN BOEDEKER	1025 ELDORADO BLVD, BROOMFIELD, CO 80021	512-334-8351	JOHN.BOEDEKER@LUMEN.COM
PHONOSCOPE	TBD	TBD	TBD	TBD
PS LIGHTWAVE	ORION KESTER	5959 CORPORATE DR, STE 3300, HOUSTON, TX 77036	832-615-8087	OKESTER@PSLIGHTWAVE.COM
VERIZON (MCI)	DANIEL GALVAN	14503 LUTHE RD, HOUSTON, TX 77039	281-414-6075	DANIEL.GALVAN@VERIZON.COM
ZAYO	DEAN LIPPE	6630 ROXBURGH DR, STE 170, HOUSTON, TX 77041	713-344-2171	DEAN.LIPPE@ZAYO.COM
CENTERPOINT ENERGY (ELEC DIST OH)	ED HULSEY	18018 HUFFMEISTER RD, CYPRESS, TX 77429	832-773-6011	EDWARD.HULSEY@CENTERPOINTENERGY.COM
CENTERPOINT ENERGY (ELEC DIST UG)	NICOLAS ROBINSON	3000 HARRISBURG BLVD, HOUSTON, TX 77003	713-207-6151	NICOLAS.ROBINSON@CENTERPOINTENERGY.COM
CENTERPOINT ENERGY (ELEC TRAN)	ALEX E BARRERA, JR	1111 LOUISIANA ST, OFC 1675, HOUSTON, TX 77002	713-207-6386	ALEX.BARRERA@CENTERPOINTENERGY.COM
CENTERPOINT ENERGY (ELEC STREET LIGHT)	CORBIN KASPAR	2301 GEARS RD, HOUSTON, TX 77067	713-945-4271	CORBIN.KASPAR@CENTERPOINTENERGY.COM
CENTERPOINT ENERGY (GAS)	VICTOR GUTIERREZ	1111 LOUISIANA ST, HOUSTON, TX 77002	(713) 207-7945	VICTOR.GUTIERREZ@CENTERPOINTENERGY.COM
CITY OF HOUSTON (WTR/SAN)	AHMAD AHADI	P.O. BOX 1562, HOUSTON, TX 77251	832-395-4754	AHMAD.AHADI@HOUSTONTX.GOV

Figure 9.5 Example - Legend including Existing Utilities, Symbols, and Owners' Information

- **Add Provisions for Reviewing and Documenting Unforeseen Conflicts** The SOP describes all known conflicts at the time of certification but does not address how to manage and document unforeseen conflicts, such as abandoned utilities or undocumented ROW usage after project letting. An additional provision is recommended to encourage optional notes on potential conflicts identified during construction through field verification. In addition, it would be beneficial to establish a formal protocol for how unforeseen conflicts, once discovered during construction, should be documented, tracked, and resolved to maintain accountability and data consistency. For example, Figure 9.6 includes a note within the red box. This note implies the presence of a potential conflict not explicitly shown in the drawing, highlighting the need to document such field-identified issues systematically. Including provisions for these types of notes, especially when they indicate a temporary workaround or unresolved conflict, can enhance communication among stakeholders and support better resolution tracking during construction.

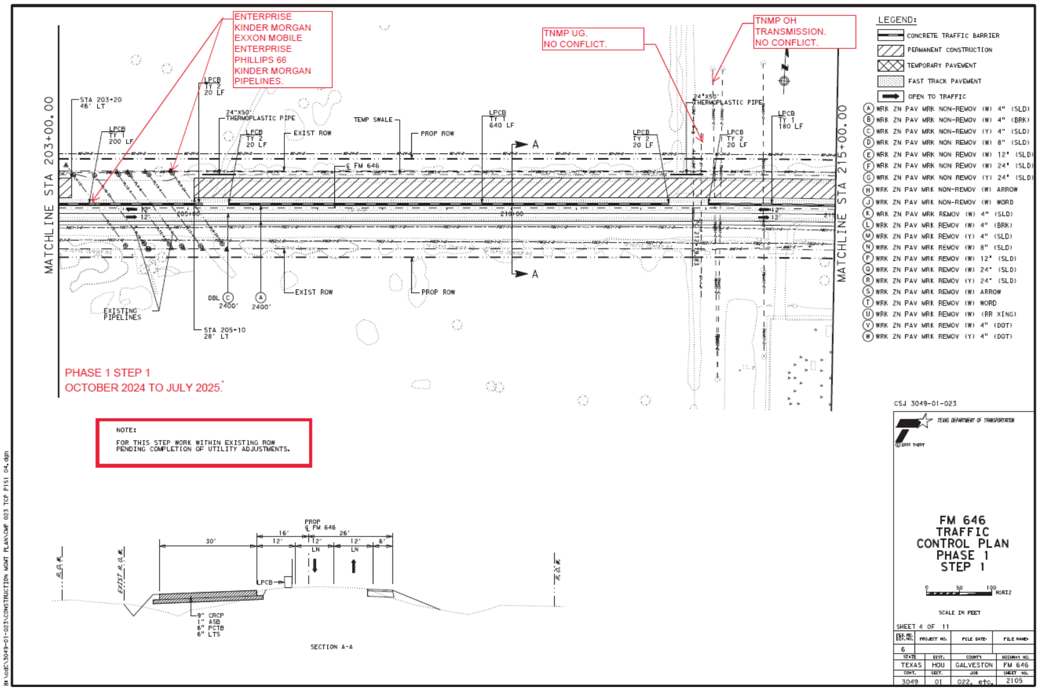


Figure 9.6 Example - Markups of Cleared Conflicts and An Additional Note

9.3. **Lessons Learned and Recommendations from Analysis Key Findings**

Based on insights from prior research and data analysis, this section outlines key findings and corresponding recommendations to enhance CMP effectiveness. These findings provide quantitative insights into CMP implementation and outcomes. Based on the key findings derived from the CMP data analysis, this section presents targeted insights and actionable recommendations aimed at improving the planning, implementation, and outcomes of CMP.

- **Utility-Related Conflicts Are the Most Critical Issue in CMP Projects**

  <u>Lessons Learned</u>

  Among all conflict types addressed in CMPs, utility-related conflicts emerge as the most common and impactful. These conflicts not only appear more frequently than right-of-way or railroad-related issues but also tend to result in a greater number of change orders, with significant implications for project cost and schedule. Within the category of utility conflicts, telecommunications systems are the most frequently involved, followed by electricity and gas/oil lines. The fact that these systems are typically buried underground adds to the difficulty of early detection and increases the likelihood of unexpected disruptions during construction.

Recommendation 1

Strengthen Utility Conflict Identification in Early Project Phases
Utility conflicts emerged as the most frequent and impactful issues, both in terms of occurrence and their contribution to change order cost and schedule delays. Despite being identified early through CMPs, many utility-related problems persist due to inaccuracies or unforeseen conditions. To address this, TxDOT should expand the use of advanced utility investigation techniques such as subsurface utility engineering (SUE) and strengthen collaboration protocols with utility owners to prevent misalignment between design assumptions and field conditions in projects with CMPs. The Federal Transit Administration provides best practices in utility relocation, emphasizing active coordination in the early stage of the project and encouraging regular meetings with stakeholders to mitigate issues in relocation proactively (FTA, 2022).

Implementing this recommendation has several clear advantages. Improved utility data accuracy can enhance the reliability of CMPs, reduce unexpected field conflicts, and support better decision-making for both design and construction teams. It also builds greater accountability among stakeholders and improves overall confidence in project delivery. However, these benefits come with trade-offs. SUE investigations may require increased early-phase budgets and longer planning timelines, and some districts may face challenges with limited access to specialized consultants or inconsistent utility owner responsiveness.

Despite these limitations, the potential of this recommendation to reduce project delays is high. Early conflict detection allows TxDOT to avoid disruptive field rework and delays stemming from late-stage utility discoveries or relocation issues. When combined with proactive coordination, this approach can significantly reduce the likelihood of change orders and support smoother project execution.

From an implementation standpoint, this strategy is highly feasible. SUE and early utility coordination practices are already established in TxDOT and other transportation agencies. TxDOT can strengthen its programs in high-risk projects, gradually incorporating utility investigation requirements and coordination checklists into standard CMP workflows. With proper funding, guidance, development, and internal training, this recommendation can be scaled effectively and deliver strong long-term value.

Recommendation 2

Coordinate Clearance Plans for Interrelated Utility Systems
The analysis revealed a strong correlation between utility systems, such as electricity and telecom, both of which frequently appear together in conflicts. These overlapping utilities can create compound disruptions when not managed jointly. Accordingly, CMP planning should promote bundled conflict resolution strategies and shared clearance timelines for interdependent systems, supported by integrated utility maps and coordinated engagement with multiple utility providers (FTA, 2022).

Implementing this recommendation offers several distinct advantages. Joint planning reduces the chance of redundant clearance efforts and miscommunication between utility providers. It also allows for better construction sequencing and minimizes the risk of rework in shared corridors. However, coordinating multiple entities can be challenging, particularly when providers operate under different schedules, priorities, or jurisdictions. This may require more time in the planning phase and a centralized coordination role within TxDOT or district offices.

From the standpoint of delay avoidance, the potential is high. Since electricity and telecom conflicts are among the most frequent and closely correlated, resolving them through integrated plans can significantly reduce clearance-related delays and cascading schedule impacts.

In terms of implementation feasibility, this approach is moderately feasible but would benefit from a phased rollout. Starting with high-density or urban corridor projects—where co-located utilities are common—TxDOT can pilot shared clearance strategies, establish utility coordination roles, and formalize expectations through CMP templates. As practices mature, statewide standardization can follow.

- **Delays in Conflict Clearance Are Closely Related to Project Schedule and Cost Impacts**

Lessons Learned

Analysis of CMP projects revealed a consistent pattern: delays in conflict clearance are strongly correlated with both the frequency of change orders and the associated cost variations. This relationship held true not only across all CMP projects but also within subgroups categorized by project size, district, and type. Larger projects, which tend to have higher contract amounts and longer planned durations, are especially prone to such impacts, as longer actual durations and greater schedule growth often accompany these delays. Furthermore, the analysis showed that projects with shorter planned durations tended to experience proportionally higher schedule growth, suggesting that overly optimistic scheduling may compound the effects of unresolved conflicts. Together, these findings highlight the critical importance of realistic scheduling and proactive conflict clearance in minimizing project delays and cost escalation.

Recommendation 1

Set Minimum Buffer Requirements Based on Historical Clearance Delays

Historical analysis indicates that unresolved utility and ROW conflicts at the time of letting are major contributors to schedule growth and change orders. As a risk mitigation strategy, TxDOT should set a minimum buffer of days for unresolved utility conflicts and ROW conflicts, which tend to experience longer clearance timelines. These values can be further refined based on conflict type, past clearance performance, and the reliability of the responsible utility or ROW owner.

The primary advantage of this approach is that it brings greater realism and predictability to project schedules by accounting for known risks in advance. Projects are less likely to encounter unplanned delays related to clearance activities, allowing for better coordination with contractors and stakeholders. However, a potential disadvantage is that buffers may artificially extend project durations in cases where clearance is resolved more quickly than anticipated. This can lead to perceived inefficiency or underutilized resources unless buffers are actively managed and calibrated.

The delay avoidance potential of this recommendation is high. Since clearance delays are among the most frequent and disruptive causes of schedule overruns, proactively allocating time for their resolution reduces the need for mid-project rescheduling and mitigates knock-on effects that impact construction sequencing and resource allocation.

The implementation of standardized buffer requirements is moderately feasible. It does not require new tools or technologies but depends on access to reliable historical data and commitment from planners to follow and justify buffer guidelines. Integration into the CMP template and scheduling review process is relatively straightforward. However, institutionalizing this recommendation would also require periodic review of buffer standards to ensure they remain aligned with current clearance performance trends.

Recommendation 2

Strengthen Management of CMP-Related Change Order Causes
To mitigate the significant financial impact of CMP-related change orders—particularly those linked to Reason Code 6—TxDOT should enhance the conflict classification system to allow for traceability by conflict type and anticipated change order reasons. A tracking mechanism that links each change order to its specific cause and financial impact would enable more accurate identification of recurring issues. Moreover, establishing a process for continuous monitoring after CMP approval, particularly focusing on utility and ROW clearance activities, would provide valuable feedback for refining CMP strategies and improving future project delivery.

There are several advantages to this approach. First, it allows for a more targeted and transparent understanding of why change orders occur, enabling smarter policy adjustments and design-phase decisions. It also reinforces accountability by requiring documentation of delays and outcomes. However, there are trade-offs. Implementing such a system may require updates to project databases, staff training on how to categorize and report change order causes consistently, and additional effort at the project level to maintain proper documentation.

In terms of its potential to prevent future delays, this recommendation is moderately high. While it doesn't directly eliminate delay risks, it significantly improves TxDOT's ability to learn from past issues and prevent similar problems in future projects. Over time, this can reduce both the frequency and cost of CMP-related change orders.

The feasibility of this recommendation is moderate. It builds on existing tools but would require system-level adjustments and staff adoption to be fully effective. A phased implementation—beginning with high-volume or high-risk districts—would allow TxDOT to pilot the approach, refine it, and scale it statewide based on results.

9.4. Lessons Learned and Recommendations from CMP-related Change Order

9.4.1. Lessons Learned from CMP-related Change Orders and Their Underlying Causes

In previous research tasks, change orders from CMP projects were comprehensively reviewed and analyzed. From the dataset, CMP-related change orders were classified and examined in detail to understand their unique characteristics and quantitative impact on projects. Revisiting CMP-related change orders and their project conditions, characteristics, and surrounding external circumstances, this section provides findings and recommendations aimed at minimizing CMP-related change orders in future projects.

Although most CMP-related change orders were linked to additional work required to resolve conflicts, often leading to cost overruns and schedule delays, their root causes can be further categorized into specific underlying factors. Table 9.1 provides a summary of the major categories of CMP-related change orders along with detailed descriptions of each cause.

Table 9.1 Classification of Root Causes of CMP-related Change Orders

CMP-related Change Order Causes	Description
Unforeseen Conflicts Discovered During Construction	Unanticipated conflicts were encountered during construction, requiring additional detection methods such as potholing and clearance scope, resulting in increased costs and schedule adjustments.
Additional Conflicts from Pre-identified Items	Existing utilities not initially identified as conflicts during the CMP review were later found to interfere with construction, indicating gaps in early investigation and field conditions.
Delayed Clearance by ROW or Utility Owners	Although conflicts were expected to clear within 90 days based on prior agreements, delays occurred due to owner-side issues such as slow ROW acquisition or utility relocation. Clearance sequencing issues between owners also caused change orders.

Site Conditions Not Accounted for in CMP	Site conditions such as existing trees, fencing, or other obstructions during conflict clearance work were not considered in CMPs, resulting in additional work effort by contractors.
Scope Changes Requiring Additional Clearance	Changes in project scope or additional work items (e.g., new stub-outs from water pipes, expansion of pavement area) led to the need for relocating previously non-conflicting utilities or performing a redesign.
Missing Information during CMP Approval	During the CMP review and approval phase, certain critical items are often overlooked or insufficiently reviewed, which may later contribute to change orders during construction.
Delays in Acquiring ROW or Railroad Agreement Preventing Utility Relocation	Due to delays in ROW acquisition or railroad agreement, utility relocation was unable to begin on time and meet the relocation deadline.

9.4.2. **Recommendations by Change Order Lessons Learned**

Following the implementation of the CMPs, a total of 113 change orders were identified as related to CMP projects. These change orders have been classified according to their root causes in Table 9.1, and key lessons learned with corresponding recommendations for improving the management of CMP-related change are presented below.

- **Strengthening Conflict Identification and Field Condition Assessment**

  Related Causes

  - Unforeseen Conflicts Discovered During Construction
  - Additional Conflicts from Pre-identified Items
  - Site Conditions Not Accounted for in CMP

  Recommendation

In the early phases of CMP development, it is critical to establish a systematic field investigation process to identify potential conflicts before letting. This includes expanding the use of SUE methods such as potholing, ground-penetrating radar (GPR), or utility mapping to detect unmarked or mislocated utility lines and physical site conditions. Visual inspection alone is often insufficient, especially in dense utility corridors or in areas with limited as-built documentation.

The investigation sometimes should extend beyond known utility lines to identify other physical obstructions such as retaining walls, mature trees, drainage structures, and fences that may interfere with conflict clearance activities. The findings from this investigation should be thoroughly documented in the Conflict Layout and Certifications sections of the CMP, or alternatively included as a separate note with a narrative explanation, to support realistic construction sequencing and buffer planning.

- **Enhancing Clearance Schedule Management Considering Interrelations Between Conflicts**

Related Causes

- Delayed Clearance by ROW or Utility Owners
- Delays in Acquiring ROW or Railroad Agreement Preventing Utility Relocation

Recommendation

As highlighted in previous data-driven recommendations, CMPs should include not only estimated clearance dates but also clearly identify the responsible parties (e.g., utility owners, ROW agents), the sequence in which clearances must occur, and the overall coordination plan. However, in practice, CMPs lack sufficient detail regarding the interdependencies among conflicting elements, especially in cases involving potential interrelation between multiple third parties such as utility companies, railroad agencies, and ROW owners. To address this issue, CMPs should clearly specify which entity is accountable for each clearance activity, outline the required sequence of actions, and incorporate contingency measures in case of potential delays, if necessary.

For example, when utility relocation is contingent upon prior ROW acquisition or the execution of a railroad agreement, this dependency chain should be explicitly documented in both the Certifications and the

Construction Time Determination (CTD) schedule. In such cases, CMPs should also include realistic buffer durations and define conditional work zones that allow construction to proceed in unaffected areas while access to high-risk or unresolved conflict zones remains restricted.

- **Establishing a System for Managing Scope Change Impacts**

  Related Causes

  - Scope Changes Requiring Additional Clearance

  Recommendation

  When scope changes or additional work items are introduced after CMP approval, such as pavement widening, new utility tie-ins, or design revisions, the CMP should be revisited and updated accordingly. A formal mechanism should be established to reassess potential impacts on utility relocation and ROW acquisition, ensuring that clearance assumptions remain valid. These updates should include a thorough evaluation of whether new conflicts have emerged, whether existing clearance dates and buffer times are still appropriate, and how the proposed changes affect the overall project schedule and cost. Updated versions of the CMP should be documented through revised certifications, adjusted CTD schedules, and amended conflict layouts if necessary. This process would reinforce transparency, maintain alignment with real project conditions, and improve communication among stakeholders during execution.

- **Strengthening CMP Approval Review Process**

  Related Causes

  - Missing Information during CMP Approval

  Recommendation

  To reduce the risk of omissions or inaccuracies during the CMP approval phase, a more structured and comprehensive review process should be adopted. This includes implementing a standardized checklist that ensures all required items, such as conflict descriptions, clearance timelines, buffer durations, and phase start dates, are thoroughly reviewed and confirmed. In addition, a peer review process involving an independent reviewer can provide an extra layer of quality assurance, helping to identify commonly overlooked details such as missing utility owners, vague clearance sequencing, or assumptions left undocumented. Strengthening this review process would ensure that CMPs are more accurate, complete, and reflective of actual field conditions, ultimately reducing unexpected issues during construction.

9.5. Review of CMP SOP with Supplementary Recommendations

The TxDOT Design Division released the CMP Standard Operating Procedure in 2025 to define the preparation, review, and approval processes for CMPs as part of statewide project delivery (TxDOT, 2025). The SOP outlines the required documentation and its definitions, including the Cover Memo, Certificates, Construction Time Determination (CTD), TCP Phase Narrative, and Conflict Layout, which are reviewed as part of the final PS&E submission process.

Each component is described in detail, including what content is required and how each document should be formatted. Notably, the Certificates section provides clear formatting templates and specific data requirements for different types of conflicts, such as utility, ROW, and railroad. These forms capture critical clearance information and are designed to standardize documentation across districts.

One of the key strengths of the SOP is the standardization of certification formats across conflict types, which promotes documentation consistency and ensures that essential information, such as clearance dates, buffer times, and construction impacts, is thoroughly captured. The SOP also includes guidance on buffer calculation and sets approval thresholds based on the expected timing of conflict resolution.

However, there are certain areas to be improved; most notably, the management of quantitative data, the systematic tracking of clearance progress, and the handling of changes that may arise during project execution after CMP approval. These gaps highlight the need for additional recommendations that address post-approval conflict management, data integration, and real-time tracking to support more comprehensive CMP implementation across the project lifecycle. Building on this review of the CMP SOP, the recommendations below outlines additional items aimed at enhancing the SOP's practicality and overall effectiveness. While the SOP provides a strong procedural framework for CMP preparation and approval, several improvements can be made to support better conflict tracking, data integration, and post-approval management.

- **Define Systemic Data Storage and Management Protocols**

The SOP outlines how CMPs are to be developed and approved, but it lacks specific instructions on how signed CMPs and associated conflict information (e.g., conflict types, clearance dates, buffer times, owners) should be stored or integrated into TxDOT's centralized project systems. To ensure traceability and transparency, it is recommended that the SOP reference specific systems or platforms (e.g., SiteManager) for storing CMP documents and associated data. This would support post-approval conflict tracking and ensure that clearance progress is visible to all stakeholders throughout the project lifecycle, including closeout.

Additionally, while the SOP notes that the data is managed and monitored through the Tableau dashboard**,** it lacks a defined feedback loop for using this data to improve future CMP procedures. Establishing a structured feedback mechanism—tied to both systemized data and project outcomes—would help bridge the gap between policy and on-the-ground performance, enabling continuous improvement in CMP development and implementation.

A key advantage of this recommendation is that it promotes accountability, accessibility, and seamless coordination among districts, engineers, and contractors. However, the disadvantages include the initial resource requirements for configuration, user training, and possible resistance from teams accustomed to decentralized or manual processes.

This recommendation also demonstrates strong potential to avoid project delays, as centralized conflict tracking enables teams to make real-time decisions based on accurate information. It minimizes the risk of last-minute surprises related to unresolved ROW, utility, or railroad issues, allowing for more efficient scheduling and reduced downtime during construction.

In terms of implementation impact and feasibility, the use of existing systems already in place across TxDOT makes this approach practical and scalable. With modest updates to policy, training, and internal procedures, this improvement could be rolled out efficiently across districts. The long-term benefits—such as improved transparency and process consistency—are likely to outweigh the short-term investment required for adoption.

- **Clarify Post-Approval CMP Management**

The current CMP SOP provides detailed instructions for the development and approval of CMPs but lacks direction on how they should be managed after approval. In practice, during the construction phase, it is common for issues such as delayed clearances, the emergence of unforeseen conflicts, or changes in the status of previously identified conflicts to arise. However, the SOP does not clarify whether these changes require formal modifications to the CMP or how such changes should be recorded or communicated. This lack of post-approval management guidance creates uncertainty for project teams and limits TxDOT's ability to maintain up-to-date oversight.

To address these gaps, the SOP should include guidance on conditional approvals, procedures for CMP updates, and version tracking. These measures would allow districts to formally document and communicate changes in conflict status without initiating a full rewrite of the CMP. Additionally, while the SOP mentions the importance of actual clearance dates, it does not explicitly require their submission for all listed conflicts. Reinforcing this requirement would strengthen accountability and provide TxDOT with higher-quality data for performance monitoring and process improvement over time.

The advantages of this recommendation include improved adaptability to real-world conditions and more structured conflict documentation throughout the construction phase. It enhances transparency by ensuring that changes, especially those affecting project risk, are formally captured and reviewed. The disadvantages, however, may include added administrative burden, particularly if update procedures are not streamlined or if field staff require training on version control protocols.

In terms of its potential to reduce project delays, this improvement is highly relevant. Allowing for timely updates and better visibility into ongoing conflict status helps project managers adjust phasing and resources as needed. This can minimize delays stemming from miscommunication or overlooked risks and ensure that decisions are based on current and accurate project conditions.

From an implementation and feasibility standpoint, these additions are moderately complex but achievable. They do not require new software systems but rather expanded procedural guidance and documentation standards. Most TxDOT districts already track evolving project conditions informally; formalizing these practices within the SOP would support consistency and better cross-project learning.

Chapter 10. Conclusion

The research project assessed the effectiveness of CMPs, which were first implemented in Fiscal Year 2019, with a specific focus on their role in managing conflict clearance. Key performance indicators examined included change order frequency, cost variation, and schedule delays. The research employed a multi-level analytical approach, examining over 9,800 highway projects let between 2010 and 2024, including a targeted analysis of 255 CMP projects initiated after its first use. The key findings from research tasks are summarized below:

- **Application to Larger Projects**: CMPs were primarily utilized for larger and more complex highway projects, which are typically characterized by multiple conflicts. As a result, CMP projects had significantly higher average contract values and longer durations than non-CMP projects. The average contract value for CMP projects was approximately $70 million, compared to just $6 million for non-CMP projects.

- **Project Cost Variation Due to Change Orders Didn't Increase After the Use of CMPs**: Completed projects let after CMP implementation (September 2018–September 2024) experienced lower cost variation due to change orders when compared to pre-CMP completed projects (January 2010–August 2018).

- **Effectiveness of CMPs**: Statistical tests confirmed that CMPs didn't significantly impact change orders**,** especially for medium- and small-scale projects, which benefitted most from the conflict resolution procedures provided by the CMP framework.

- **Importance of Managing Utility Conflicts**: Among the three major conflict categories—utility relocation (UTL), right-of-way acquisition (ROW), and railroad coordination (RR)—utility conflicts emerged as the most prevalent and impactful**.** They accounted for the highest number of conflict cases, the largest cumulative change order amounts, and the greatest frequency of schedule adjustments.

- **Relative Impact of CMP-Related Change Orders**: Although CMP-related change orders represented just 3.82% of total change order occurrences on CMP projects, they contributed to 13.5% of the total change order costs**,** indicating that CMP-related change orders in CMP projects tend to carry a greater financial impact per instance**.**

- **Correlations Between Conflict Clearance Delay and Change Orders in CMP Projects**: CMP projects exhibited a few significant correlations between conflict clearance delays and change orders— in terms of change order frequency and cost variation due to change orders. These relationships were particularly strong for utility and ROW-related conflict clearance delays**,** highlighting the importance of early and proactive conflict resolution in these types.

- **No Significant Correlations Between Conflict Clearance Delays and Change Orders in Non-CMP Projects**: By contrast, non-CMP projects with conflicts cleared more than 90 days after the letting date showed no statistically significant correlation between their conflict clearance delays and change orders.

- **Environmental Permit Issues**: While environmental permit-related change orders were rare, the analysis found that they can have substantial localized impacts when they do occur, further emphasizing the value of early coordination and regulatory compliance.

- **Impact of ROW and RR Conflicts**: Exploratory factor and correlation analyses revealed moderate correlations between ROW conflicts and both schedule delays ($r = 0.42$) and change order counts ($r = 0.46$), reflecting the procedural complexity and coordination challenges often associated with such conflicts. Similarly, positive correlation between delays in railroad conflict clearance and the cost growth due to change order ($r = 0.48$), highlight that delays in railroad coordination directly contribute to project cost overruns.

The findings from this research confirm that CMPs serve as an effective and valuable strategic tool for managing conflict clearance. CMPs have been useful for streamlining the delivery of larger and more complex TxDOT projects. The use of CMPs did not increase the relative number and amount of change orders in TxDOT projects. Statistically significant associations between CMP use and key project performance metrics, demonstrated the benefits of proactive conflict management.

Based on the comprehensive data analysis and empirical findings, this study also presents a set of recommendations aimed at enhancing the content, format, implementation, and operational effectiveness of CMPs in future TxDOT projects. These improvements are intended to strengthen the CMP's role as a proactive conflict management tool, enabling more effective identification, control, and resolution of conflicts throughout the project lifecycle.

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Appendices

Appendix A. CMP Conflict and Clearance Data from Active CMP Projects

No	District	Conflicts																Buffer Time Shown in the CMP (Month)	Actual – Expected Clearance Date		
		Total Count	ROW (Right-of-way Acquisition)			RR (Railroad Agreement)			UTL (Utility Relocation)												
			ROW Total Conflict Count	Expected ROW Clearance Date	Actual ROW Clearance Date	RR Total Conflict Count	Expected RR Clearance Date	Actual RR Clearance Date	UTL Total Conflict Count	UTL Conflict Count by Type						Expected UTL Clearance Date	Actual UTL Clearance Date				
										Water	Sewer	Telecom	Electric	Power Pole	Gas/ Oil				ROW	RR	UTL
1	Houston	39				1			38	12		13	12	1		12/31/2018	11/1/2019				1
2	Beaumont	26	21	11/30/2018	1/21/2020				5			2	2	1		1/31/2020	11/10/2020		417		2
3	El Paso	107	5	4/30/2019	7/31/2022				12	27		22	46	7		4/29/2019	5/23/2024		1188		3
4	Houston	13	11	1/15/2020	2/15/2020				2				1		1	12/31/2019	1/22/2021		31		4
5	Lufkin	42							42			29	12		1	9/30/2019	1/30/2020				5
6	Lufkin	53	2	2/19/2021	6/19/2019				51			18	15	18		3/31/2020	2/19/2021		-611		6
7	San Antonio	3							3			1	1	1		12/27/2020	3/9/2020				7
8	Houston	68	13	10/15/2019	8/17/2021		7/1/2020	11/16/2020	55			3	16	9		12/15/2019	7/15/2021		672	138	8
9	Houston	9							9				9			5/1/2020	5/1/2020				9
10	Houston	65	1	8/30/2019	4/21/2020				55			21	32	2		6/30/2020	11/23/2021		235		10
11	Houston	85	31	12/30/2019	4/30/2021				54			18	17	19		4/1/2020	6/30/2022		487		11
12	Houston	17	7	12/31/2019	12/31/2019				1			2	4	4		2/7/2020	6/11/2021				12
13	Houston	27	15	12/31/2019	3/7/2021				12			1	7	4		4/15/2020	7/22/2022		432		13
14	Houston	90	67	9/30/2019	6/1/2020				23				1		22	1/31/2020	1/31/2020		245		14
15	Corpus Christi	38	1	12/31/2019	8/5/2019				37			7	14	16		8/30/2020	8/5/2019		-148		15
16	Yoakum	16	2	1/31/2020	4/8/2020				14			4	1			10/1/2020	11/24/2020		68		16
17	Paris	85							85	12		21	36	16		5/31/2020	5/1/2020				17
18	Dallas	9							9			1	7	1		2/21/2020	8/31/2020				18
19	Lufkin	54							54	13		8	24	9		12/31/2020	6/30/2021				19
20	Yoakum	11				1	5/31/2020	1/13/2020	1			1	7	2		8/31/2020	5/31/2021			-139	20
21	Amarillo	14							14			4	1			11/30/2020	11/30/2020				21
22	Dallas	62				1			61			8	39	14		8/31/2020	10/27/2020				22
23	Lubbock	17							17			14	3			9/30/2021	5/10/2021				23
24	Corpus Christi	24							24	5			16	3		11/30/2020	6/25/2021				24
25	Atlanta	1				1	8/31/2020	6/10/2020												-82	25
26	Laredo	15				2	5/1/2021	8/13/2021	13			4	9			11/2/2022	5/8/2023			14	26
27	Fort Worth	4							4			1	2	1		11/1/2023	2/16/2024				27

No	District	Conflicts: Total Count	ROW (Right-of-way Acquisition): ROW Total Conflict Count	ROW: Expected ROW Clearance Date	ROW: Actual ROW Clearance Date	RR (Railroad Agreement): RR Total Conflict Count	RR: Expected RR Clearance Date	RR: Actual RR Clearance Date	UTL (Utility Relocation): UTL Total Conflict Count	UTL Conflict Count by Type: Water	UTL Conflict Count by Type: Sewer	UTL Conflict Count by Type: Telecom	UTL Conflict Count by Type: Electric	UTL Conflict Count by Type: Power Pole	UTL Conflict Count by Type: Gas/Oil	Expected UTL Clearance Date	Actual UTL Clearance Date	Buffer Time Shown in the CMP (Month)	Actual – Expected Clearance Date: ROW	Actual – Expected Clearance Date: RR	Actual – Expected Clearance Date: UTL
28	Houston	275	2	8/1/2020	2/1/2020				273	2	6	1	114	4	128	7/1/2021	12/1/2023		-182		28
29	Beaumont	3							3	1			2			6/30/2021	8/31/2021				29
30	Fort Worth	14					2/1/2021	5/26/2021	14	5		2	5	2		8/15/2021	12/31/2021			114	30
31	Fort Worth	15							15	4			11			12/31/2020	12/31/2020				31
32	Fort Worth	11							11	11						12/29/2020	6/14/2021	2			32
33	Houston	4	3	3/31/2021	3/31/2021				1				1			7/1/2022	12/1/2022				33
34	Houston	113	7	12/31/2020	4/15/2021				16			7	73	26		5/31/2021	5/30/2021		15		34
35	El Paso	1							1			1				11/30/2020	11/7/2022				35
36	San Antonio	20		10/1/2022	6/30/2022				2	2		2	15	1		12/31/2021	8/16/2023		-93		36
37	Bryan	29							29	5		11	8	5		3/1/2021	11/9/2021				37
38	Pharr	2				2	11/15/2020	10/15/2021												334	38
39	Houston	33	6	12/31/2020	10/18/2021		10/30/2020	2/25/2021	27	1		5	2	1		7/31/2021	11/14/2023		291	118	39
40	Tyler	9							9	1		3	1	4		4/30/2021	12/3/2021				40
41	Houston	13				1			12				12			7/31/2021	1/31/2020				41
42	Austin	95							95			24	71			8/6/2021	1/7/2022				42
43	Fort Worth	5							5	1		1	2	1		7/31/2021	4/1/2021				43
44	Houston	46	3	10/31/2020	10/31/2020				43	12			14	16	1	12/22/2021	3/9/2023				44
45	Bryan	23	4	9/20/2021	10/20/2021				19			1	9	8	1	10/2/2020	2/10/2021		3		45
46	Dallas	6							6			6				1/29/2021	5/1/2021				46
47	Fort Worth	35	27	12/31/2021	5/31/2021	1	3/21/2021	12/27/2021	7			2	1	4		10/17/2022	12/31/2021		-214	281	47
48	Odessa	3							3	1		2				3/8/2021	2/26/2021				48
49	Fort Worth	50							5	1			48	1		2/1/2021	7/31/2021	16			49
50	Bryan	6	1	11/30/2020	10/5/2020	1	11/30/2020	9/2/2021	4				3	1		7/12/2021	1/31/2021		-56	276	50
51	Laredo	19	1	12/1/2020	11/30/2020				18	3			14	1		3/1/2021	2/28/2021	9	-1		51
52	San Angelo	23							23				2	3		10/31/2022	8/14/2022				52
53	Pharr	10							1			8	2			9/21/2021	5/24/2021				53
54	San Angelo	5							5			1		4		10/2/2021		6.5			54
55	San Antonio	6							6				6			7/9/2021	7/16/2021	13			55
56	Wichita Falls	86	8	6/30/2021	9/24/2021				78			12	56	4	6	1/26/2022	8/19/2022		86		56

No	District	Conflicts: Total Count	ROW (Right-of-way Acquisition): ROW Total Conflict Count	ROW: Expected ROW Clearance Date	ROW: Actual ROW Clearance Date	RR (Railroad Agreement): RR Total Conflict Count	RR: Expected RR Clearance Date	RR: Actual RR Clearance Date	UTL (Utility Relocation): UTL Total Conflict Count	UTL Conflict Count by Type: Water	Sewer	Telecom	Electric	Power Pole	Gas/ Oil	Expected UTL Clearance Date	Actual UTL Clearance Date	Buffer Time Shown in the CMP (Month)	Actual – Expected Clearance Date: ROW	RR	UTL
57	Dallas	18							18	7		3	7	1		7/31/2022	6/28/2022				57
58	San Antonio	22							22			4	14	4		9/30/2021	5/9/2023	19			58
59	San Antonio	4							4			4				12/12/2022					59
60	San Antonio	29				1			28			5	22	1		8/20/2024		34			60
61	Austin	14							14			2	1	2		10/1/2021	7/6/2022	35			61
62	San Antonio	15					6/30/2023	3/2/2023	15			4	11			10/20/2022	11/30/2023	36		-12	62
63	San Antonio	3							3				3			4/2/2022					63
64	San Antonio	8							8	2			3	2	1	1/31/2022		29			64
65	Lubbock	60	2	9/30/2021	6/2/2022				58	43		3	1	2		8/24/2021	10/28/2021		245		65
66	Wichita Falls	111	4	10/31/2021	10/14/2021				17			47	52	8		10/31/2021	3/16/2022	7	-17		66
67	Bryan	14	8	11/15/2021	3/29/2022				6	1		1	4			6/15/2022	5/29/2024	23	134		67
68	Dallas	22							22	8		3	11			1/6/2022	12/8/2021	5			68
69	Fort Worth	5	3	3/31/2022	6/8/2022				2	1			1			6/1/2022	9/1/2022	3	69		69
70	Houston	31	11	12/31/2021	7/23/2024				2			3	5	12		8/30/2022		21	935		70
71	Houston	41	15	7/1/2022	11/3/2022				26	2		5	16	3		5/30/2022			125		71
72	Houston	71							71			37	32	2		6/30/2022	10/21/2022				72
73	Beaumont	9							9			1	8			1/15/2022	9/30/2021				73
74	Beaumont	1							1				1			12/31/2021	7/31/2021				74
75	Waco	9				3	10/1/2021	8/12/2021	6	1		2	1	1	1	1/30/2022	9/30/2022			-5	75
76	Houston	14	2	9/1/2021	12/21/2021	1	7/31/2022	12/20/2023	11			2	6	3		6/30/2022		7	111	57	76
77	Houston	169	18	11/30/2021	2/15/2024				151	19		18	68	38	8	3/15/2022		18	87		77
78	Waco	36							36	8		17	11			11/26/2021	1/1/2022	12			78
79	Paris	13							13	4		5	4			1/31/2022	7/1/2022	7			79
80	Beaumont	9							9				9			5/2/2022	5/9/2022	8			80
81	Bryan	18							18	2		1	8	7		6/2/2025		9			81
82	Austin	6							6	6						1/31/2022	9/29/2022				82
83	San Antonio	14		9/1/2022	6/30/2022				14	4		2	8			5/19/2022	4/21/2023	3	-63		83
84	Austin	7	4	5/31/2022	6/22/2022				3				3			2/28/2022	7/13/2023	28	22		84

No	District	Conflicts																Buffer Time Shown in the CMP (Month)	Actual – Expected Clearance Date		
		Total Count	ROW (Right-of-way Acquisition)			RR (Railroad Agreement)			UTL (Utility Relocation)												
			ROW Total Conflict Count	Expected ROW Clearance Date	Actual ROW Clearance Date	RR Total Conflict Count	Expected RR Clearance Date	Actual RR Clearance Date	UTL Total Conflict Count	UTL Conflict Count by Type						Expected UTL Clearance Date	Actual UTL Clearance Date				
										Water	Sewer	Telecom	Electric	Power Pole	Gas/Oil				ROW	RR	UTL
85	Pharr	29							29	1		24	4			9/30/2022	2/1/2023	15.5			85
86	Lufkin	1							1			1				6/20/2022	8/6/2022				86
87	El Paso	10							1	3		1	3	3		5/31/2022	3/21/2024	53			87
88	Corpus Christi	21							21			1	2			7/29/2022	2/16/2023	9			88
89	Beaumont	11				1	6/1/2022	1/6/2023	1			2	4	4		8/9/2022	12/31/2022	54		219	89
90	Houston	22							22	4	8		9	1		12/31/2022	7/15/2023				90
91	Dallas	62				1	4/29/2022	2/24/2022	61	23	12	8	18			7/31/2022	9/30/2022	9		-64	91
92	Houston	5							5	1		1	3			11/17/2022	4/30/2023				92
93	El Paso	8							8	3			3	2		12/21/2023					93
94	Austin	191	112	11/1/2024					79			12	7	6		8/31/2026		26			94
95	Lufkin	40					1/2/2023	9/9/2022	4	1	3	12	2	4		11/1/2022	8/31/2023			-115	95
96	Houston	1							1				1			9/1/2022	12/27/2022	3			96
97	Dallas	2					7/27/2022	10/3/2022	2	2						6/30/2022	8/19/2024			68	97
98	San Antonio	24							24			6	18			11/10/2023	1/18/2024				98
99	Bryan	11	5	2/1/2023					6				6			1/1/2023		22			99
100	Lufkin	6							6			1	3	2		10/31/2022	10/17/2022				100
101	Dallas	4							4	1			1	2		1/5/2023	3/16/2023	5			101
102	Tyler	3							3	1			2			2/1/2023	4/24/2024	3			102
103	Bryan	3							3				3			9/15/2023	2/21/2024	8			103
104	Houston	481	89	2/1/2023	4/30/2023				392			148	16	138		10/1/2023		22	88		104
105	Tyler	9							9	2		2	3	2		6/17/2023		13			105
106	Houston	8							8			4	2	2		5/30/2023	10/27/2023	3			106
107	Fort Worth	5							5				5			12/19/2022	12/1/2022				107
108	Houston	6				2	10/31/2024		4			1	2	1		6/30/2023		4			108
109	Odessa	17	1	9/30/2022	10/7/2022				16	1		2	2	11		5/31/2023	10/25/2023	27	7		109
110	Austin	8	6	9/1/2022	1/30/2023				2	2						1/31/2023	10/20/2023	8	151		110
111	Atlanta	2				1	12/6/2022	11/8/2022	1				1			10/1/2022	9/14/2022	6		-28	111
112	Houston	10	3	2/1/2023	4/30/2023				7	1		2	4			5/31/2024		13	88		112
113	Houston	21	1	1/2/2023	7/19/2023				2			2	9	9		10/31/2023		8	198		113

No	District	Conflicts																Buffer Time Shown in the CMP (Month)	Actual – Expected Clearance Date		
		Total Count	ROW (Right-of-way Acquisition)			RR (Railroad Agreement)			UTL (Utility Relocation)												
			ROW Total Conflict Count	Expected ROW Clearance Date	Actual ROW Clearance Date	RR Total Conflict Count	Expected RR Clearance Date	Actual RR Clearance Date	UTL Total Conflict Count	UTL Conflict Count by Type						Expected UTL Clearance Date	Actual UTL Clearance Date		ROW	RR	UTL
										Water	Sewer	Tele com	Electric	Power Pole	Gas/ Oil						
114	Houston	23	16	5/1/2023					7	2		2	2	1		1/31/2023	3/20/2024	7.5			114
115	Bryan	21	1	9/30/2024					11	4		2	4	1		3/31/2024		29			115
116	Amarillo	16							16			6	4	6		7/31/2023	7/13/2023	15			116
117	Pharr	8	4	2/28/2023	1/30/2024				4		4					6/1/2023	5/23/2023	7	336		117
118	Brownwood	2							2					2		11/15/2023	11/15/2023	1			118
119	Atlanta	9							9	1			7	1		6/1/2023	7/10/2023	4			119
120	Houston	40	14	4/24/2023	4/24/2023				26	3		3	15	5		2/22/2024		21			120
121	San Antonio	10							1			3	7			5/3/2023		28			121
122	Pharr	10	5						5	4		1				5/31/2023	10/24/2023	4			122
123	Brownwood	1							1			1				5/1/2023	7/27/2023	3			123
124	Houston	27	4	6/1/2024		2	6/30/2024		21			7	11	3		6/1/2025		3			124
125	Odessa	8							8				4	4		10/31/2024		1			125
126	Austin	28	6	9/2/2023	9/12/2023				22		1	9	12			8/15/2024		11	1		126
127	Houston	15							15				11	4		9/1/2023	10/20/2023	4			127
128	Tyler	15							15	4		2	5	4		1/31/2024		5			128
129	Houston	16	5	12/1/2023	6/15/2023	7	9/1/2023	9/20/2024	4	1			3			12/14/2023	1/1/2024	33	-169	385	129
130	El Paso	12	1	8/31/2023	9/21/2023				11			2	9			6/17/2024			21		130
131	Houston	35	2	7/31/2023	7/31/2023	14	11/1/2024	8/25/2024	19	1		3	6	9		12/31/2023		28		-68	131
132	Dallas	29							29	4		9	11	5		6/30/2024		5			132
133	Atlanta	2							2	1			1			9/23/2025		11.5			133
134	San Antonio	13							13	3		2	6	2		3/27/2024		9			134
135	Pharr	52	4	6/15/2023	12/1/2023				48	15		15	13	5		3/29/2024		23	169		135
136	Austin	5	5	2/1/2024	1/16/2024													3	-16		136
137	Houston	119	6	6/1/2023					113	3			57	38	15	2/28/2026		13.5			137
138	San Antonio	5							5				5			9/30/2023		4.5			138
139	Austin	26							26	5			21			10/10/2023		27			139
140	Houston	26	1	5/31/2024	6/27/2023				25				16	9		3/1/2024	4/1/2024	22	-339		140
141	Lufkin	22	2	8/1/2023	1/5/2023				2	3		4	9	4		7/1/2024		6	-28		141
142	Houston	17							17			6	6	5		7/31/2024		34			142

No	District	Conflicts																Buffer Time Shown in the CMP (Month)	Actual – Expected Clearance Date		
		Total Count	ROW (Right-of-way Acquisition)			RR (Railroad Agreement)			UTL (Utility Relocation)												
			ROW Total Conflict Count	Expected ROW Clearance Date	Actual ROW Clearance Date	RR Total Conflict Count	Expected RR Clearance Date	Actual RR Clearance Date	UTL Total Conflict Count	UTL Conflict Count by Type						Expected UTL Clearance Date	Actual UTL Clearance Date				
										Water	Sewer	Tele com	Electric	Power Pole	Gas/ Oil				ROW	RR	UTL
143	Austin	12							12			2	9	1		10/30/2023		13			143
144	Pharr	35							35	35						8/1/2024		18			144
145	Houston	39							39	1			34	4		11/30/2023		13			145
146	El Paso	79	5	1/1/2024	4/18/2024				74	13			3	31		2/1/2024	5/21/2024	21	18		146
147	Houston	72	3	7/31/2024					69	13		14	41	1		4/29/2024		9			147
148	Yoakum	61	4	9/15/2023	6/13/2023				57			24	29	4		10/1/2024			-94		148
149	San Antonio	5							5				5			11/13/2023		9			149
150	Bryan	22				1	6/20/2023	6/20/2023	21	4		6	1	1		10/31/2023	1/31/2024	15			150
151	Abilene	5	4	12/29/2023	2/2/2024	1													35		151
152	Austin	7							7				7			12/1/2023	11/10/2023	9			152
153	Laredo	173	11	12/1/2025					162			44	81	37		1/31/2025		5			153
154	Yoakum	3							3			2		1		3/1/2024	1/26/2023	14			154
155	San Antonio	23	4						19			5	14			4/29/2025		45			155
156	Paris	19							19	4		3	1	2		12/31/2023		35			156
157	Houston	41	8	10/30/2023	2/15/2024				33				16	17		7/31/2024		26	18		157
158	Tyler	7							7			1	4	2		1/9/2024		2			158
159	Yoakum	44							44	1		13	3			2/1/2024	3/31/2024	41			159
160	Laredo	1				1	11/30/2023	2/20/2024										5		82	160
161	Abilene	3							3			2	1			5/31/2024	6/13/2024	12.5			161
162	Houston	7				2	10/1/2023	5/3/2021	5	2			3			6/8/2024	8/1/2023	18		-881	162
163	Houston	1				1	1/31/2024	5/15/2024										4		15	163
164	Beaumont	29	6	2/28/2024	11/9/2023				23			16	7			7/1/2024		11	-111		164
165	Houston	2	1	10/2/2023	9/8/2023				1			1				10/2/2023	11/23/2023	15	-24		165
166	Austin	3							3			1	2			4/30/2024					166
167	Tyler	5							5	1		1	2	1		11/22/2024		33			167
168	San Antonio	9				1			8	2		1	4	1		6/6/2024		39			168
169	Austin	5							5				4	1		3/1/2024		1			169
170	San Antonio	9							9	8			1			1/21/2025					170
171	San Antonio	9	3						6			1	5			6/28/2025		19			171

No	District	Conflicts																Buffer Time Shown in the CMP (Month)	Actual – Expected Clearance Date		
		Total Count	ROW (Right-of-way Acquisition)			RR (Railroad Agreement)			UTL (Utility Relocation)												
			ROW Total Conflict Count	Expected ROW Clearance Date	Actual ROW Clearance Date	RR Total Conflict Count	Expected RR Clearance Date	Actual RR Clearance Date	UTL Total Conflict Count	UTL Conflict Count by Type						Expected UTL Clearance Date	Actual UTL Clearance Date				
										Water	Sewer	Tele com	Electric	Power Pole	Gas/ Oil				ROW	RR	UTL
172	Pharr	83				1	1/2/2024	11/1/2023	82			28	54			8/31/2024		38		-62	172
173	Yoakum	26							26	4	14	8				4/15/2024		11			173
174	Houston	33							33			1	23	7	2	5/6/2024		18			174
175	Amarillo	23	4	3/1/2024	5/8/2024				19	1		3	14	1		8/31/2024		51	68		175
176	Waco	6							6			1	5			12/13/2024		26			176
177	San Antonio	9							9			2		7		12/3/2024		4			177
178	El Paso	2	2	7/31/2024	8/14/2024														14		178
179	Pharr	97							97	21		22	53	1		8/31/2024		8			179
180	Lufkin	1							1			1				8/24/2025		2			180
181	Wichita Falls	16							16			15	1			3/9/2025		26			181
182	Houston	2	2	8/31/2024														25			182
183	Beaumont	32				3	6/1/2024	4/1/2024	29	1		13	6			6/23/2025		8		-61	183
184	Laredo	14	4	6/1/2024					1			3	1	3	3	3/4/2026		21			184
185	Yoakum	44	1	8/1/2024					43		2	19	18		4	11/1/2025		49			185
186	Pharr	37							37			25	7		5	11/1/2024		18			186
187	Brownwood	8	1	10/31/2024					7				7			10/31/2024		4			187
188	El Paso	2	2	11/1/2024														5			188
189	Austin	49	5	7/1/2024			9/1/2024	8/14/2024	44			22	1		12	6/1/2025		39		-18	189
190	Houston	11							11		1	8	2			2/28/2025		15			190
191	Houston	138	47	10/1/2024		1	6/5/2025		9	5		52	2		13	9/30/2025		22			191
192	El Paso	69	29	8/31/2025			2/5/2025		4			23	9		8	3/12/2026		42			192
193	Houston	8	4	11/1/2024					4			1	1		2	3/1/2025		39			193
194	Houston	2				2	12/31/2024									9/30/2024		13			194
195	San Antonio	12				1	11/1/2024		11			9	2			6/12/2029		13			195
196	Houston	117	17	4/1/2025					1			47	25		28	10/1/2026		88			196
197	Houston	289	6	2/28/2025					283	23		223	35		2	10/30/2025		1			197
Total		6220	771	-	-	59	-	-	4670	466	51	1431	2037	718	264	-	-	-	-	-	-

Appendix B. Analysis Results on Conflict Occurrence Types and Change Orders

In Chapter 6, for each conflict category of ROW/RR/UTL, the presence of a conflict was represented as a binary variable (Yes/No). The correlation analysis tested whether the occurrence of conflicts in these categories was associated with the occurrence of change orders.

Additionally, the number of conflicts in each category was treated as a numerical variable, and its relationship with the change order occurrence was analyzed. The conflict counts for each ROW/RR/UTL category were recorded individually, with the sum of conflicts across all categories labeled as the total conflict count. UTL conflicts were further categorized by utility line types, including Water, Sewer, Telecommunication, Electricity, Power Poles, and Gas/Oil Lines. The correlation between the number of change order conflicts for each utility type and the occurrence of change orders was also analyzed.

However, the correlation analyses revealed that, in almost all cases, the correlation between conflict type and change order occurrence was not statistically significant. The only statistically significant correlation observed was between ROW conflicts and change order occurrence, as shown in Table B1. This finding suggests that projects involving ROW conflicts are more likely to experience change orders compared to those without ROW conflicts.

On top of that, as shown in Table B2, among the utility conflict types, only telecommunication conflicts demonstrated a statistically significant correlation with change order occurrence when analyzing all projects. In other project groups, no significant correlation was found between conflict types and change order occurrence.

Table B1. Change Order Occurrence vs Conflict Occurrence Types

Variable 1	Variable 2	p-value	Correlation Coefficient	Result
Change Order Occurrence (Y/N)	ROW Conflict Occurrence (Y/N)	0.021	-	Significant correlation
	RR Conflict Occurrence (Y/N)	0.974	-	No Significant Correlation
	UTL Conflict Occurrence (Y/N)	0.082	-	No Significant Correlation

Table B2. Change Order Occurrence vs The Number of Conflicts by Types

Variable 1	Variable 2	p-value	Correlation Coefficient	Result
Change Order Occurrence (Y/N)	Total (count)	0.425	-0.050	No Significant Correlation
	ROW (count)	0.448	0.081	No Significant Correlation
	RR (count)	0.589	0.087	No Significant Correlation
	UTL (count)	0.389	-0.054	No Significant Correlation
	UTL – Water (count)	0.240	-0.118	No Significant Correlation
	UTL – Sewer (count)	0.526	-0.171	No Significant Correlation
	UTL – Telecom (count)	0.010	-0.195	Weak negative
	UTL – Electricity (count)	0.739	0.024	No Significant Correlation
	UTL - Power Pole (count)	0.713	0.035	No Significant Correlation
	UTL – Gas (count)	0.970	0.006	No Significant Correlation

Appendix C. Value of Research (VoR)

Introduction

For the estimation of the Value of Research, four functional areas were identified, spanning qualitative and economic categories. A summary of the selected functional areas is shown in Table C1.

Table C1. Functional Areas of Project 0-7182

Benefit Area	Qualitative	Economic	Both	TxDOT	State	Both
Level of Knowledge	X			X		
Management and Policy	X			X		
Expedited Project Delivery		X		X		
Reduced Construction, Operations, and Maintenance Cost		X			X	

Qualitative Benefits

The qualitative benefits related to the performance of this project are summarized as follows:

Level of Knowledge

Project 0-7182 increased the Level of Knowledge related to the impact and effectiveness of Construction Management Plans (CMPs). The project developed recommendations for improving the preparation, review, approval, and management of these plans. To achieve these goals, data from hundreds of TxDOT highway projects were collected and analyzed. Findings confirmed the prevalence and importance of CMPs for large and complex highway construction projects since many of these had utility, right-of-way (ROW), or railroad agreements that were not clear at the time of letting. CMPs were considered effective since the number of change orders and the project cost variation due to change orders was lower in the period after the implementation of CMPs by TxDOT.

Management and Policy

Project 0-7182 developed practical, data-driven recommendations for improving the effectiveness of CMPs as a conflict clearance and project risk management tool. Results may be used to inform management and policy decisions related to the implementation of CMP.

Quantitative Benefits

The economic benefits related to the performance of this project are summarized as follows:

Expedited Project Delivery

Expedited project delivery is essential to TxDOT operation and all relevant stakeholders. CMPs allow TxDOT to let projects with unclear conflicts earlier, provided that certain conditions are met. In order to be ready to let, projects are required to have 100% PS&E (Plan, Specifications, and Estimates), environmental permits secured, railroad coordination complete and agreement in place, ROW acquisition cleared, utility agreements in place, and utility relocations in progress. The requirement is to clear these items sufficiently to proceed into construction without delays and that any other remaining issues should be cleared within three months after letting. If a TxDOT district concludes that a project will not be possible to meet this deadline, the district would have to submit a CMP describing specific activities and a schedule of completion of the pending items. A CMP serves as a structured plan that outlines how construction can progress while concurrently addressing pending issues such as utility conflicts, ROW acquisition or relocation, ROW encroachments, and unresolved railroad agreements. By providing a conflict clearance plan, sequence of construction activities, and traffic control plan in the presence of these constraints, CMPs facilitate better coordination among stakeholders, expedite project delivery, and reduce the risk of schedule slippage and contractual disputes.

Reduced Construction, Operations, and Maintenance Cost

The research project examined trends and patterns in change orders before and after CMP implementation, with a focus on their impact on project cost and schedule performance. Statistical analyses and tests identified correlations between CMP-related variables and change orders. In addition, the influence of CMP-related variables on project cost and schedule performance were evaluated. These findings and recommendations should contribute to the reduction of change orders on CMP projects. Therefore, they will contribute to reducing the overall construction cost of these projects.

Quantitative Analysis of Economic Benefits

The quantitative analysis of Project 0-7182's is shown in Figure C1. The estimated total savings of conducting this project is approximately $88.3 million, which equates to a net present value of approximately $72.6 million. The payback period is 0.03 years and the cost-benefit ratio is 242.

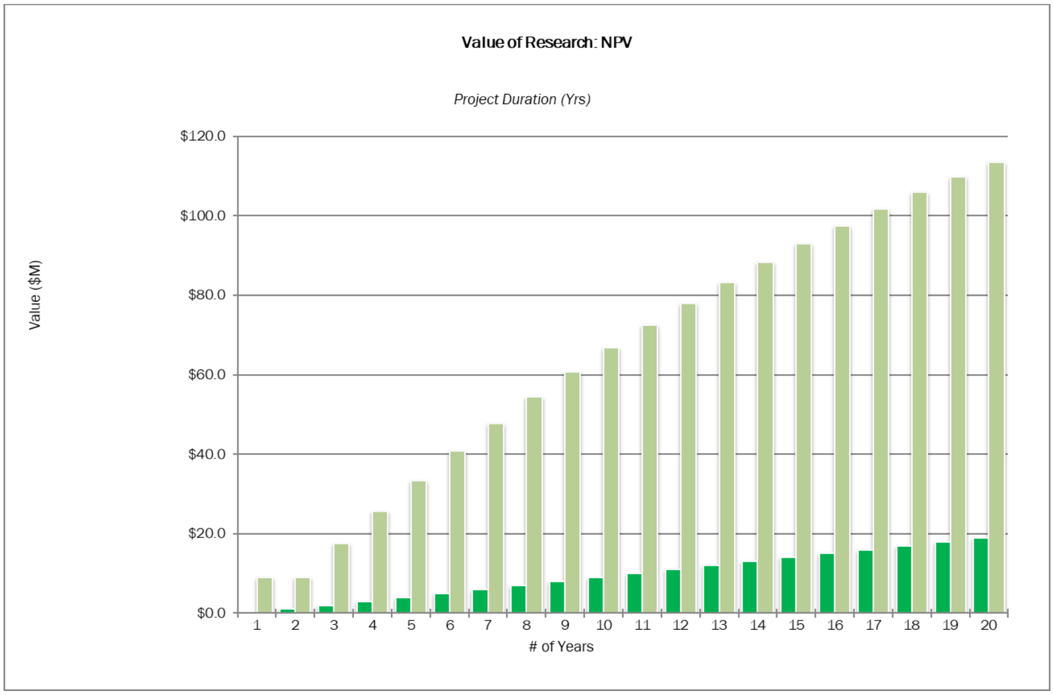

Figure C1. Preliminary Estimates of Net Present Value of the Project 0-7182

Explanation of VoR

Figure C2 represents the input and output of the project's value analysis that was used to generate Figure C1. The inputs were based on relevant publications as well as the analyses obtained from this research project.

	Project #	0-7182			
	Project Name:	Determine Effectiveness of Construction Management Plans			
	Agency:	UT/CTR	Project Budget	$	299,302
	Project Duration (Yrs)	2.0	Exp. Value (per Yr)	$	9,844,815
Expected Value Duration (Yrs)		20	Discount Rate		5%
Economic Value					
Total Savings:	$	88,304,030	Net Present Value (NPV):	$	72,560,522
Payback Period (Yrs):		0.030402	Cost Benefit Ratio (CBR, $1 : $___):	$	242

Figure C2. Input and Output Values of Project 0-7182

Each input term is presented in detail as follows:

Project Budget: $299,302 is the total budget of the research project. This value was determined from the project's contract.

Project Duration (Yrs.): The project was initiated on September 1, 2023, and will be terminated on August 31, 2025. Therefore, the project duration is 2.0 years.

Expected Value Duration (Yrs.): An expected value duration of at least 20 years was adopted.

Exp. Value (per Year):

Reduced Construction, Operations, and Maintenance Cost: The expected value per year due to a reduction in construction, operations, and maintenance cost was calculated based on an **expected reduction of 50% on the cost impact of CMP-related change orders after the implementation of 0-7182's findings and recommendations**. Based on the data provided by TxDOT to the research team, the **average contract amount of all 255 CMP Projects analyzed by 0-7182 is $70,761,182.00**. The **average number of new CMP Projects per year is 42**. Based on these values, **the total contract amount of new CMP Projects per year is $2,971,969,644.00**. Based on the 0-7182 analyses, **the average project cost variation due to CMP-related change orders is 0.65%**. Therefore, **the annual total project cost variation due to CMP-related change orders is $19,317,802.69**. **Considering an annual reduction of 50% in the total project cost variation due to CMP-related change orders after the implementation of research findings and recommendations, <u>the expected annual reduction in total project cost variation due to CMP-related change orders is $9,658,901.34</u>**

Average Contract Amount of All CMP Projects from FY 2019 to FY 2024 ($18,044,101,328 / 255)	$70,761,182.00
Average Number of New CMP Projects per Year (255 / 6)	42
Total Contract Amount of New CMP Projects (Per Year) ($70,761,182 * 42)	$2,971,969,644.00
Average Project Cost Variation Due to CMP-Related Change Orders (From 0-7182 R1A Page 62)	0.65%
Total Project Cost Variation Due to CMP-Related Change Orders (Per Year) (0.65% * 2,971,969,644)	$19,317,802.69
Expected Annual Reduction in Total Project Cost Variation Due to CMP-Related Change Orders due to Research (%)	50%
Expected Annual Reduction in Total Project Cost Variation Due to CMP-Related Change Orders due to Research ($)	$9,658,901.34

Expedited Project Delivery: The expected value per year due to expedited project delivery was calculated based on an **expected reduction of 50% on the schedule impact of CMP-related change orders after the implementation of 0-7182's findings and recommendations**. Based on the data provided by TxDOT to the research team, **the total time adjustment due to CMP-related change Orders is 47 days on 55 completed CMP projects**. Therefore, **the average time**

adjustment per project due to CMP-related change orders is 0.81, and the **total time adjustment on all CMP projects due to CMP-related change orders is 34.03 days per year**. Considering an annual reduction of 50% in the total time adjustment due to CMP-related change orders after the implementation of research findings and recommendations, **the expected annual reduction in total time adjustments due to CMP-related change orders is 10.21 days**.

To assess the financial impact of early completion of CMP projects, the **TxDOT Road User Cost (RUC)** and **Additional Project-Specific Liquidated Damages (APSLD)** were utilized, following the guidelines provided in the TxDOT Calculation Handbook and the associated calculator sheet.

The **RUC** represents the incentive/disincentive values associated with project milestones, as announced annually by TxDOT. For the year 2025, the RUC rates are set at **$38.97 per vehicle hour for passenger cars** and **$53.80 per vehicle hour for trucks**.

The **APSLD**, which estimates the potential daily cost for early project completion or delay, is calculated based on traffic data, specifically the **Annual Average Daily Traffic (AADT),** sourced from the **TxDOT Statewide Planning Map**, an open-access resource. For CMP projects, typically large-scale, complex, and located in high-congestion areas, the AADT values are extracted by matching each project's **Control-Section-Job (CSJ)** number and then averaged by TxDOT district.

Six major districts account for the majority of CMP projects: **Houston, Austin, San Antonio, Dallas, El Paso**, and **Fort Worth**. The average AADT for each of these districts is calculated. Using standard assumptions (e.g., vehicle type distribution, work zone slowdown speeds, etc.), the **average financial incentive for early completion** is derived for each district. CMP projects' AADT is 160% than the average AADT in total. Therefore, we can conclude that CMP's project incentives for the early completion of a day is **$6,828*1.6 = $10,925/day on average.**

Based on the data above, <u>**the expected annual reduction in costs due the reduction on time adjustments on CMP-related change orders after research implementation is $185,913.36**</u>.

Average Number of New CMP Projects per Year (255 / 6)	42
Total Time Adjustment to CMP-Related Change Orders (From 0-7182 R1A Page 62)	47
Average Time Adjustment Per Project Due to CMP-Related Change Orders	0.81
Time Adjustment on All CMP Projects Due to CMP-Related Change Orders	34.03
Expected Annual Reduction in Total Time Adjustment Due to CMP-Related Change Orders Due to Research (%)	50%
Expected Annual Reduction in Total Time Adjustment Due to CMP-Related Change Orders due to Research (In Days)	10.21
Incentive for Early Completion of a CMP Project (In $ per day)	$10,925.00
Expected Annual Reduction in Total Time Adjustment Due to CMP-Related Change Orders after Research Implementation (In $)	$185,913.36

Discount Rate: The 5% discount rate recommended in the University Handbook was used (TxDOT, 2019).

Output values: The following terms were determined automatically in the spreadsheet (Figure 1): Total Savings, Payback Period (Yrs.); Net Present Value (NPV), and Cost-Benefit Ratio (CBR). These terms were determined based on the equations in the University Handbook (TxDOT, 2019).

References for VoR

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