UNIVERSITY OF TEXAS ARLINGTON

TxDOT Report 0-7146-1

Develop Guidance for Local Government Building Codes for Bridges

Mohsen Shahandashti
Shih-Ho (Simon) Chao
Nur Yazdani
Pooya Darghiasi

Report Publication Date: Submitted: August 2023
Published: September 2025
Project: 0-7146
Project Title: Develop Guidance for Local Government Building Codes for Bridges

SYNTHESIS: DEVELOP GUIDANCE FOR LOCAL GOVERNMENT BUILDING CODES FOR BRIDGES

Prepared for:

Texas Department of Transportation

Project Manager:

Chris Glancy

Prepared by:

Mohsen Shahandashti, Ph.D., P.E.

Shih-Ho (Simon) Chao, Ph.D., P.E.

Nur Yazdani, Ph.D., P.E.

Pooya Darghiasi, Ph.D.

The University of Texas at Arlington

Report 0-7146-1

Project 0-7146

Project Title: Synthesis: Develop Guidance for Local Government Building Codes for Bridges

August 2023

UNIVERSITY OF TEXAS ARLINGTON | Department of Civil Engineering

425 Nedderman Dr., 416 Yates St.

Box 19308, Arlington, TX 76019

Technical Report Documentation Page

1. Report No. FHWA/TX-25/0-7146-1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Synthesis: Develop Guidance for Local Government Building Codes for Bridges		5. Report Date Submitted: August 2023 6. Performing Organization Code
7. Author(s) Mohsen Shahandashti (https://orcid.org/0000-0002-2373-7596), Shih-Ho (Simon) Chao, Nur Yazdani, Pooya Darghiasi (https://orcid.org/0000-0002-2357-5507)		8. Performing Organization Report No. 0-7146-1
9. Performing Organization Name and Address Department of Civil Engineering The University of Texas at Arlington 425 Nedderman Dr., 416 Yates St. Box 19308, Arlington, TX 76019		10. Work Unit No. (TRAIS) 11. Contract or Grant No. 0-7146
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Division 125 E. 11th Street Austin, TX 78701		13. Type of Report and Period Covered Technical Report September 2022 – August 2023 14. Sponsoring Agency Code
15. Supplementary Notes Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.		
16. Abstract The design, construction, and maintenance of off-system bridges vary across local governments (cities and counties), often resulting in inferior performance compared to bridges managed by state highway agencies. Limited knowledge of local government practices hinders understanding of the factors contributing to these deficiencies and poses challenges for state highway agencies in providing effective guidance. This study synthesizes current practices for the design, construction, and maintenance of Texas off-system bridges managed by local governments, including the use of bridge-related design manuals and standards. The findings aim to improve the performance of off-system bridges by identifying the best practices, highlighting deficiencies, and providing recommendations to support more consistent and effective bridge management at the local level.		
17. Key Words Off-system bridges, best practices in bridge management, Infrastructure performance improvement, Design manuals and criteria.	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Alexandria, Virginia 22312; www.ntis.gov.	

19. Security Classif. (of report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages TBD [Total count excl. cover]	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation. This report is not intended for construction, bidding, or permit purposes.

ACKNOWLEDGEMENT

This project was conducted in cooperation with the Texas Department of Transportation (TxDOT). The authors are grateful for the support and guidance provided by Mr. Chris Glancy, Project Manager of the TxDOT Research and Technology Implementation (RTI) division, and the project advisory committee, Mr. Bernie Carrasco, Mr. Keith Taylor, and Mr. Manuel Padron. Their assistance has been central to the successful completion of this project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Design, construction, and maintenance of off-system bridges in Texas vary among local governments. Current bridge codes or standards put in place by local governments have not been synthesized and well-documented, making it challenging for the Performing Agency divisions and districts to provide the necessary guidance in their continued partnerships with cities and counties. Therefore, it is essential to thoroughly synthesize the current state of practice on the design, construction, and maintenance procedures of off-system bridges within local governments, including the building codes utilized and the procedures followed to acquire the engineering plans after the construction is completed. This synthesis documents the existing practices regarding the design, construction, and maintenance of off-system bridges within local governments. It also identifies the most effective practices that can enhance the overall performance of off-system bridges in Texas. Based on the findings, actionable recommendations are provided to enhance these procedures within local governments.

The research findings were obtained through an extensive literature review, fact-finding surveys, and structured follow-up interviews. A thorough literature review was conducted to obtain a detailed understanding of the procedures involved in the design, construction, and maintenance of off-system bridges in Texas, including the building codes utilized and the procedures followed to acquire the engineering plans after the construction is completed. The findings of the literature review were used to develop three questionnaires, one for Texas local governments, one for engineering consulting firms, and one for TxDOT personnel with prior bridge experience. Responses were collected from forty-nine (49) local governments in Texas, ten (10) engineering consulting firms involved in the design or construction of off-system bridges in Texas, and three (3) TxDOT personnel with bridge experience. Based on the survey responses, structured follow-up interviews were conducted with individuals having experience in the design, construction, and maintenance of off-system within local governments. The research team conducted fourteen detailed follow-up interviews. The interview participants were asked to provide detailed information on their procedures to design, construct, and maintain off-system bridges within their respective jurisdictions.

The information collected from literature, survey questionnaire, and interviews were analyzed to present recommendations for enhancing the procedures related to the design, construction, and

maintenance of off-system bridges in local governments. Some of these recommendations are summarized as follows:

- It is recommended that local governments adopt TxDOT manuals and guidelines for bridges to promote standardized design procedures and alleviate confusion among engineering firms in Texas.
- It is recommended that bridge design manuals incorporate supplementary requirements to address specific local needs, such as ensuring sufficient width to accommodate farming equipment in rural areas. This will ensure that the design process adequately considers and meets the unique demands of the local environment.
- It is recommended to organize training workshops or educational courses specifically designed for city/county engineers. This initiative would greatly enhance local governments' knowledge and understanding of the building design codes and standards applicable to off-system bridges, thereby fostering improved expertise in this field.
- It is recommended to establish a standard communication and coordination guideline for local governments and TxDOT to streamline communication of essential requirements concerning off-system bridges, encompassing the Preliminary Bridge Layout Review (PBLR) process and the requirement of submitting final bridge plans to TxDOT. This will ensure that city/county engineers are well-informed about the necessary prerequisites for this aspect.
- It is recommended that local governments develop comprehensive guidelines for developers, providing them with clear information about the necessary procedures, including the applicable building codes, to be followed during the design, construction, and maintenance of off-system bridges.
- It is recommended to enhance the clarity and comprehension of TxDOT bridge inspection reports for city/county engineers. This can be achieved by incorporating additional visual aids, such as pictures and diagrams, in the reports to clearly illustrate the precise locations of deterioration and deficiencies. Furthermore, enriching the reports with comprehensive definitions and examples would contribute to a better understanding of the content.

- It is recommended to provide repair options and maintenance guides for the issues identified in the inspection report. By incorporating these repair options or maintenance guides, cities/counties can effectively address and rectify the identified problems, enabling them to implement appropriate measures for resolution.
- It is recommended that TxDOT arrange follow-up meetings with local governments to facilitate face-to-face discussions concerning bridge issues outlined in inspection reports. This proactive step would be advantageous for local governments, as it allows for direct engagement on matters related to bridges.
- It is recommended that municipalities allocate a budget, even if it is small, for bridge maintenance on an annual basis. This practice guarantees that if TxDOT notifies about any issues with bridges, there is sufficient funding available to address them promptly.
- It is recommended that different entities, such as the Corps of Engineers and TxDOT, coordinate with each other while providing reviews about off-system bridges. This collaboration aims to ensure non-conflicting assessments and evaluations.
- It is recommended to disseminate information regarding the funding opportunities available to local governments related to off-system bridges. This approach assists them in becoming acquainted with these funding options and utilizing them effectively.
- It is recommended that local governments adopt and implement the appropriate hydraulic design criteria specified in the state's (e.g., TxDOT Hydraulic Design Manual) and the national's (e.g., HEC-18) design codes to mitigate the potential risks associated with flooding or scour.

Chapter 1
INTRODUCTION

Texas has the largest U.S. bridge inventory, operating and maintaining nearly 54,528 bridges, of which 35,602 bridges are on the state system and 18,926 bridges are off the state system (TxDOT, 2020). The on-system bridges are on the state-designated highway system and are owned, constructed, and maintained by the Texas Department of Transportation (TxDOT), while the off-system bridges are owned and maintained by local governments. The off-system bridges that are not in a state-designated highway system can be designed and built according to local government guidelines; the toll authorities must also abide by the guidelines from state or local authorities (Harris County Toll Road Authority, 2017). Bridge inspection reports reveal that off-system bridges have inferior performance compared to on-system bridges (TxDOT, 2019). Current bridge codes or standards, that are put in place by the local governments for design, construction, and maintenance, have not been synthesized and well-documented, which makes it challenging for TxDOT divisions and districts to provide the necessary guidance in their continued partnership related to off-system bridge projects. Therefore, a comprehensive synthesis is needed to identify the procedures that local governments follow to design, construct, or maintain off-system bridges and the most effective methods employed in this regard. This research aims to synthesize and evaluate these procedures to identify the best practices and provide recommendations to enhance them. This technical report explains all the tasks performed to acquire this set of recommendations. The report is organized as follows:

Chapter 1 is this introductory chapter.

Chapter 2 provides the literature review for building codes and procedures involved in the design, construction, and maintenance of off-system bridges in Texas.

Chapter 3 provides the results of survey questionnaires distributed among local governments in Texas, engineering consulting firms, and TxDOT personnel.

Chapter 4 summarizes fourteen follow-up interviews about the procedure followed for the design, construction, and maintenance of off-system bridges in Texas.

Chapter 5 provides case studies, presenting in-depth information on the procedures implemented for the design, construction, and maintenance of off-system bridges in five example local governments.

Chapter 6 provides the project summary and recommendations to enhance the procedures involved in the design, construction, and maintenance of off-system bridges in Texas local governments.

Appendix A is the survey questionnaire distributed among Texas local governments.

Appendix B is the survey questionnaire distributed among Texas engineering consulting firms.

Appendix C is the survey questionnaire distributed among TxDOT personnel with bridge experts.

Chapter 2
REVIEW THE EXISTING BRIDGE CODES AND STANDARDS THAT CITIES AND COUNTIES HAVE IN PLACE

2.1 Introduction

Texas is currently experiencing unplanned and unprecedented growth, impacting a vast expanse of the state, including 254 counties, 1218 cities, towns, and villages, along with 2798 special districts (US Census Bureau, 2017). The growth in cities demands the construction of new infrastructures, including bridges. Despite the efforts of the local governments to design, construct, and maintain bridges, only 69.2 percent of off-system bridges are in good or better condition compared with 89 percent of on-system bridges (TxDOT, 2019). Additionally, the number of off-system bridges recommended for closure in 2018 is nearly eight times higher than on-system bridges, as shown in Figure 2-1 (TxDOT, 2019).

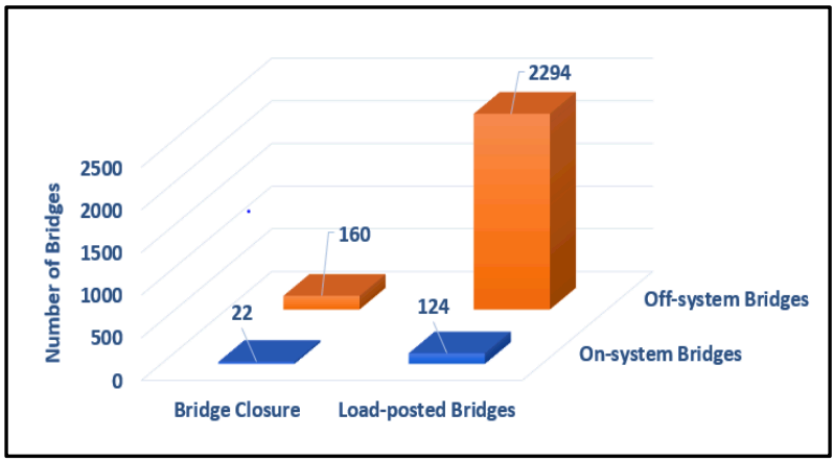

Figure 2-1 On-system and off-system bridges closed to traffic and load posted (prepared by authors using the data from TxDOT Report on Texas Bridges [2018])

Bridge deficiencies are result of various factors, such as hydraulic incidents (e.g., flood and scour), geotechnical problems (e.g., erosion, slope stability, sinkhole, etc.), overload, collision, construction, and design error (Cook, 2014; Lee et al., 2013). Figure 2-2 shows the contribution of various factors to bridge deficiencies based on a dataset of bridges in the U.S. from 1920 to 2011 (Cook, 2014). Cook (2014) reported that hydraulic incidents are the most significant cause of bridge deficiencies in the U.S., accounting for over 50% of all deficiencies.

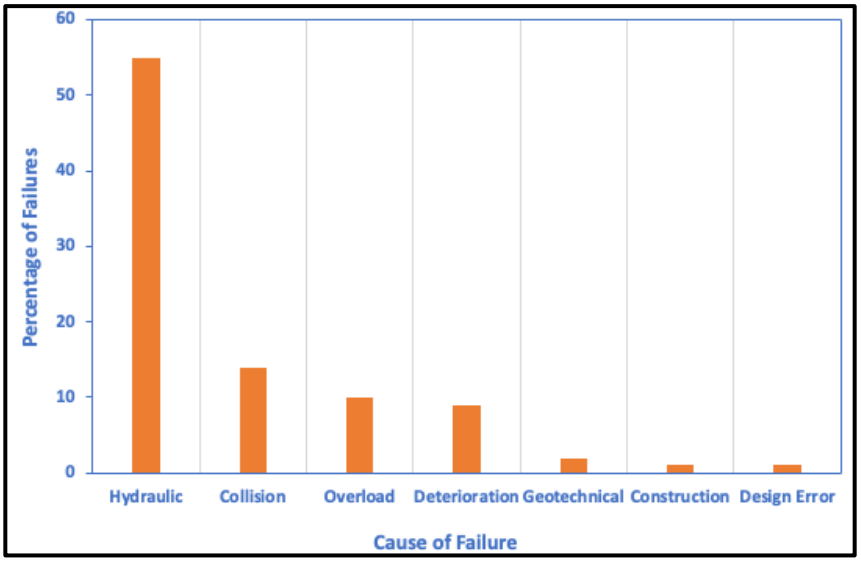

Figure 2-2 Bridge deficiencies due to different factors (prepared by authors using the data from a study conducted by Cook [2014])

Local governments' existing codes, guidelines, and standards for bridge design, construction, and maintenance have not been synthesized and well-documented, making it challenging for TxDOT divisions and districts to provide necessary guidance in continued partnership with off-system bridge projects. Considering TxDOT engineers' extensive experience with bridge design and construction, their guidance is essential to improve the deteriorating conditions of off-system bridges in Texas. For this purpose, a comprehensive synthesis of bridge codes and standards currently put in place by local governments is needed to identify gaps and challenges so that guidance can be developed for improving the existing local government guidelines. This chapter aims to: (1) conduct a literature review for identifying and evaluating various bridge design manuals, guidelines, and standards that are put in place by local governments for bridge developers in Texas and (2) acquire the necessary background to design a survey to fully capture the current state of practices for off-system bridges in Texas.

2.2 Bridge Design Manuals, Guidelines, and Standards in Texas

This section provides a synthesis of the national, state, and local governments' manuals, guidelines, and standards currently implemented for the design, construction, and maintenance of bridges in Texas. The design manuals, guidelines, and standards can be compared in different categories, as shown in Figure 2-3.

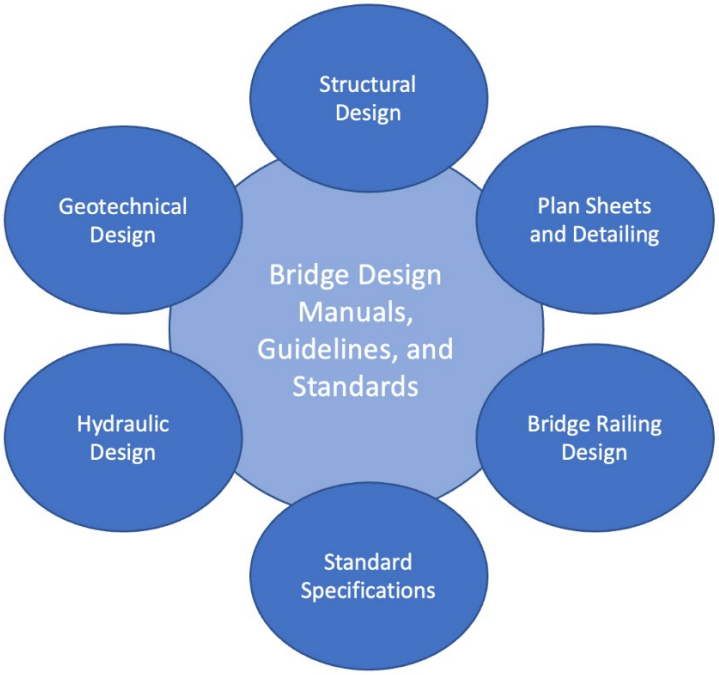

Figure 2-3 Different aspects of manuals, guidelines, and standards for bridge design, construction, and maintenance

Regardless of the funding source (state or federal), all bridges on the Texas state and the national highway system must follow TxDOT manuals, procedures, standards, and guidelines (TxDOT, 2009). However, off-system bridges without state or federal funds may be designed according to local manuals and standards adopted by the local governments (TxDOT, 2009). Various cities and counties in Texas have established different manuals and standards for the guidance of bridge developers. These manuals and guidelines may differ in some provisions, as highlighted in Figure 2-4.

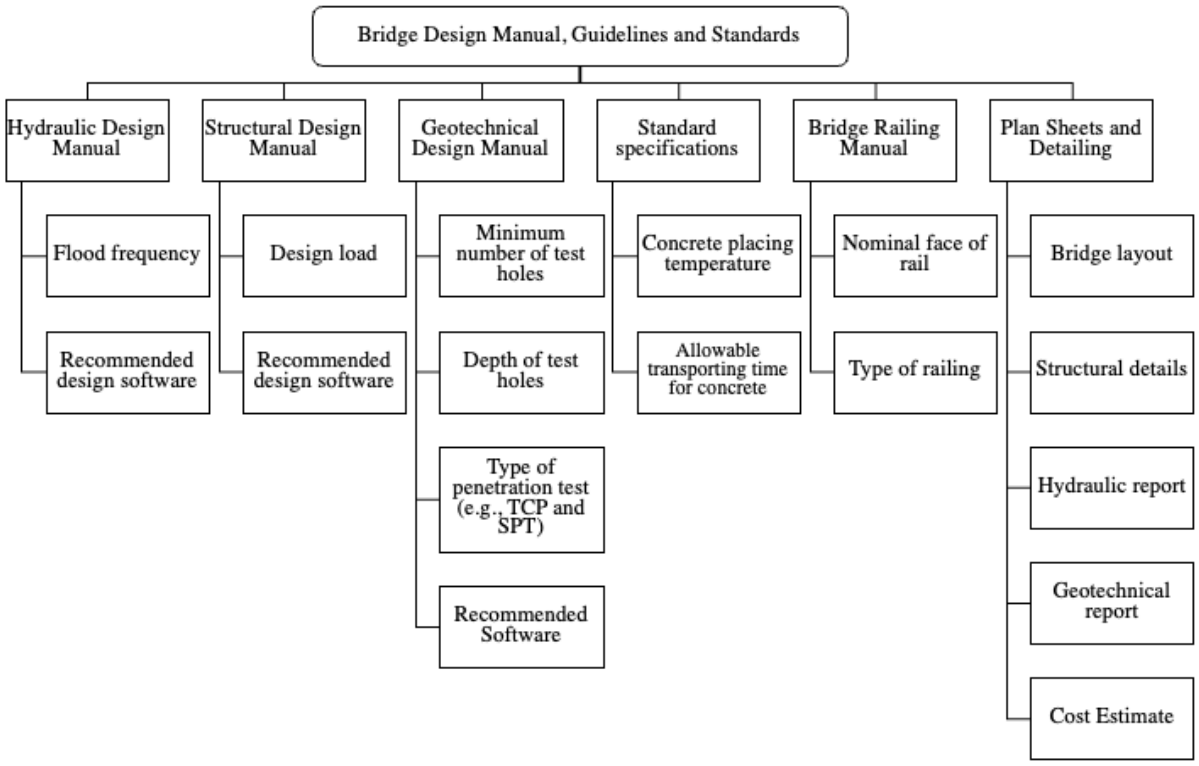

Figure 2-4 Differences between federal, state, and local governments' bridge design manuals, guidelines, and standards

In this chapter, a literature review is conducted to synthesize the national, state, and local governments' manuals, guidelines, and standards currently in place for bridge design, construction, and maintenance in Texas. Furthermore, a detailed discussion is presented to elaborate on how these documents could differ in some provisions. Table 2-1 summarizes examples of existing manuals, guidelines, and standards implemented in the state and local governments of Texas.

Table 2-1 Manuals, standards, and specifications for design, construction, and maintenance of bridges in Texas

Local/State Agency	Structural Design Manual	Geotechnical Manual	Hydraulic and Scour Manual	Bridge Railings	Standard Drawings	Standard Specification	Reference
Texas Department of Transportation	• TxDOT Bridge Design Manual-LRFD • TxDOT Bridge Design Guide • TxDOT Bent Protection Guide	• TxDOT Geotechnical Manual	• TxDOT Hydraulic Design Manual	• TxDOT Bridge Railing Manual	• TxDOT Bridge Detailing Guide	• TxDOT Standard Specifications	• TxDOT Bridge Publications
City of Dallas	• AASHTO LRFD Bridge Design Specifications- Latest Edition	• City of Dallas Street Design Manual	• City of Dallas Drainage Design Manual	*(Not Available)*	• Standard Construction Details file 251D-1, City of Dallas	• Addendum to the NCTCOG Public Works Construction Standards	• City of Dallas Street Design Manual, 2019
City of Houston	• AASHTO LRFD Bridge Design Specifications	• Chapter 11 of the City of Houston Infrastructure Design Manual	• Chapter 9 of the City of Houston Infrastructure Design Manual	*(Not Available)*	• Section 2 of the City of Houston Infrastructure Design Manual	• City of Houston standard construction specification	• City of Houston Infrastructure Design Manual, 2022
City of Midland	• TxDOT Bridge Design Manual – LRFD	*(Not Available)*	*(Not Available)*	• TxDOT Bridge Railing Manual • City of Midland Engineering Design and Development Manual	• Section 2 of the Engineering Design and Development Manual	• City of Midland standard specification	• City of Midland Engineering Design and Development Manual, 2021
City of San Antonio	• TxDOT Bridge Design Manual – LRFD	• TxDOT Geotechnical Manual	• TxDOT Hydraulic Design Manual	• COSA Unified Development Code	• Section 9, CAD Standards, of COSA Design Guidance Manual	• COSA Standard Specifications for Construction & Standard Details	• City of San Antonio (COSA) Design Guidance Manual, 2017 • COSA Unified Development Code, 2022
City of Austin	• TxDOT Bridge Design Manual - LRFD	*(Not Available)*	• City of Austin Drainage Criteria Manual	• TxDOT Bridge Railing Manual	• Section 1803S.10, Shop Drawings and Submittals of Standard Specification Manual	• City of Austin Standard Specification Manual	• City of Austin Transportation Criteria Manual, 2020 • Drainage Criteria Manual, 2022

City of Fort Worth	*(Not Available)*	*(Not Available)*	*(Not Available)*	*(Not Available)*	• City of Fort Worth standard and detailed drawing	*(Not Available)*	• City of Fort Worth Transportation Engineering Manual, 2019
City of Arlington	*(Not Available)*	*(Not Available)*	• TxDOT Hydraulic Design Manual	*(Not Available)*	*(Not Available)*	*(Not Available)*	• City of Arlington Design Criteria Manual, 2020
Harris County	• AASHTO Bridge Design Specifications-Latest Edition	• Harris County Guidelines for Consultants Performing Geotechnical Investigations	• Harris County Hydrology and Hydraulics Manual	*(Not Available)*	• Harris County Guideline	• Harris County Standard Engineering Design Specifications	• Harris County Guideline, 1988
City of McKinney	• Section 6 City of McKinney Engineering Design Manual	• Section 6 City of McKinney Engineering Design Manual	• Section 4 of City of McKinney Engineering Design Manual	• TxDOT Bridge Railing Manual • Section 6.5.E of City of McKinney Engineering Design Manual	• Section 1.9 City of McKinney Engineering Design Manual	• TxDOT Standard Specifications	• City of McKinney Engineering Design Manual, 2018
City of Mesquite	• AASHTO Bridge Design Specifications-Latest Edition	• Section 7.4 of the City of Mesquite Engineering Design Manual	• Section 3 of the City of Mesquite Engineering Design Manual	• TxDOT Bridge Railing Manual • MASH • NCHRP Report 350 • Section 7.5.5 of the City of Mesquite Engineering Design Manual	• The City of Mesquite Standard Details • TxDOT Standard Details Upon Calculations that Validate the Applicability	• TxDOT Standard Specifications	• City of Mesquite Engineering Design Manual
Travis County	• Determined by the County Executive of Travis County Transportation and Natural Resources (TNR) on a Project-by-Project Basis	• Determined by the TNR on a project-by-project basis	• Determined by the TNR on a project-by-project basis	• Determined by the TNR on a project-by-project basis	• Determined by the TNR on a project-by-project basis	• Determined by the TNR on a project-by-project basis	• Travis County Code

City of Denton	• Criteria from the following applicable sources may be warranted: o TxDOT o AASHTO o City of Denton mobility plan o NCTCOG o Other city transportation manuals in surrounding areas						• City of Denton Transportation Design Criteria Manual, 2018
City of Pharr	Code and standard specifications requirements will be published at the time of advertisement for the bid						• City of Pharr Standard Manual, 2006
Denton County	• Related AASHTO Manual	*(Not Available)*	*(Not Available)*	*(Not Available)*	*(Not Available)*	• TxDOT Standard Specifications	• Denton County Planning Department Subdivision Process, 2009
William County	*(Not Available)*	*(Not Available)*	• City of Austin's Drainage Criteria Manual	*(Not Available)*	*(Not Available)*	• TxDOT Standard Specifications	• Williamson County Subdivision Regulations, 2021
Brazoria County	*(Not Available)*	*(Not Available)*	• Brazoria County Drainage Criteria Manual	*(Not Available)*	*(Not Available)*	• TxDOT Standard Specifications	• Brazoria County Subdivision Regulations, 2006
Galveston County	*(Not Available)*	*(Not Available)*	• TxDOT Hydraulic Design Manual	*(Not Available)*	*(Not Available)*	• TxDOT Standard Specifications	• Galveston County Rules, Regulations, and Requirements Relating to the Approval and Acceptance of Improvements in Subdivisions, 1997

City of Corpus Christi	*(Not Available)*	*(Not Available)*	*(Not Available)*	*(Not Available)*	*(Not Available)*	• City of Corpus Christi Standard Construction Specifications	• City of Corpus Christi Infrastructure Manual, 2022
City of Garland	• AASHTO Bridge Design Specifications-Latest Edition	• Section 7.03 of the City of Garland Technical Standard Manual	• Section 4 of the City of Garland Technical Standard Manual	*(Not Available)*	• Section 2 of the City of Garland Technical Standard Manual	• City of Garland Standard Construction Specifications • TxDOT Standard Specifications	• City of Garland Technical Standard Manual, 2020
City of McAllen	*(Not Available)*	*(Not Available)*	*(Not Available)*	*(Not Available)*	*(Not Available)*	*(Not Available)*	• City of McAllen Standard Design Guide for Public Infrastructure Improvements, 2021

2.1.1 Hydraulic Design

Incorporating pertinent hydraulic design criteria into bridges reduces maintenance costs and enhances vehicle safety (Bani-Hani et al., 2023; Shahandashti et al., 2021). According to the Federal Highway Administration (FHWA), bridge owners should follow the guidance outlined in the state hydraulic or drainage manuals. If the state manual is unavailable, the AASHTO Highway Drainage Guidelines must be followed (AASHTO, 2020). Texas Department of Transportation has developed the TxDOT Hydraulic Design Manual to provide guidelines for analyzing and designing effective drainage facilities for on-system bridges. While the Texas Department of Transportation requires using the TxDOT Hydraulic Design Manual for on-system projects, local governments may follow their local manuals. These manuals may differ in some provisions from the TxDOT manual. For example, the TxDOT Hydraulic Manual requires that the bridge drainage facilities be designed for a range of Annual Exceedance Probabilities (AEP) depending on the functional classification and structure type. However, the local governments may select a different design AEP depending on other criteria based on their local hydraulic or drainage manuals. Table 2-2 shows examples of design AEP for drainage facilities according to various local governments' manuals.

Table 2-2 Design annual exceedance probability for drainage facilities

Local/State Government	**Functional Classification and Structure Type**	**Design Annual Exceedance Probability (Average Recurrence Interval)**					
		50% (2-year)	20% (5-year)	10% (10-year)	4% (25-year)	2% (50-year)	1% (100-year)
TxDOT	Bridges in Freeways					✓	
	Bridges Principal arterials			✓	[✓][1]	✓	
	Bridges in Minor arterial and collectors			✓	[✓]	✓	
	Bridges on local roads and streets[2]	✓	✓	✓			
City of Arlington	Off-system bridges			✓			

City of Keller	Off-system bridges						✓
City of Houston	Off-system bridges						✓
City of Austin	Off-system bridges						✓
City of Dallas	Off-system bridges						✓
City of San Antonio	Off-system bridges			✓ For upstream drainage areas less than 100 acres			✓ For upstream drainage areas greater than 100 acres
City of McKinney	Off-system bridges						✓
City of Lubbock	Off-system bridges						✓[3]
Travis County	Off-system bridges			✓[4]			✓[5]
Denton County	Off-system bridges						✓
Cameron County	Off-system bridges						✓
Williamson County[6]				✓	✓		

Notes:
[1] When a range of design frequencies is marked, the recommended frequency is highlighted by square brackets.
[2] It may be necessary to calculate the 4% (25-yr), 2% (50-yr), 0.5% (200-yr), or 0.2% (500-yr) for scour computations.
[3] It should be checked against the scour depth associated with the 500-year flood.
[4] Whenever drainage structures are required to pass surface water under any road, such drainage structures shall be pipes, box culverts, or bridges of sizes sufficient to convey the 25-year rainfall without overtopping the roads
[5] A 100-year storm event if the roadway is located in the Colorado River Corridor floodplain and a 500-year storm event if the roadway is located outside the Colorado River Corridor floodplain.
[6] 25-year storm for arterial and collector roads, and 10-year storm for local roads

Recommended Software Programs

Hydraulic analysis and design can be done using various software programs to minimize the risk of design error. Table 2-3 presents the hydraulic bridge design software programs recommended by the Federal Highway Administration, the Texas Department of Transportation, and some local governments in Texas.

Table 2-3 Software programs recommended for hydraulic and/or hydrologic modeling according to different guidelines

Local, State, or Federal Government	**Software Program**	**Description**
The Federal Highway Administration	• HY 8	Automates the culvert hydraulic computations utilizing several essential features that make culvert analysis and design easier.
	• Hydraulic Toolbox	Performs routine hydrologic and hydraulic analysis and design computations.
	• HEC-RAS	Performs one-dimensional steady flow, one- and two-dimensional unsteady flow calculations, sediment transport/mobile bed computations, and water temperature/water quality modeling.
	• SMS	Simulates surface water using one- and two-dimensional modeling.
Texas Department of Transportation	• HY 8	*Aforementioned*
	• HEC-RAS	*Aforementioned*
	• GEOPAK Drainage	Designs and analyzes storm drain systems, which can leverage many roadway design features to create a seamless information exchange in the drainage design process.
City of Houston	• HouStrom	HouStorm is a derivative software program based on the Texas Department of Transportation's WinStorm computer program (no longer supported by TxDOT).
City of San Antonio	• HEC-RAS	*Aforementioned*
	• XPSWMM	Performs one- and two-dimensional hydraulic and hydrologic modeling.
City of Arlington	• HEC-RAS	*Aforementioned*
City of Austin	• HEC-RAS	*Aforementioned*
City of McKinney	• HEC-RAS	*Aforementioned*
Denton County	• HEC-RAS	*Aforementioned*
City of Corpus Christi	• HEC-RAS if the drainage area is over 500 acres • Other industry-standard software packages if the drainage area is below 500 acres	*Aforementioned*

Although some local governments have recommended software programs that facilitate the bridge hydraulic design process for engineers, there is still a gap in many local governments' guidelines about recommending appropriate programs that can be used for the hydraulic design of bridge components.

2.1.2 Structural Design

As of October 2007, the Federal Highway Administration (FHWA) required the Texas Department of Transportation (TxDOT) to use the Load and Resistance Factor Design (LRFD) for all on-system bridges (TxDOT, 2021). For this purpose, the TxDOT developed the Bridge Design Manual– LRFD and Bridge Design Guide to assist Texas bridge designers in applying provisions documented in the latest edition of the AASHTO LRFD Bridge Design Specifications— which bridge designers should adhere to unless directed otherwise (TxDOT, 2021a). For projects off the state highway system, with no state or federal funds, the local governments are encouraged to follow the same practices as the state projects. However, local governments may use their local manuals, which may differ from those provided by TxDOT in some provisions. The following paragraphs provide examples of these differences.

Design Load

According to AASHTO Bridge Design Specifications, the HL-93 vehicular live loading is required as the design load for bridges. HL-93 is a combination of three different loads (AASHTO, 2020):

- HS20 Design Truck
- HL-93 Design Tandem
- Design Uniform Lane Load

The Design Truck consists of a front and two rear axles, with the front axle weighing 8 kips and two rear axles weighing 32 kips (a total 72,000-pound truck), as shown in Figure 2-5. The distance between the front and the first rear axle is 14 ft., the tire-to-tire distance in any axle is 6 ft., and the distance of two rear axles can be varied between 14 ft. to 30 ft. to obtain the most critical, as well as to analyze bridges with continuous spans and the fatigue limit state of a bridge.

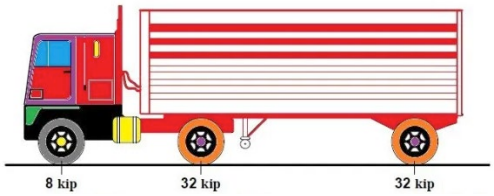

Figure 2-5- AASHTO HS20 design truck (adapted from engineeringcivil.org)

The design tandem consists of twin axles spaced four (4) ft. apart; the distance between the tires in each axle is six (6) ft.; and the weight of each axle is 25 kips, as shown in Figure 2-6. Moreover, the design lane load consists of a load of 640 pounds per linear foot of design lane that is uniformly distributed in the longitudinal direction.

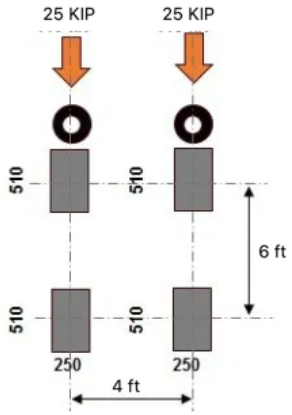

Figure 2-6 AASHTO design tandem tire plan (adapted from engineeringcivil.org)

According to AASHTO LRFD Bridge Design Specifications, the HL-93 designation is determined by taking the worst combination of the above loads and using the appropriate load factors and placements (AASHTO, 2020). Although the latest edition of AASHTO LRFD Bridge Design Specifications and the TxDOT Bridge Design Manual requires using HL-93 design load for state bridges, some local governments may still use outdated manuals that require the old HS-20 design load. The outdated HS-20 design load calculates the truckload and lane load moments separately, and the larger moment controls the design (Shipman, 2014). Table 2-4 lists examples of local governments in Texas which still recommend the outdated HS-20 design load in their available design manuals.

Table 2-4 Examples of the local governments recommending outdated design loads for bridge design

Local Government	Design Load	Reference
Harris County	HS-20	Harris County design guideline, 1988
Montgomery County	HS-20	Montgomery County Subdivision Rules and Regulations, 1984
Brazoria County	HS-20	Brazoria County Subdivision Rules and Regulations, 2006
Galveston County	HS-20	Galveston County Rules, Regulations, and Requirements Relating to the Approval and Acceptance of Improvements in Subdivisions or Re-Subdivisions, 1997
Nueces County	HS-20	Nueces County Subdivision Rules and Regulations, 2006

Recommended Software Programs

Bridge components can be designed using various engineering software programs. Software programs are essential for the efficient and cost-effective design and evaluation of bridges (Russo et al., 2003). The TxDOT has recommended different software programs that can be used to design the structural components of bridges (e.g., superstructures and substructures). Examples of software programs recommended by the TxDOT for the structural design of bridge components are presented in Table 2-5.

Table 2-5 Recommended software programs by the TxDOT for the design of structural components of bridges (TxDOT, 2022a)

Bridge Component		**Software Program**	**Descriptions**
Superstructure	Pretensioned concrete I girders	BridgeLink (PGSuper)	A windows-based software program for the design, analysis, and load rating of multi-span precast-prestressed concrete bridge beams/girders according to the AASHTO LRFD Bridge Design Specifications (thru the 9th Edition, 2020) and by TxDOT design policies and guidelines.
	Pretensioned concrete U beams		
	Pretensioned concrete slab beams and decked slab beams		
	Pretensioned concrete box beams		
	Prestressed concrete beam	PSTRS14	Windows-based software for the design and analysis of standard and user-defined non-standard, simple span prestressed concrete beams having fully bonded draped or straight strands, or partially de-bonded straight strands, according to the AASHTO Load and Resistance Factor Design (LRFD) Specifications (3rd Edition, 2004-2006; 4th Edition, 2007-2009; 5th Edition, 2010; and 6th Edition, 2012), AASHTO Standard Specifications for Highway Bridges (15th Edition, 1994 Interim thru 17th Edition, 2002), or American Railway Engineering and Maintenance-of-Way Association (4th Edition, 2008-2009).
Substructure	Bent cap	CAP 18	A specialized structural analysis program using a discrete element model that produces envelopes of maximum bending and shear forces acting on bridge bent caps. Analytical results are for working stress and/or load factor design according to the AASHTO LRFD Bridge Design Specifications or the AASHTO Standard Specifications for Highway Bridges.
	Concrete piers	PIER	A specialized program that performs non-linear analysis of slender, non-prismatic, and hollow core concrete

Although the Texas Department of Transportation has recommended different software programs to assist engineers in the design of bridges, there is a gap in the local governments' design manuals regarding the documenting software programs that the designers may use to design off-system bridge components.

2.1.3 Geotechnical Design

The latest edition of AASHTO LRFD Bridge Design Specifications provides minimum standards for the geotechnical investigations related to the design of bridge substructures, including the spread footings, driven piles, drilled shaft, and micro-pile foundations (AASHTO, 2020). Moreover, the Texas Department of Transportation has developed the TxDOT Geotechnical Manual that meets the minimum standards outlined in the AASHTO LRFD Bridge Design Specifications and is approved by the FHWA. While the Texas Department of Transportation requires using the TxDOT Geotechnical Manual for on-system projects, local governments can use their local manual for geotechnical investigations and design of off-system bridges, which may differ in some provisions from TxDOT manuals. For example, while the TxDOT Geotechnical Manual requires the Texas Cone Penetration (TCP) test for the bridge field exploration, the local governments may recommend the Standard Penetration Test (SPT) as outlined in the AASHTO LRFD Bridge Design Specifications (TxDOT, 2020b). Table 2-6 shows examples of provisions for soil sampling methods and intervals based on different reference manuals.

Table 2-6 Examples of soil sampling method and interval provisions based on different reference manuals

State, Local, or Federal Government	Soil Sampling Method and Interval Provisions	Reference
FHWA	SPT is performed continuously or at intervals of 2.5 ft. at depths shallower than 10 ft., SPT is performed at intervals of 5 ft. when the depth is deeper than 10 ft.	FHWA, 2006
TxDOT	TCP is performed at 5-ft. intervals beginning at 5-ft depth.	TxDOT Geotechnical Manual, 2020
City of Houston	If a soil boring is within the TxDOT right-of-way, then the current TxDOT guidelines shall be followed, including TCP tests. If a soil boring for a bridge or retaining wall is outside the TxDOT right-of-way, then the TCP test is not required. However, TxDOT sampling interval guidelines shall be followed.	City of Houston, 2021
City of Galveston	Test holes near each abutment of the proposed structure plus a sufficient number of intermediate holes to determine the depth and location of all significant soil and rock strata.	City of Galveston Technical Standard Manual, 2022

Recommended Software Programs

Various engineering programs assist engineers in the geotechnical investigation and design of bridge foundations. Table 2-7 provides information about the TxDOT-supported program for the analysis and design of bridge foundations.

Table 2-7 Recommended software program by TxDOT for the analysis of bridge foundations and soil reports

Purpose	Software Program	Description
Foundation and soil report	WINCORE	Analyzes and reports soil borings in accordance with TxDOT Standards. Accompanying MicroStation macros allows WinCore files to be accessed from inside MicroStation for the automated drawing of core logs in design files. Macros are compatible with MicroStation Versions J and V8.

In addition, there are other industry-standard software packages, such as LogPlot, LogitEasy, and LogDraft, that engineering consulting firms or bridge developers may use for geotechnical investigations related to bridge projects. While the Texas Department of Transportation has developed and recommended WINCORE to facilitate the geotechnical investigations in accordance with TxDOT standards, there is a gap in local governments' guidelines about documenting appropriate programs that bridge designers may utilize for geotechnical investigations of bridge projects.

2.1.4 Standard Specifications

A standard or specification sets rules and conditions to define, measure, and test materials and products. To ensure compatibility between products from different sources, the Federal Highway Administration has issued standard specifications for constructing roads and bridges under the direct management of the FHWA (FHWA, 2014). According to the FHWA, state agencies may use their local standard specifications to construct projects on the state highway systems (FHWA, 2014). The Texas Department of Transportation has established standards and specifications for constructing and maintaining highways, streets, and bridges (TxDOT, 2014). While the TxDOT requires the on-system state projects to be constructed following the TxDOT Standard Specifications, the local governments may develop and follow local procedures for the construction of off-system projects (TxDOT, 2009). These procedures may result in some differences in the material specifications or construction as described below:

Concrete Placing Temperature

The hydration of concrete can be significantly impacted by extreme temperatures, which can compromise the strength development of concrete (Hu et al., 2021). The TxDOT Standard Specifications, Item 422, requires that the minimum and maximum temperature for concrete placing for superstructures (e.g., bridge slabs) be 50°F and 85°F, respectively. It also specifies that the minimum temperature could be increased to 60°F if slag cement is used in the concrete (TxDOT, 2014). The Federal Highway Administration's standard specification has decreased the maximum temperature by 5°F and indicates that the concrete placing temperature for bridge slabs should be between 50°F and 80°F (FHWA, 2014). Table 2-8 summarizes the provisions for concrete placing temperature based on currently used standard specifications in the federal, state, and local governments.

Table 2-8 Concrete maintaining temperature based on different standards.

Local, State, or Federal Government	**Minimum Concrete Placing Temperature**	**Maximum Concrete Placing Temperature**	**Placing Concrete in Cold Weather**	**Placing Concrete in Hot Weather**
TxDOT	50°F (60°F if slag cement is used)	85°F	• Maintain the temperature of the top surface of the bridge. • Slabs and top slabs of direct traffic culverts at 50°F or above for 72 hours. • Maintain the temperature of bent piers and other similar forms at 40°F or above for a period of 72 hours from the time of placement.	• Maintain the concrete temperature at or below the maximum temperature during place placement.
FHWA	50°F	90°F (80°F for bridge deck)	• Maintain concrete temperature for at least 72 hours, according to Table 2-9.	• Reduce the temperature of the surfaces that come in contact with the mix below 90 °F by shading the material storage, sprinkling, and material and water refrigeration.
City of Lubbock	50°F	85°F	• Maintain the temperature of slab concrete of all unformed surfaces at 50°F or above for 72 hours from the time of placement and above 40°F for an additional 72 hours. • Maintain the temperature of bents, piers, and other similar forms at 40°F or above for 72 hours from the time of placement.	• Use retarding agent when the air temperature is above 85°F.
City of Austin	50°F	95°F	• Maintain the temperature of slab concrete of all unformed surfaces at 50°F or above for 72 hours from the time of placement and above 40°F for an additional 72 hours. • Maintain the temperature of bents, piers, and other similar forms at 40°F or above for 72 hours from the time of placement.	• Use retarding agent when the air temperature is above 85°F. If concrete mixes include high-range water reducers, a maximum temperature of 100°F is allowed.

Table 2-9 Cold weather concrete surface temperature (FHWA, 2014)

Minimum Section Size Dimension	**< 12 inches**	**12 – 36 inches**	**36 – 72 inches**	**> 72 inches**
Minimum temperature of concrete during the protection period	55 °F	50 °F	45 °F	40 °F
Maximum allowable temperature drops in 24 hours after the end of protection	50 °F	40 °F	30 °F	20 °F

Concrete Transporting Time

Concrete transporting time can also vary according to standard specifications adopted by federal, state, or local governments. Ready-mix concrete is generally produced in large quantities and is transported to distant places for placement in structural elements. Transit time influences the quality of concrete; the concrete quality decreases when the transit time is long. Different standard specifications have set the maximum allowable transporting time for the concrete to ensure the quality of concrete during placement. Table 2-10 and Table 2-11 summarizes the concrete transporting times according to different standard specifications.

Table 2-10 Concrete transportation time for bridge superstructures (e.g., bridge deck)

State or Local Government	Type of Concrete	Concrete Temperature (°F)	Maximum Time w/o Retarder (minutes)	Maximum Time with Retarder (minutes)
TxDOT	-	90 and above	45	75
		75 to 90	60	90
		below 75	90	120
City of Austin	Non-agitated	35 to 79	45	45
		80 and above	30	45
	Agitated	90 and above	45	75
		75 to 89	60	90
		35 to 74	90	120
City of Dallas	Non-agitated	80 or above	15	45
		38 to 79	30	60
	Agitated	90 or above	45	75
		75 to 79	60	90
		38 to 74	90	120
City of Abilene	Non-agitated	80 and above	15	30
		80 and below	30	45
	Agitated	90 and above	45	75
		75 to 90	60	90
		below 75	90	120

Table 2-11 Concrete remixing and discharge time limits with a truck agitator (FHWA, 2014)

Cement Type	Admixture	Remixing Time Limit (hour)	Discharge Time Limit (hour)
Type I, IA, II, IIA, V, or approved blended hydraulic cement	None	0.75	1
Type I, IA, II, IIA, V, or approved blended hydraulic cement	AASHTO M 194, Type B, D, or G	1.25	1.5

Type I, IA, II, IIA, V, or approved blended hydraulic cement	Hydration stabilizer	3	Approved design discharge time limit, 3.50 maximum
Type III	None	0.5	0.75
Type III	AASHTO M 194, Type B, D, or G	1.00	1.25

Note: non-agitating equipment may be used to deliver concrete if the concrete discharge is completed within 20 minutes from the beginning of the addition of the cement to the mixing drum.

2.1.5 Bridge Railing

Bridge railings are guardrail systems designed to prevent people or vehicles from falling off the bridge. There are various types of railings, including metal railings, concrete railings, and metal and concrete railings. These railings are classified for use according to the following definitions (TxDOT, 2020c):

- Traffic Railing: a railing used adjacent to vehicular traffic and successfully crash-tested to current test criteria.
- Pedestrian Railing: a railing adjacent to a pedestrian walkway, with specific height and opening requirements.
- Combination Railing: a traffic railing satisfying the height and opening requirements of a pedestrian railing.

The AASHTO Manual for Assessing Safety Hardware (MASH) presents guidelines for crash testing of permanent and temporary highway safety features and recommends evaluation criteria to assess test results. The FHWA recommends MASH for highway design engineers with safety features such as bridge railing used on highways. Prior to MASH, the National Cooperative Highway Research Program (NCHRP) Report 350 recommended procedures for the safety performance evaluation of highway features. According to a memorandum from Thomas Everett on the subject of "AASHTO/FHWA Joint Implementation Agreement for Manual for Assessing Safety Hardware," all new installations of safety hardware on the national highway system shall be evaluated using the 2016 edition of MASH (TxDOT, 2020c). This memorandum indicates that the safety hardware previously accepted using the NCHRP criteria does not need to be retested using MASH criteria (AASHTO, 2020). The highway safety hardware not previously evaluated

must utilize MASH criteria for testing and evaluation. Some significant differences between MASH and NCHRP Report 350 guidelines are summarized in Table 2-12.

Table 2-12 Major differences between NCHRP Report 350 and MASH guidelines

Topic	NCHRP Report 350	MASH
The small car test vehicle	820C vehicle (1,800 lbs.)	1100C vehicle (2,420 lbs.)
The small car impact angle	20°	25°
The light truck test vehicle	2000P (4,400 lbs.)	2270P (5,000 lbs.)
The gating terminals and crash cushion impact angle	15°	5° - 15°
The variable message signs and arrow board trailers	Not mentioned	Added to TMA crash test matrix
The support structure and work zone traffic control device testing	Only small cars tested	Small car and light truck tested
The windshield damage criteria	Subjective/Qualitative	Objective/Quantitative
The vehicle rebound in crash cushion tests	None	Required
TL-4 truck weight	17,600 lbs.	22,000 lbs.
TL-4 truck speed	80 km/hr.	90 km/hr.
The option for using passenger car test vehicles older than six years	Exist	Removed
The windshield damage evaluation	Qualitative	Quantitative
The CAD drawing of the test device and test installation	Not required	Required
The vehicle rebound in crash cushion tests	None	Required
The support structure and work zone traffic control device testing	Tested only small car	Tested both small car and light truck
Variable message sign and arrow board trailers	Not mentioned	Added to the truck-mounted attenuators

According to the AASHTO, agencies may develop objective guidelines for using bridge railings. These guidelines should consider factors such as traffic conditions, volume and mix, cost and in-service performance, and life-cycle cost of existing railings (AASHTO, 2020). For this purpose, the Texas Department of Transportation has developed the TxDOT bridge railing manual as

guidelines for the district and division personnel and consultants employed by TxDOT. This manual describes the policy on using bridge railing in Texas and provides guidelines for railing selection. According to the TxDOT bridge railing manual, the railing on new bridges must meet the FHWA crash-test criteria as specified in MASH 2016. For the upgrading of existing bridge railings, although the MASH implementation memorandum requires that only MASH-approved devices are allowed for bridge railing installations, TxDOT has set specific requirements for the upgrading of existing railings depending on the project classifications (Table 2-13).

Table 2-13 TxDOT requirements for upgrading existing bridge railing for various project classifications (TxDOT, 2020c)

Project Classification		**Railing Action**
Preventive Maintenance and Restoration		• Replacement of traffic railing not complying with MASH or NCHRP Report 350 is recommended but not required if the minimum rail height requirement is met. • Existing traffic railing complying with MASH or NCHRP Report 350 may be raised to meet the minimum rail height requirement. • Existing rail that does not meet the minimum rail height and does not comply with MASH or NCHRP Report 350 must be upgraded to comply with MASH.
Rehabilitation	If the structure is not widened and if no work affecting the existing railing is done as part of the 3R project	• Replacement of traffic railing not complying with MASH or NCHRP Report 350 is recommended but not required if the minimum rail height requirement is met. • Existing traffic railing complying with MASH, NCHRP Report 350 may be raised to meet the minimum rail height requirement.
	If the rehabilitation work is scheduled or performed with the widening of the structure or full-depth repair of the deck, or if any work affecting the rail is done to the existing structure as part of the 3R project	• All traffic railing on the structure must comply with MASH. Railing adjacent to pedestrian walkways must comply with chapter 3 of the bridge railing manual requirements. • Exceptions by approval of Design Exception or Design Waiver Request. Submit the Design Exception or Design Waiver Requests to the Bridge Division. • Exceptions to compliance with MASH: 1. Design exception approval is required if the average daily traffic is greater than 1,500 vehicles per day. 2. Design Waiver approval is required if the average daily traffic is less than 1,500 vehicles per day
Reconstruction		• Traffic railing must comply with MASH. Railing adjacent to pedestrian walkways must comply with chapter 3 of the bridge railing manual requirements. • Exceptions by approval of Design Exception Request.
Hazard Elimination Program (HES) Projects		• Rehabilitation or Reconstruction criteria as applicable to the elements affected by the programmed scope of the HES project.
All Project Classifications		• When traffic rail is upgraded to MASH, the adjacent metal beam guard fence and guard fence transition must also be upgraded.

Although TxDOT encourages the local governments to adhere to the same practices followed for the state project, the local governments may have additional details or provisions for the design, selection, or placement of railing systems. Table 2-14 illustrates examples of provisions in local or state design manuals related to bridge railings.

Table 2-14 Different requirements set by local/ state agencies related to the design of bridge railing

State or Local Government	**The nominal face of the rail from the outside edge of bridge slabs**	**Separator railing**
TxDOT	• 1.5 ft. for T66, T224, T80TT, C412, and C66 railing types • 1 ft. for other types	• Separator railing may be appropriate on lower-speed bridges close to schools or with significant pedestrian traffic. Sites should be evaluated on a case-by-case basis.
City of McKinney	2 ft.	• Separation rails shall be provided on all major and minor arterial bridges. • Separation rails shall not be required on collectors, local streets, or culverts where the sidewalk is not located adjacent to the back of the curb.
City of Dallas	2 ft.	*Not available*
City of Austin	*Same as TxDOT*	• Pedestrian railing shall be used in conjunction with a non-combination bridge railing when a bridge railing is to be specified on a bridge with a pedestrian access route, and a combination railing is deemed inappropriate.
City of Mesquite	2 ft	• Separation rails shall be provided on all major and minor arterial bridges. • Separation rails shall not be required on collectors, local streets, or culverts where the sidewalk is not located adjacent to the back of the curb.

2.1.6 Plan Sheets and Detailing

The state and local governments generally set guidelines for bridge designers and technicians regarding the detailing criteria applied to bridge plan sheets before submission. The plan sheets are used by the contractor to bid on a project and ultimately build it. Therefore, the plans must convey the bridge designer's intent and give clear direction to the contractor during construction. Moreover, the as-built plans developed for bridge projects should be turned over to the state or

local governments to be archived. These plans can help to determine structural capacity, foundation depths for flood planning, and maintenance needs. For this purpose, the Texas Department of Transportation has developed the Bridge Detailing Guide to provide information for designers in preparing the bridge plan sheets. This guideline covers various topics concerning the detailing of plans for on-system bridges. According to TxDOT Bridge Detailing Guide, a typical bridge plan sheet set includes (TxDOT, 2022b):

- Bridge Hydraulic Data Sheets, Bridge Scour Data Sheet
- Bridge Layout, Detailed Quantity Summary, and Structural Details (grouped for each bridge):
    - Layout
    - Bridge Typical Section and/or Phasing Sheets (if needed)
    - Demolition and/or Work Sequencing Sheets (if needed)
    - Detailed Quantity Summary
    - Foundation Layout (if needed)
    - Abutment Structural Details
    - Interior Bent Structural Details
    - Framing Plans
    - Spans or Units Structural Details (in order)
    - Miscellaneous Bridge Details
- Structural Standards

The TxDOT requires developers to electronically submit the plan sheets to be reviewed by different divisions at 30%, 60%, 95%, or 100% milestones or the district's request (TxDOT, 2017). The Design Division's field operations section reviews the layout for roadway items, such as roadway width, compliance with approved schematic, and vertical and horizontal curvature (TxDOT, 2017); the Design Division's hydraulics section reviews the layout for hydraulic items, such as design frequency, Federal Emergency Management Agency (FEMA) requirements, as well as the hydraulic methodologies used (TxDOT, 2017); the Bridge Division's geotechnical section reviews the layout for geotechnical items, such as types of foundations, soil borings, retaining walls, and scour analysis (TxDOT, 2017); and the Bridge Division's design section reviews the layout for structural items, such as beam types, span lengths, and crash-tested railings (TxDOT,

2017). Once the review process is over and the bridge layout is approved, the final plan sheets will be submitted to the TxDOT Bridge Division. For the final as-built plan, the title sheet shall be signed, sealed, and dated by the responsible registered professional engineer to reflect that the construction work was performed following the plans and contract (TxDOT, 2017). Although the TxDOT encourages local governments to follow similar practices that TxDOT follows for preparing and submitting bridge plan sheets, the local governments may use their local procedures. Table 2-15 summarizes examples of the current practices in state or local governments in Texas for preparing and submitting the bridge plan sets based on the published guidelines.

Table 2-15 Current practices of the state or local governments of Texas in collecting the bridge plans' set

State or Local Government	Bridge Hydraulic and Scour Data	Structural Detail	Plan Layout	Profile Layout	Geotechnical Report	Cost Estimate	Electronic	Hard-Copy
TxDOT	✓	✓	✓	✓	✓	✓	✓	-
City of Dallas	-	✓	✓	✓	✓	✓	✓	-
City of Houston	-	✓	✓	✓	✓	-	✓	-
Harris County	-	✓	✓	✓	✓	✓	-	-
Williamson county	✓	-	-	-	-	-	✓	-
City of San Antonio	✓	✓	✓	✓	-	-	✓	-
Travis County	-	✓	✓	✓	✓	✓	-	-
City of McAllen	✓	✓	✓	✓	-	-	✓	
Montgomery County	-	✓	✓	✓	-	-		✓
Denton County	All engineering shall be of a level of detail and quality required of a qualified and competent engineer meeting the professional standards of a licensed professional engineer practicing in Denton County, Texas.						-	✓
Nueces County	Final plans shall be prepared to show the structure as built, including the depth of the drill shafts, piling, footings, etc. The final plans shall be signed and sealed by a professional engineer registered in the state of Texas and furnished to the Nueces County Department of Public Works.						-	✓

2.3 Conclusion

This chapter synthesized and evaluated the information available in the literature about the manuals, guidelines, and standards for bridge design, construction, and maintenance. Initially, the prevalent aspects of bridges that have dedicated manuals, guidelines, and standards were identified. Subsequently, these guidelines were categorized into different groups: structural design, geotechnical design, hydraulic design, bridge railing, standard specifications, and plan sheets and detailing. Each category was discussed in detail, and examples of differences between the existing federal, state, and local governments' manuals, guidelines, and standards were presented. This chapter highlighted the discrepancies among local governments in designing, constructing, and maintaining bridges, showing the crucial need for a comprehensive synthesis of local government guidelines. Although TxDOT and some local governments have published comprehensive guidelines for developing, constructing, and maintaining bridges, many local governments, especially small or remote cities/counties, do not provide these guidelines. Therefore, it is necessary to create appropriate survey questions and conduct follow-up interviews with the bridge engineering personnel of counties and cities, along with engineering consulting firms, to identify potential gaps in the procedures followed for the design, construction, and maintenance of off-system bridges in Texas.

Chapter 3
SURVEY ANALYSIS ON BUILDING CODES FOR BRIDGES

3.1 Introduction

Three surveys were designed for local governments, engineering consulting firms, and TxDOT personnel and bridge experts to identify the current building codes and standards that cities/counties have in place for developers to design and construct off-system bridges, as well as their practices for acquiring the designs and plans after construction is completed. The research team used "QuestionPro" as an online platform to conduct the survey for this research. The survey questionnaires for local governments, engineering consulting firms, and TxDOT can be found in Appendix A, Appendix B, and Appendix C, respectively. The surveys were distributed among directors of the local government's engineering department (807 individuals), engineering consulting firms (290 individuals), and TxDOT bridge experts (173 individuals). An invitation email along with the online link to the survey was sent to potential survey respondents to distribute the surveys.

The first survey questionnaire for local governments comprised six sections: participants' contact information, overall conditions of off-system bridges within local governments, current bridge codes and standards in place, preparation and submission of plans, adherence to the TxDOT recommendations for off-system bridges, and willingness for follow-up interviews.

The second survey for engineering consulting firms was designed to identify the building codes and standards they use to design and construct off-system bridges and the practices they follow to prepare and submit the plans to local governments. This survey comprised five sections: participants' contact information, type of engineering services they offer, bridge codes and standards they use, preparation and submission of plans, and willingness for follow-up interviews.

The third survey questionnaire for TxDOT personnel was designed to determine if the TxDOT districts' bridge engineers are particularly interested in including certain local governments in the research project.

The following sections present a descriptive analysis of the survey results from local governments, engineering consulting firms, and TxDOT.

3.2 Local Governments Survey Structure

The final survey questionnaire for local governments was designed to identify the (1) common causes and locations of deficiencies in off-system bridges within local governments, (2) current building codes and standards that local governments have in place for developers for the design and construction of off-system bridges, and (3) the state of practice in local governments for preparation and submission of final bridge plan sets. The first section of the survey required participants to provide their contact information. The second section of the survey provided a brief overview of off-system bridges and inquired whether the local government owns or maintains any of these bridges. If the respondent indicated that they do not maintain any off-system bridges, the survey was stopped. Otherwise, it continued to ask about the overall conditions of the off-system bridges (i.e., frequency of observing bridge deficiencies, locations where the deficiencies mostly observe, and the causes of the deficiencies). The third section of the survey asked if the local government requires developers to follow any building codes or standards for the design and construction of off-system bridges. If the answer was yes, the survey became more specific and asked about the type of building codes and the standards that the local governments have in place for developers. The fourth section of the survey asked about the local government's requirements for developers in terms of preparation and submission of bridge plan sets. The fifth section asked about the adherence of local governments to the recommendations provided by TxDOT for off-system bridges, and the last section asked participants if they were interested in participating in a follow-up interview.

3.2.1 Local Government Survey Responses

In total, seventy-one (71) local governments across Texas responded to the survey. Figure 3-1 presents a descriptive analysis of respondents, including the job title of the responders, the number of cities and counties that responded to the survey, and the number of local governments maintaining off-system bridges.

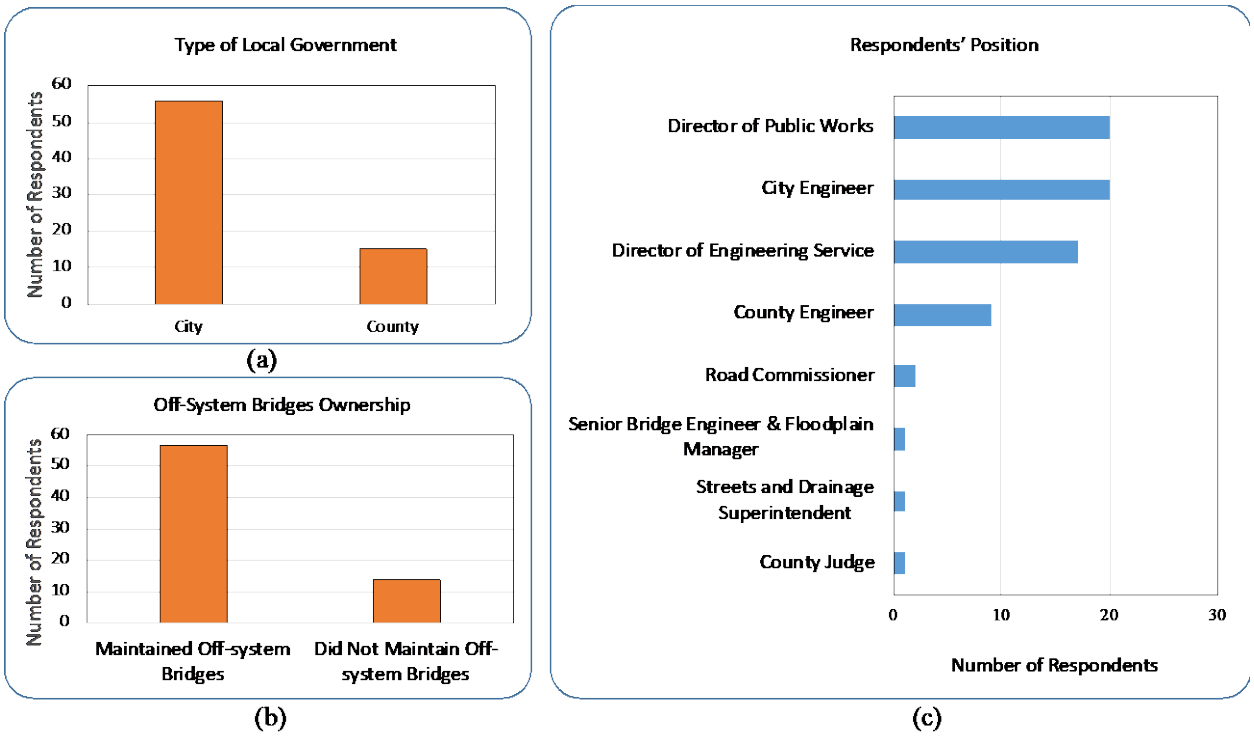

Figure 3-1 Descriptive analysis of the survey respondents from local governments: (a) the total number of cities and counties, (b) the number of local governments with off-system bridges, and (c) the job title of the responders

3.2.2 Overall Conditions of Off-system Bridges in Local Governments (LGs)

The survey results from forty-nine (49) respondents who indicated that they maintain off-system bridges within their local government are summarized in Figure 3-2. According to the results, approximately 15% of respondents observed bridge deficiencies in their off-system bridges frequently or occasionally. The remaining 85% of local governments faced such deficiencies in their off-system bridges rarely, very rarely, or never. Furthermore, the respondents indicated that most frequently observed deficiencies are with the bridge railing, followed by deficiencies in signs, deck, substructure, and superstructure. In addition, the respondents indicated that hydraulic issues are the most frequent cause of bridge deficiencies, followed by lack of maintenance, overload, construction error, and design error.

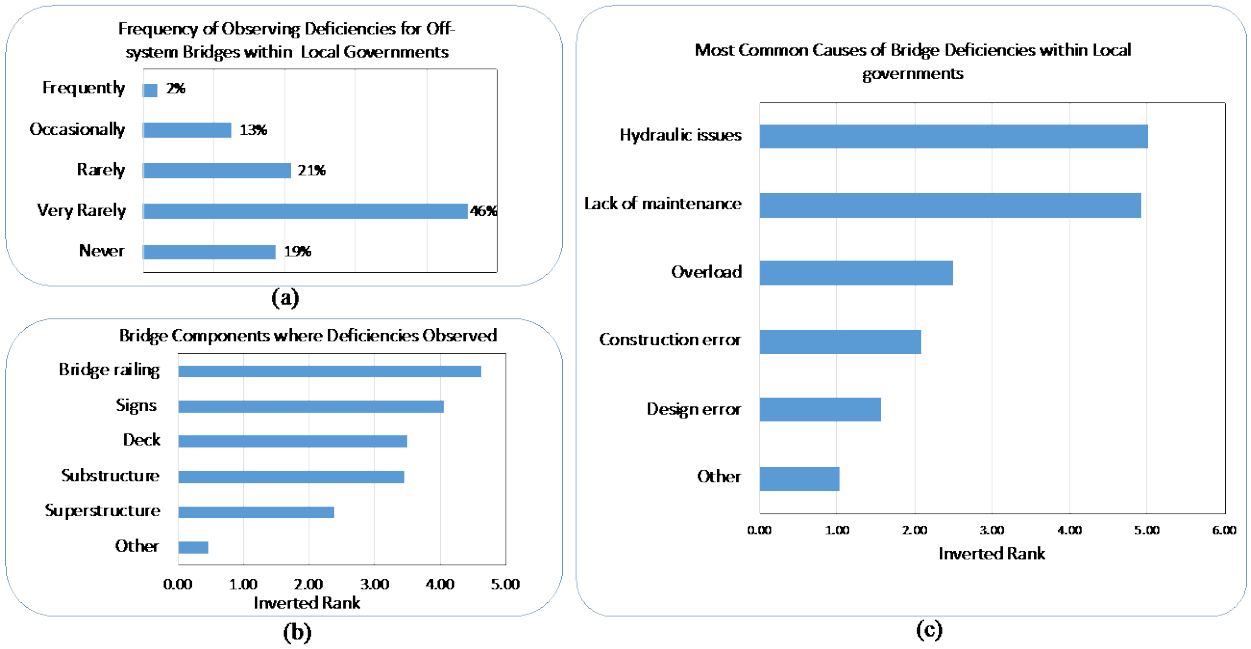

Figure 3-2 Overall conditions of off-system bridges: (a) Frequency of observing bridge deficiencies for off-system bridges within local governments, (b) locations where deficiencies mostly observe, and (c) most common causes of bridge deficiencies

3.2.3 Building Codes and Standards for Off-System Bridges

Survey responses of participants from forty-nine (49) local governments with off-system bridges are summarized in Figure 3-3. Approximately 16% of these local governments indicated that they do not have any requirements for developers for the design and construction of bridges within their jurisdiction. Among local governments with requirements, 48% reported that they rely only on state-level manuals (i.e., TxDOT), 52% reported they use both state-level and national-level manuals (i.e., combinational of AASHTO, TxDOT, and FHWA).

Furthermore, approximately 18% reported that they have additional requirements within their local government for the design and construction of off-system bridges.

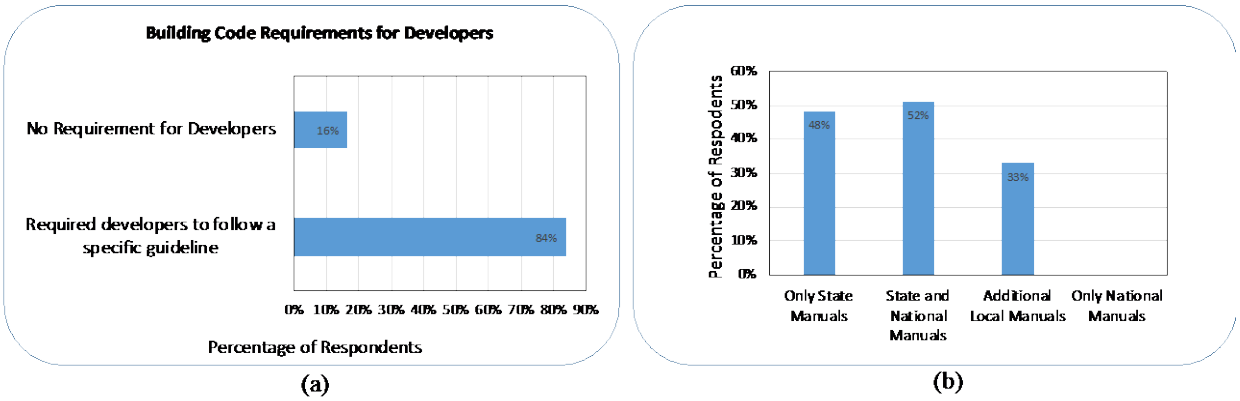

Figure 3-3 Surveys results for building codes and standards: (a) building codes and standards requirements for developers, and (b) type of design manuals that are in place for developers

Local Governments with Only State-Level Design Manuals

According to the results from the respondents that solely rely on state-level building codes and standards, the "TxDOT Bridge Design Manual-LRFD" and the "TxDOT Standard Specifications" were the primary building codes utilized for the design and construction of bridges. In contrast, the "TxDOT Corrosion Protection Guide" and the "TxDOT Quality Control and Quality Assurance Guide" were not as commonly referred to in local governments. Figure 3-4 presents the frequency of using state-level building codes and standards for off-system bridges within local governments that solely rely on state-level manuals.

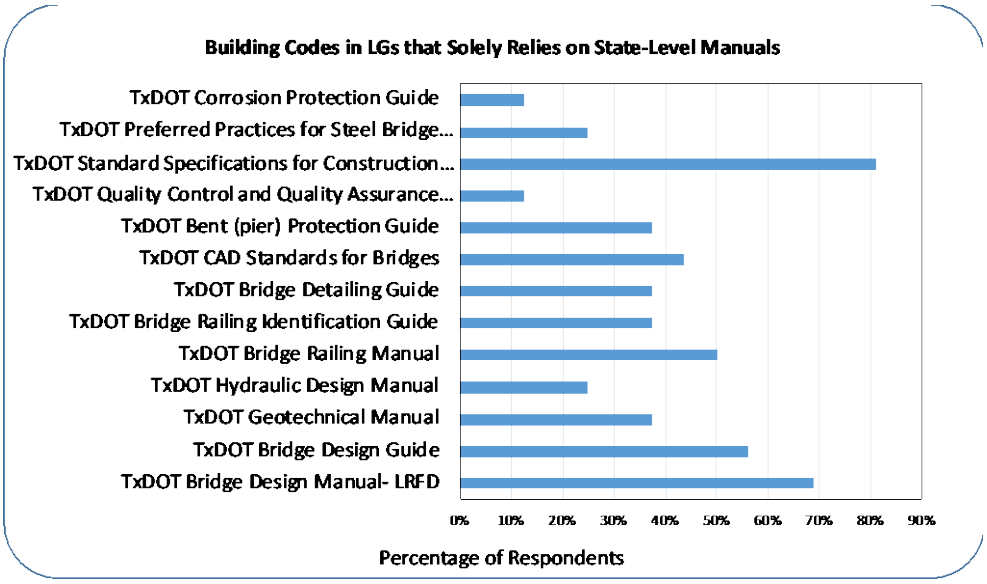

Figure 3-4 Frequency of using the state-level bridge design manuals in local governments with only state-level requirements

Local Governments with both National-Level and State-Level Design Manuals

According to the survey results from local governments that rely on both national-level and state-level design manuals, the "AASHTO LRFD Bridge Design Specifications" was the most prevalent manual in place for developers for the design and construction of off-system bridges, followed by "TxDOT Bridge Design Manual-LRFD," "AASHTO Standard Specifications for Highways Bridges, and "TxDOT Standard Specification." Figure 3-5 presents the frequency of using the bridge building codes and standards in local governments that rely on both national-level and state-level requirements.

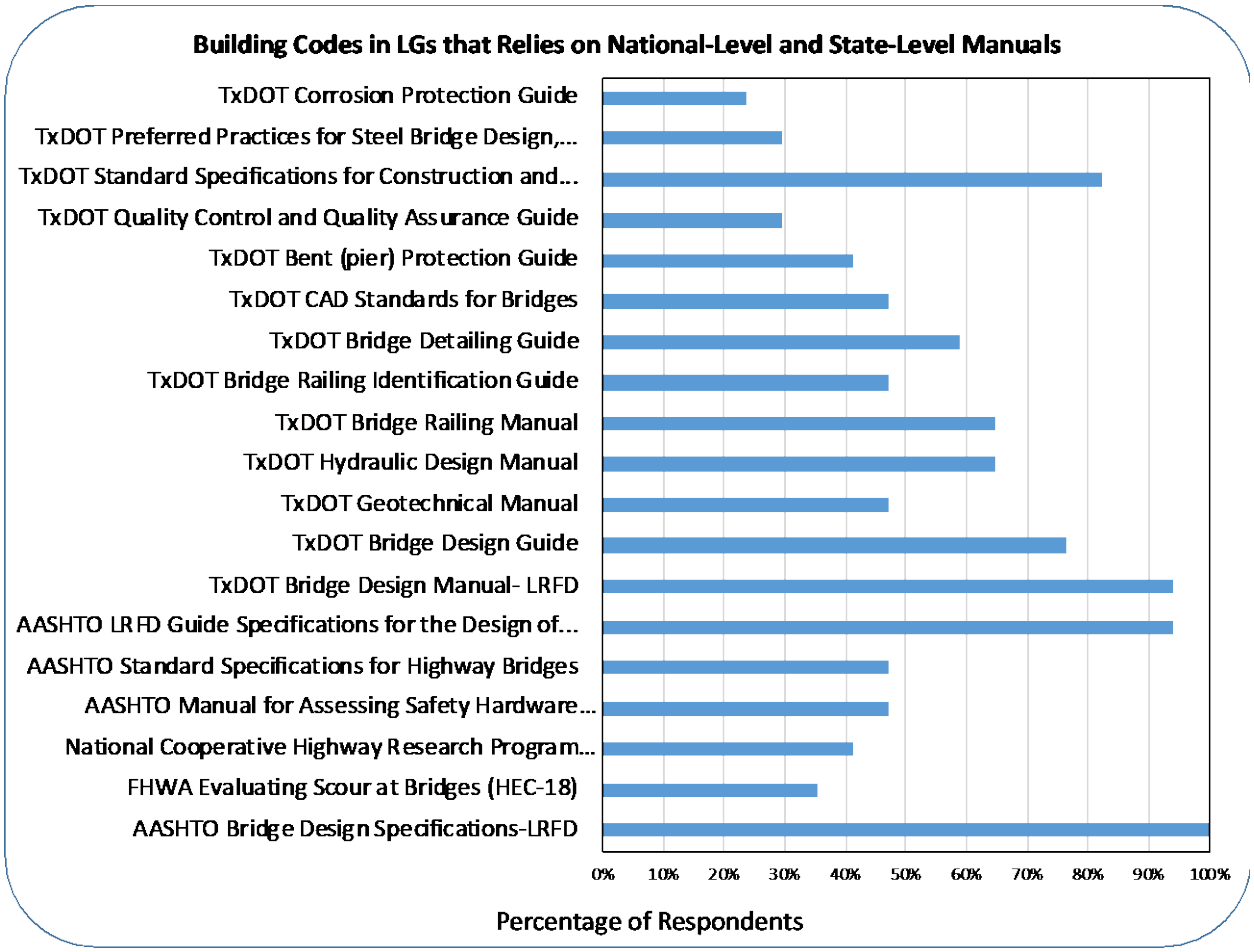

Figure 3-5 Frequency of using the design manuals in local governments with both national-level and state-level requirements

Local-Level Design Manuals

According to the survey results from respondents who indicated using local-level requirements, the Hydraulic design aspect of bridges was the most frequent aspect addressed in the local design manuals. Meanwhile, the Structural and Bridge Railing aspects were less commonly covered in the design manuals of local governments. Figure 3-6 summarizes the design aspect of bridges, along with the percentage of local governments that included each aspect in their manuals.

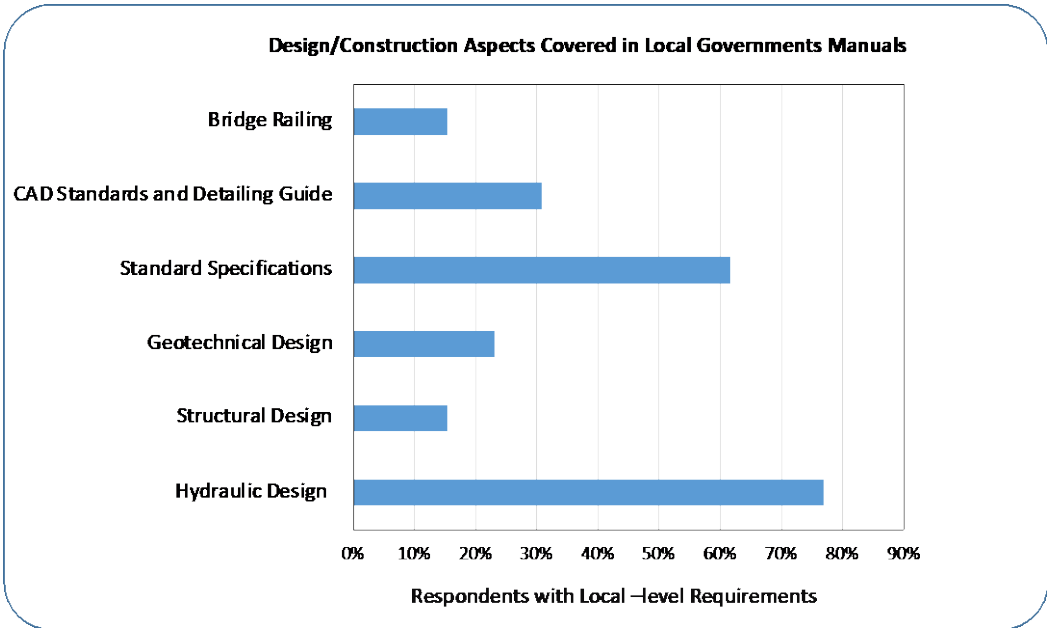

Figure 3-6 Frequency of various bridge design/construction aspects that were included in local-level design manuals.

3.2.4 Submission Requirements for Developers

In this section, responses from 42 local governments (27 cities and 15 counties) were collected. The findings revealed that all local governments enforce the signing and sealing of bridge plans set by a professional engineer. A significant majority of respondents, accounting for 98%, required developers to submit the preliminary layout to the local government for their internal review during the design process (Figure 3-7a). Only one respondent indicated that they do not require submission of the preliminary bridge plan layouts for internal review within the local government. Moreover, the survey results showed that 37% of respondents are not familiar with the TxDOT preliminary bridge layout review (PBLR) process (Figure 3-7b).

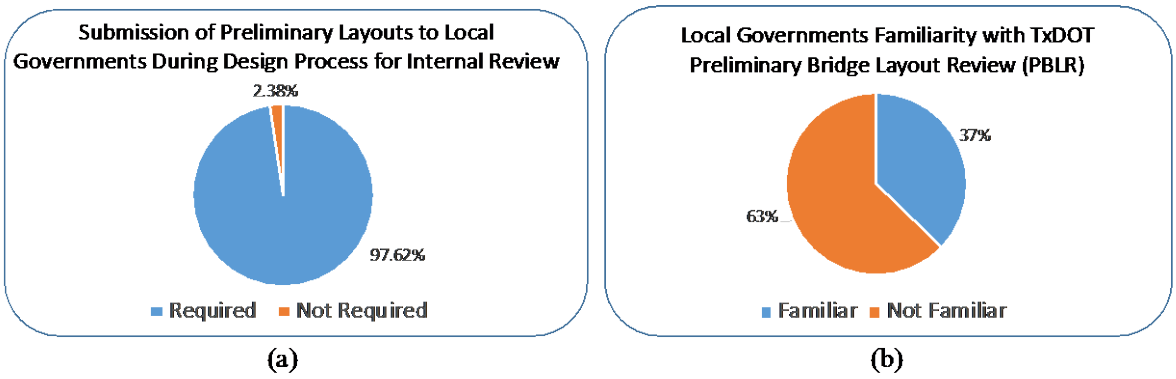

Figure 3-7 Submission requirements for developers: (a) submission of preliminary bridge layouts to local governments for internal review, and (b) familiarity of local governments with the TxDOT preliminary bridge layout review (PBLR) process

Submission of Preliminary Layout for TxDOT Review During Design Process

The results from this section of the survey showed that approximately 30% of respondents do not submit any preliminary layouts of off-system bridges for TxDOT review during the design process. Furthermore, 58% of respondents indicated that they submit the preliminary layouts for TxDOT review only for bridges that connect or cross a state highway. A minority of local governments, specifically 12%, indicated that they submit the preliminary layout of all bridges within their jurisdiction for TxDOT review (Figure 3-8).

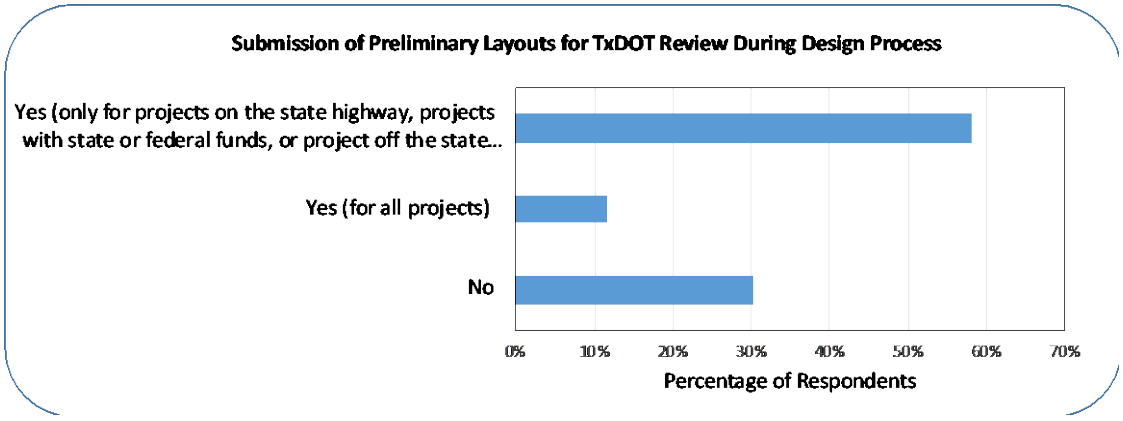

Figure 3-8 Survey results from 42 respondents on the submission of preliminary bridge layouts for TxDOT review during the design process

Records of Final Bridge Plans

According to the results, nearly 5% of respondents indicated that they do not keep records of the final bridge plan sets in their local governments (Figure 3-9a).

In addition, the results revealed that only 37% of respondents submitted the final bridge plan sets for all their off-system bridges to TxDOT. 49% of respondents indicated they submit the plans only for bridges connecting to or crossing a state highway. The remaining 14% of respondents reported not submitting the final bridge plan sets to TxDOT for any of their off-system bridges (Figure 3-9b).

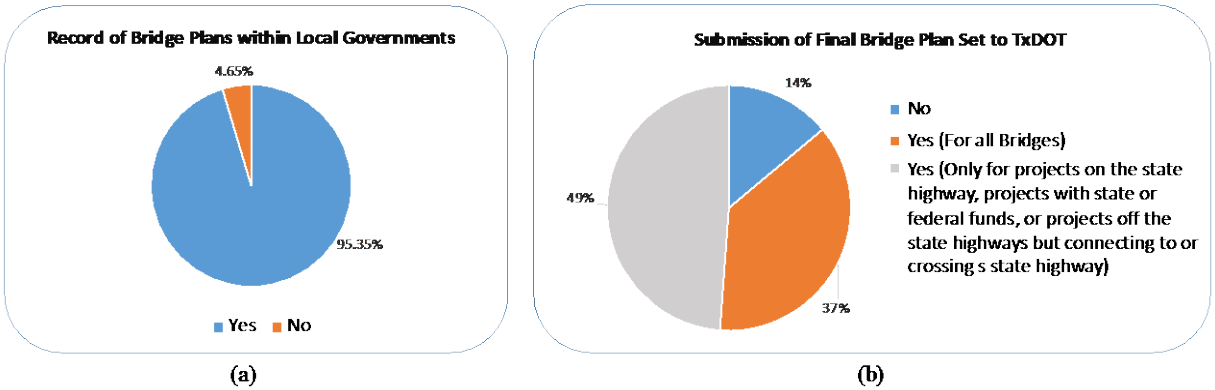

Figure 3-9 Survey results from 42 local governments on (a) record of bridge plans within local governments, and (b) submission of final bridge plan set to TxDOT

Typical Items Included in a Bridge Plan Set in Local Governments

The survey responses revealed that the "Bridge Layout and Profile" were the most common items included in the bridge set for off-system bridges in local governments. In contrast, the "Bridge Scour Datasheet" was the least frequent item in a bridge plan set within local governments. Figure 3-10 summarizes the items typically included in a bridge set, along with the frequency of including these items in a standard bridge set in local governments.

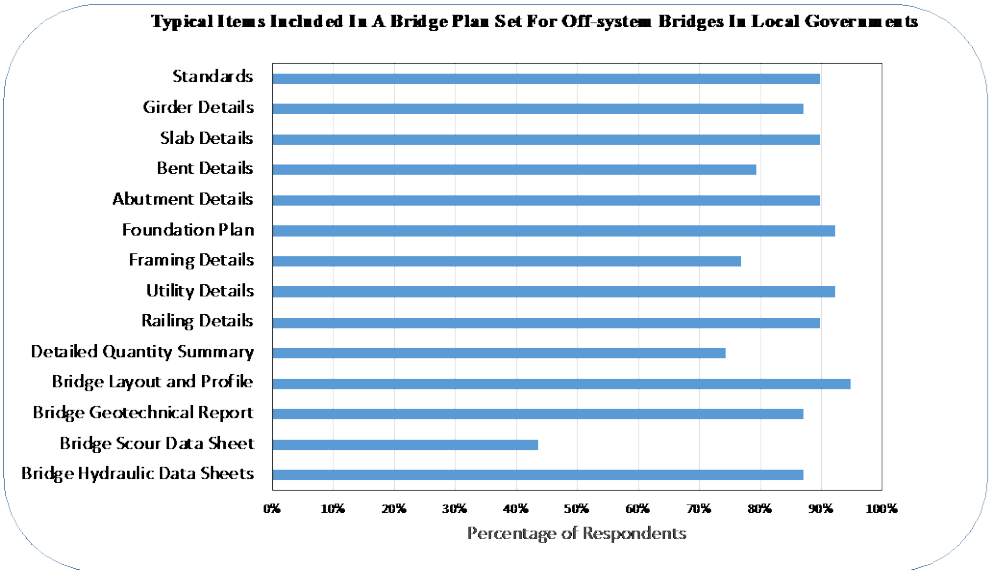

Figure 3-10 Survey results from 42 local governments on the inclusion of specific engineering items in a typical bridge plan set for off-system bridges

3.2.5 Local Governments' Adherence to TxDOT's Recommendations for Off-System Bridges

Responses from 42 local governments (27 cities and 15 counties) were collected for this question. According to the survey, nearly a quarter (around 23%) of the local governments indicated that they do not adhere to the recommendations provided in the TxDOT's inspection report for their off-system bridges (Figure 3-11).

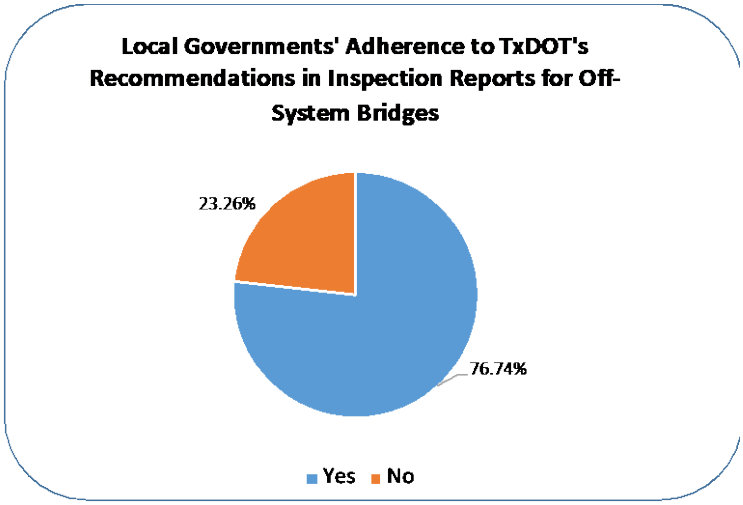

Figure 3-11 Survey results from 42 respondents on the adherence of local governments to TxDOT's recommendations for off-system bridges

3.2.6 Follow-up Interview

The follow-up section asked the respondents if they were willing to participate in the follow-up interviews and wanted to share more insight about their experience in using the existing building codes and manuals related to bridge design and construction, as well as their practices to acquire and submit the final plans. According to survey results, twenty-one (21) respondents indicated that they are willing to participate in the follow-up interviews.

3.3 Engineering Consulting Firms Survey Structure

The final survey questionnaire for the engineering consulting firms was designed to identify the current building codes and standards that engineering firms follow to design and construct off-system bridges. It also captured the existing procedures that engineering firms follow to prepare and submit bridge plans to local governments. The first section of the survey required participants to provide their contact information. Then, it provided a brief overview of off-system bridges and inquired whether the engineering consulting firm was involved in the design or construction process of these bridges in Texas. If the respondent indicated that they were not involved in the design or construction of off-system bridges, the survey was stopped. Otherwise, it continued to ask about their engineering services (second section). Depending on the answer, the third section of the survey asked about the specific building codes or standards that they follow for the design and construction of off-system bridges. The fourth section asked about the procedures that engineering consulting firms follow to prepare and submit bridge plan sets to local governments. Lastly, the fifth section asked participants if they were interested in participating in a follow-up interview.

3.3.1 Engineering Consulting Firm Responses

Ten (10) engineering consulting firms— involved in the design and/or construction of off-system bridges in Texas— responded to the survey. Figure 3-12 presents a descriptive analysis of the type of engineering services (i.e., design, construction, or both) that the respondents offered and the job titles of respondents.

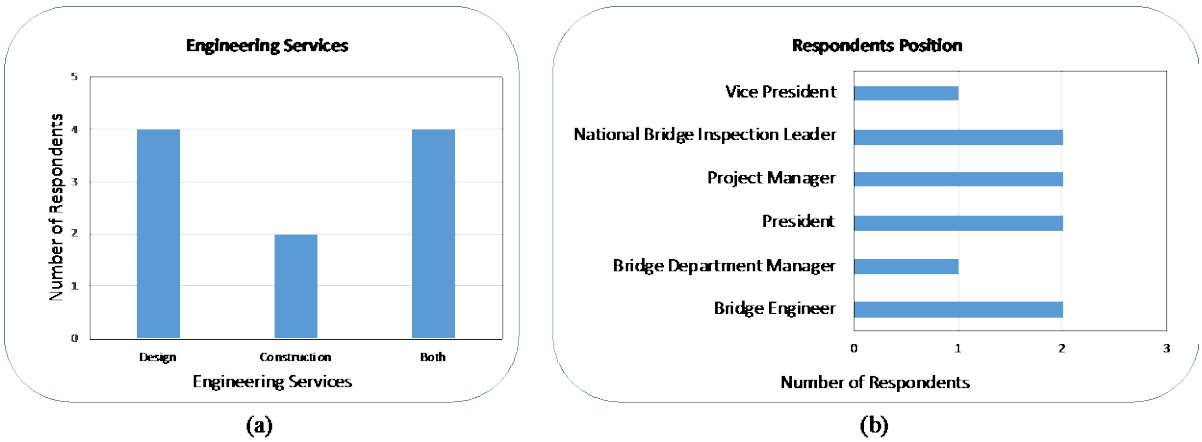

Figure 3-12 Descriptive analysis of the respondents from engineering consulting firms: (a) type of engineering service offered, and (b) respondents' job title

3.3.2 Building Codes and Standards for Off-System Bridges

Survey responses of participants from ten (10) engineering consulting firms are summarized in Figure 3-13. According to the survey results, all engineering consulting firms followed specific building codes and standards for the design and construction of off-system bridges. It was revealed that engineering consulting firms primarily rely on both state and national building codes and standards. However, 70% of the firms reported considering local-level requirements while designing or constructing bridges (Figure 3-13). It is important to note that the survey results only reflect the responses of the established firms that chose to participate in the survey. It is possible that other companies or local bridge contractors, which chose not to participate in the survey, may have different practices regarding adherence to specific building codes and standards.

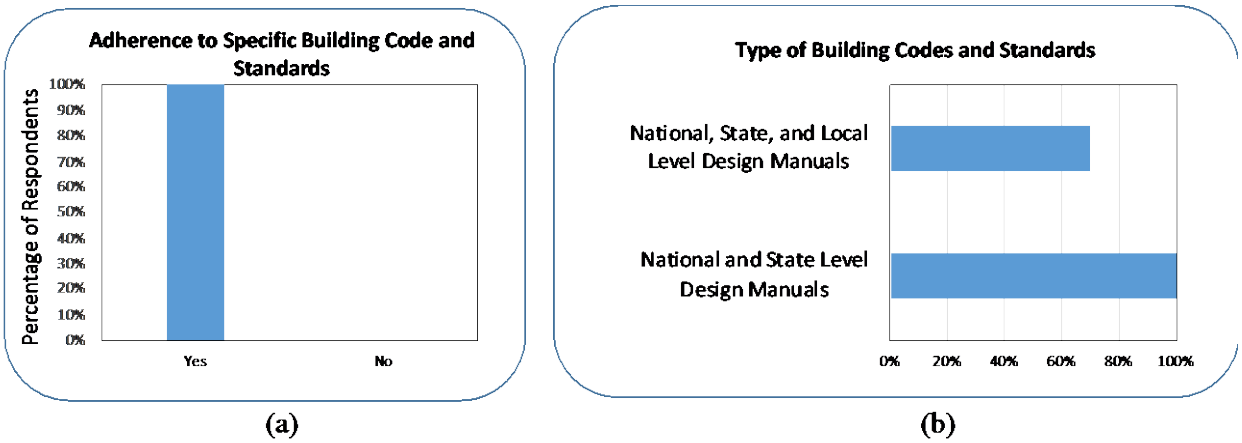

Figure 3-13 Survey results for building codes and standards: (a) adherence to specific building codes and standards, and (b) type of the building code and standards used

Figure 3-14 summarizes the state and national building codes and standards that engineering consulting firms follow to design and construct bridges. According to the survey results, engineering consulting firms frequently rely on the "TxDOT Bridge Design Manual," "TxDOT Bridge Design Guide," "TxDOT Geotechnical Design Manual," and "TxDOT Detailing Guide" as their preferred state-level manuals, as well as the "AASHTO Bridge Design Specifications" as their preferred national-level manual.

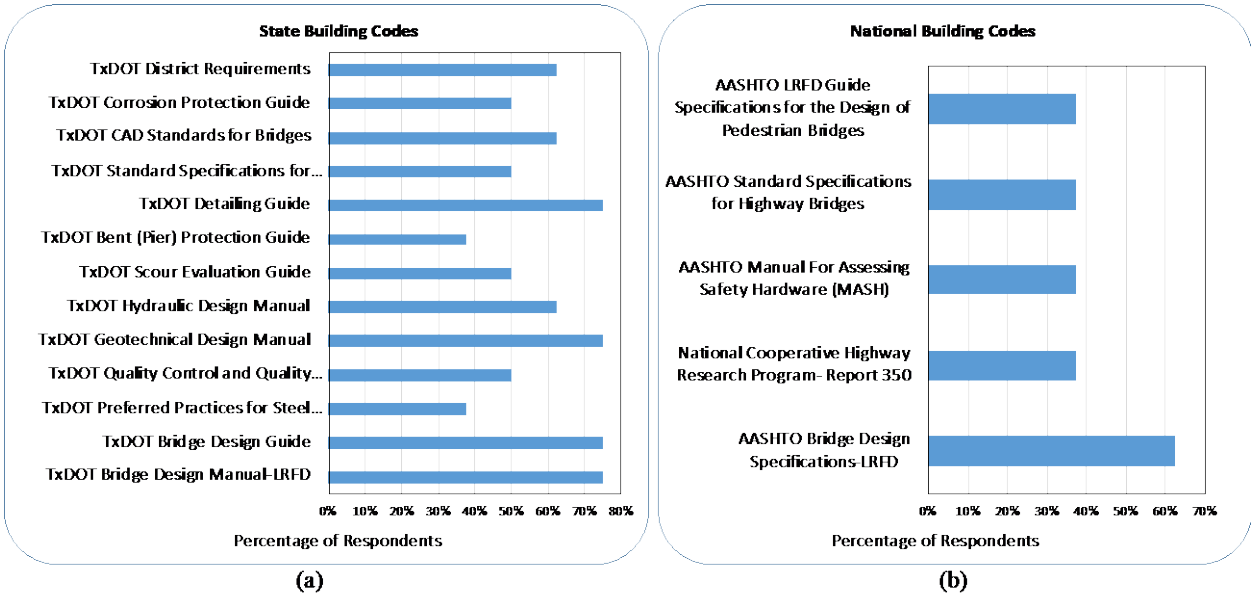

Figure 3-14 Frequency of using the State and National level building codes and standards among engineering consulting firms

3.3.3 Submission of Bridge Plans

According to survey results from the engineering consulting firms that were involved in the design of bridges (nearly seven respondents), it was revealed that all firms sign and seal their bridge plans, and they submit the final plans to their respective clients (Figure 3-15).

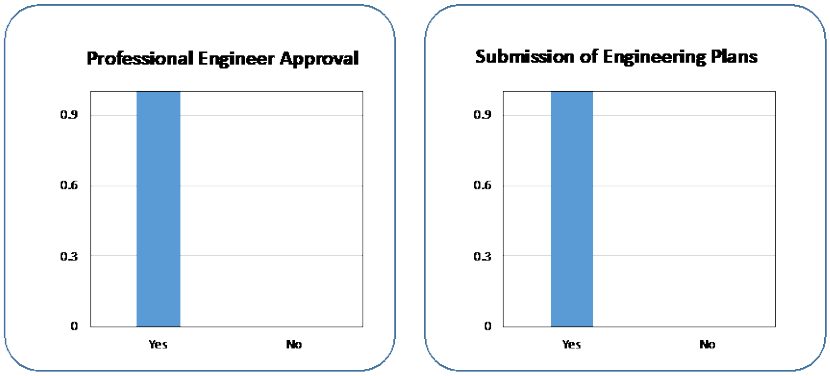

Figure 3-15 Survey results from engineering consulting firms involved in the design of bridges: (a) approval of a professional engineer, and (b) submission of final engineering plans to respective LGs

In addition, the study found that engineering consulting firms generally include most of the standard components recommended by the TxDOT Bridge Detailing Guide in their engineering plans. Nevertheless, the utility details, bridge geotechnical report, and foundation report had a slightly lower inclusion rate. Figure 3-16 summarizes the items typically included in a bridge set, along with the frequency rate of including these items in a standard bridge set.

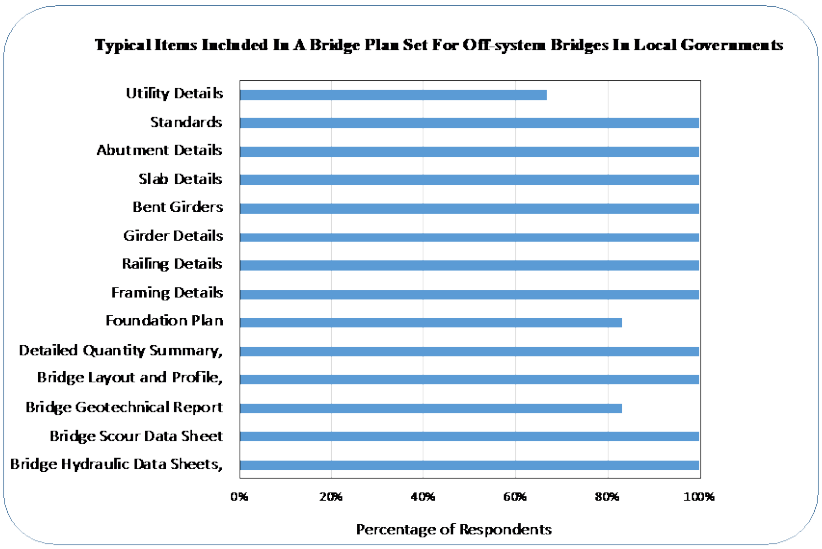

Figure 3-16 Survey results from engineering consulting firms on the inclusion of specific engineering items in a typical bridge plan set

3.4 TxDOT Survey Structure

The research team designed a short survey for TxDOT personnel and bridge experts. This survey aimed to determine if the TxDOT districts' bridge engineers are interested in including certain local governments/engineering consulting firms in this research project.

The first section of the survey required participants to provide their contact information and inquired whether the participants were interested in knowing about the current procedures followed for the design and construction of off-system bridges in any particular local government or engineering consulting firm. If the answer was yes, the survey proceeded to the second section, where it asked about the name and possible contact information of the local governments/engineering consulting firms that were of interest to TxDOT.

3.4.1 TxDOT Survey Responses

The research team distributed the survey to TxDOT personnel and bridge experts from all twenty-five (25) TxDOT districts. In total, twenty (20) respondents from TxDOT participated in the survey, in which three (3) respondents indicated that they have a particular interest in including specific local governments/engineering consulting firms in this research (Figure 3-17).

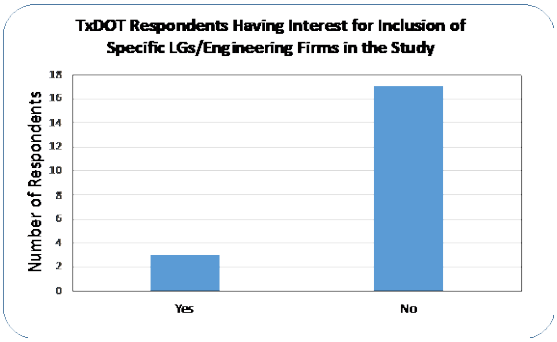

Figure 3-17 Number of TxDOT respondents having an interest in including specific local governments/engineering consulting firms in this study

The respondents specifically indicated two local governments and one engineering consulting firm to be included in this research. The research team considered these local governments/engineering consulting firms and distributed the surveys to them.

3.5 Conclusion

The statistics presented in this report identify the state of practice in Texas local governments regarding the implementation of building codes and standards for off-system bridges. The results summarized in this report highlight the most common building codes and standards along with the procedures followed to acquire the engineering plans within the local governments in Texas. The next chapter presents the recommendations and challenges encountered by local governments when utilizing these codes and standards pertaining to bridges through follow-up interviews.

Chapter 4
FOLLOW-UP INTERVIEWS

4.1 Introduction

The research team reached out to all local governments and engineering consulting firms that expressed their willingness to participate in a follow-up interview based on the surveys. Moreover, the research team approached additional local governments with experience in off-system bridges to increase the number of participants. This included contacting thirty-five (35) local governments and three (3) engineering consulting firms. Fourteen (14) individuals, comprising representatives from local governments and engineering consulting firms, responded to the invitation emails and participated in the interviews. The purpose of the interviews was to identify the best practices and challenges faced by local governments concerning the design, construction, and maintenance of off-system bridges. The instructions for interviews, interview questions, and interview results are presented in the following sections. The research team obtained the university's Institutional Review Board (IRB) approval to conduct the interviews.

4.2 Instructions for Conducting Follow-Up Interviews

The interview sessions are structured based on the four following tasks:

1. Reviewing contact information.
2. Reviewing survey responses and asking whether interviewees would like to further explain their responses
3. Acquiring more detailed information on the practices followed for the design, construction, and maintenance of off-system bridges.
4. Obtaining suggestions or recommendations to enhance the procedures related to the design, construction, and maintenance of off-system bridges.

4.3 Interview Questions

The research team conducted interviews focusing on the following questions:

- What is the overall condition of the off-system bridges within your local government?
- What is the procedure for requiring developers to follow specific building codes and standards for the design and construction of off-system bridges?

- What is the procedure for obtaining and archiving the final bridge plan sets in your local government after the bridge project is completed?
- What can be done to enhance the procedures followed for the design, construction, and maintenance of off-system bridges in local governments?

4.4 Interview Results

The research team interviewed individuals from twelve (12) local governments, which included representatives from cities and counties across Texas and two (2) engineering consulting firms. The purpose of the interviews was to identify the best practices in designing, constructing, or maintaining off-system bridges in local governments as well as any potential challenges that might exist in this regard. Summaries of the interviews are presented in this section.

4.4.1 Interviewee Number 1 (City in Southern Texas)

Overall conditions off-system bridges

- Only one off-system bridge exists within the local government.
- The bridge needs to be repaired due to deterioration.
- Insufficient maintenance was the primary reason for the bridge's poor performance.
- The city is in the process of bidding out the project for the repair.

Building codes for developers

- The city relies on state-level manuals developed by TxDOT.
- The city is part of the municode, which is a Municipal Code Corporation that maintains the legal documents for local governments in the United States.
- The city has made the code of ordinances accessible to the developers through Municode. This code outlines the requirements that developers must follow when designing or constructing structures within the city's right of way.

Submission of Plans

- The local government keeps records of both hard-copy (i.e., printed version) and soft-copy (i.e., electronic version) of engineering drawing plans.

- The local government has established its naming convention for organizing and keeping records of engineering drawings related to bridge projects.
- The local government submits the preliminary bridge design to TxDOT for review and any potential corrections or recommendations.

Recommendations and Suggestions

- TxDOT could consider organizing training workshops or educational courses for city/county engineers to increase local government's knowledge for enforcing available building design codes and standards related to off-system bridges.
- TxDOT could consider more effective communication with local governments regarding the off-system bridge design requirements, such as the Preliminary bridge layout review (PBLR) and submission of bridge plans to TxDOT. This would ensure that city/county engineers are aware of the requirements that they should follow in this regard.
- It would be great if TxDOT could include more visual aids, such as pictures and diagrams, in its inspection reports to illustrate the locations of deterioration and bridge deficiencies. It is also helpful if the reports could provide more definitions and examples to enhance understanding.

4.4.2 Interviewee Number 2 (City in Central Texas)

Overall conditions off-system bridges

- Most of the bridges within our local jurisdiction are predominantly aged from the 1950s or earlier.
- The primary challenge for the replacement of these bridges is securing funding.

Building codes for developers

- The city is currently in the process of creating a guideline for developers for the design of infrastructures within our jurisdiction. The guideline will reference both national and TxDOT standards and will include information on bridge classification for inventory purposes.

- The city has developed technical updates and technical memorandums for developers to guide them about the requirements related to the design and construction of bridges within our jurisdiction.

Submission of Plans

- As part of the city's procedures, developers are required to deliver signed and sealed as-built plans during the close-out acceptance process for record-keeping purposes.
- The as-built plans include a written clause that the engineering firm approves the actual construction in accordance with the engineering plans.
- The city requires the testing documents to be included in the submission package as well as warranties.
- The city requires developers to get the approval of all outside agencies, such as TxDOT, or the county before the bridge project is approved for construction.

Recommendations and Suggestions

- Prior to the acceptance of plans by the local government, it is important to ensure that developers coordinate with TxDOT to obtain the bridge numbers for any off-system bridges to be included in the bridge inventory.
- It is important for local government to maintain contact with TxDOT, adjacent cities, and MPOs to ensure coordination and collaboration for efficient infrastructure development.
- In addition to receiving the inspection report from TxDOT, cities could benefit from a follow-up meeting to enhance the information provided.
- Facilitating communication between local governments, existing residents, and political bodies can be advantageous in addressing concerns about infrastructure improvement, particularly when residents express apprehensions about potential population growth.

4.4.3 Interviewee Number 3 (City in Northern Texas)

Overall conditions off-system bridges

- Given the extensive new development within our jurisdiction, most of our bridges are new construction.

- As our bridges are relatively recent, we currently experience minimal issues with their performance.

Building codes for developers

- The city requires developers to follow AASHTO and TxDOT design manuals for the design of bridges.
- The city has a guideline on its website outlining the requirements for developers related to the design of bridges.

Submission of Plans

- Prior to approval, the bridge design plans undergo a thorough review process within our city.
- Regular inspections are conducted during the construction phase to ensure that the bridge is being built following the prescribed standards.
- The city archives the as-built plans (both hard copy and electronic version) for the bridges after the construction or rehabilitation is completed.

Recommendations and Suggestions

- It would be advantageous for local governments if TxDOT included solutions for addressing bridge issues outlined in the inspection reports rather than solely highlighting the problems encountered.
- Typically, cities with less experience in bridge maintenance lack sufficient knowledge in maintaining the bridges. It would be highly beneficial if TXDOT could offer local governments a maintenance guide for the bridges as part of the inspection reports or provide access to training programs or technical assistance.
- Developers may encounter challenges when incorporating new design criteria in local government's design manuals. They often prefer to rely on their experience with TxDOT procedures. Hence, implementing TxDOT design manuals would streamline their work effectively.
- Increasing the variety of aesthetic guardrail options in the design manuals would greatly benefit cities seeking to enhance the aesthetics of their bridges.

- Instead of solely submitting inspection reports from TxDOT, conducting face-to-face meetings would be beneficial to ensure a thorough understanding of the reports.
- The presence of local governments' inspectors during the routine bridge inspections that are conducted by TxDOT would offer a valuable educational opportunity for cities to learn and expand their knowledge of bridge inspection.
- Small cities can benefit from emulating the procedures followed by neighboring larger cities for the design, construction, and maintenance of bridges, to learn and obtain knowledge in this regard.
- Employing third-party consultants to perform quality control can present certain challenges, as in-house checks tend to be preferable due to a stronger sense of ownership.

4.4.4 Interviewee Number 4 (City in Central Texas)

Overall conditions off-system bridges

- Most of our bridges are on-system, and only a few are off-system.
- Following the revision of flood maps, some of our bridges are within flood zones. We are actively seeking funding to scale up or elevate the height of these bridges.
- Insufficient funding is the primary obstacle preventing the rehabilitation of bridges.

Building codes for developers

- We require developers to follow TxDOT design manuals and standards specifications for the design and construction of bridges.
- We have established online guidelines for developers, including detailed forms and instructions, ensuring compliance with our requirements.

Submission of Plans

- We keep the electronic version and hard copy of plans in our city.
- Through our online system, we streamline the submission and storage of our plans and as-built drawings, making them readily accessible.

Recommendations and Suggestions

- Less experienced cities would benefit from hiring an external program manager to oversee engineering drawings, design plans, and the entire construction process. This assistance allows for the development of their engineering department until they reach a point where they no longer require external assistance.

4.4.5 Interviewee Number 5 (County in Western Texas)

Overall conditions off-system bridges

- In our county, we have a total of six off-system bridge class culverts.
- These structures, primarily box culverts, were constructed in the mid-1970s, and we currently do not encounter any significant issues with them.

Building codes for developers

- Within our county, no off-system bridges have been built; instead, the predominant bridge class structures are culverts.
- If there are plans to construct bridges in the future, we will require developers to comply with TxDOT manuals.

Submission of Plans

- It is our standard practice to retain and archive engineering plans within our county.

Recommendations and Suggestions

- It would be beneficial to consider local needs and rural area requirements during the planning and design phase of bridge projects, such as accommodating the appropriate width required for farming equipment to pass through without damaging the guardrails. For example, we constructed a culvert that complied with TxDOT standards for the width. However, the unique characteristics of our local rural environment were not given sufficient consideration. As a result, the guardrail is consistently being damaged by farming equipment such as a 12-row planter.

4.4.6 Interviewee Number 6 (City in Southern Texas)

Overall conditions off-system bridges

- In our jurisdiction, there are around 1400 bridges spanning over 20 ft that undergo routine inspections every 24 months by TxDOT.
- We also have around 300 culverts with a span of less than 20 feet which are monitored and inspected by our local government.
- The primary cause of bridge deficiencies in our region is attributed to aging. In recent years, we have replaced 70 to 80 timber bridges, with spans of less than 20 feet, with steel frame bridges and box culverts.

Building codes for developers

- We require developers to follow TxDOT manuals for the design and construction of bridges.
- When it comes to off-system bridges, our typical approach involves issuing a Request for Quote (RFQ) and inviting consultants to bid on the projects. Once a consultant is selected, we hold pre-construction and pre-design meetings to review the design criteria that must be met.

Submission of Plans

- Upon completion of the construction, we carry out our standard final inspection to ensure that the project meets the required standards. If the project meets our satisfaction, we consider it closed. Additionally, we typically require a one-year guarantee period, during which any identified deficiencies must be addressed by the responsible party.
- We require developers to submit the plans to us at 30%, 60%, and 90% stages of review. We thoroughly review them and provide feedback on any issues or problems we identify. Once the project's design is completed, they send a complete set of drawings, distributing six copies across our city offices.

Recommendations and Suggestions

- Local government entities would greatly benefit from training sessions provided by TxDOT regarding their standards and guidelines. This is particularly important because many individuals in local governments may lack the necessary knowledge and experience in working with TxDOT manuals and guidelines.
- The inspection report could be improved by providing more explanation and information about the bridge problems and issues. Particularly, since individuals in local governments may not possess a background in bridge engineering, they often face difficulties in comprehending the problems outlined in the bridge inspection report, which may lead to disregard the report.
- It would be beneficial for local governments if TxDOT could arrange follow-up meetings with local governments for face-to-face discussions regarding the bridge issues outlined in inspection reports.
- Having multiple copies of engineering plans stored in the offices of local governments would be beneficial. This precautionary measure guarantees the availability of alternative versions in situations where unforeseen events like flooding occur, leading to the loss of the plans. For example, we encountered a flood in the past that resulted in the loss of a significant number of our plans. Since then, we have maintained multiple copies of the plans at different locations to mitigate such risks.

4.4.7 Interviewee Number 7 (Engineering Consulting Firm in Northern Texas)

Experience with designing off-system bridges

- We have extensive experience collaborating with various local government entities across Texas in the design and construction phases of bridge projects.
- We utilize TxDOT manuals extensively when it comes to designing and constructing bridges.
- Throughout the design process, we submit the engineering plans to local government entities at various stages, enabling them to provide any necessary corrections or suggestions that we can consider.

Recommendations and Suggestions for Local Governments

- Due to the extensive involvement of engineering consulting firms in various projects for TxDOT, they have developed a strong familiarity with the TxDOT manual. It would be highly beneficial if local governments also adopt the TxDOT manuals, as this would promote a standardized design procedure and prevent confusion among engineering firms.

Recommendations and Suggestions for TxDOT

- Organizing workshops or training sessions by TxDOT for local governments would be beneficial to familiarize them with the TxDOT manuals and standards applicable to bridge projects. This initiative would help ensure local governments have a comprehensive understanding of the guidelines and procedures, facilitating smoother collaboration and adherence to the required standards.

4.4.8 Interviewee Number 8 (County in Central Texas)

Overall conditions off-system bridges

- We possess and oversee a collection of more than 40 bridges within our jurisdiction.
- Our establishment is situated in a rapidly expanding area, attracting a significant influx of residents and witnessing a surge in land values. Consequently, we are bringing more money on property taxes, which we intend to utilize for enhancing our infrastructure. Currently, we have around 17 bridges undergoing the engineering design phase.
- In regard to small bridges with a span of less than 60 feet, we handle the design internally. However, we hire engineering consulting firms based in Dallas, Houston, or Austin for larger bridges.

Building codes for developers

- We require developers to follow TxDOT codes and standards.

Submission of Plans

- We maintain a comprehensive archive of plans in electronic and hard copy formats, securely stored in our local servers. This ensures that we have the backup option of relying on the physical hard copies in the event of computer malfunctions.

Recommendations and Suggestions

- Our expertise primarily lies in general engineering, and we lack experience in bridge design. It would greatly benefit our organization if TxDOT could provide training sessions or classes to educate our design team on the procedures they follow or design of bridges or utilizing the software they employ for bridge design.

- Our construction team is also lacking experience in building bridges. It would be highly advantageous for us if additional training opportunities were provided to our in-house builders, enabling them to better comprehend bridge plans and execute construction accordingly.

- Having repair options included in the inspection report would be highly beneficial, as it would provide us with valuable guidance on how to address and rectify any problematic components of the bridges. This would enhance our understanding of the necessary repairs and enable us to take appropriate action.

- It would be beneficial to receive more guidance on load posting, as there is currently a lack of instructions regarding the appropriate installation locations for these signs. Additionally, clear instructions are needed regarding the necessary information they should contain, such as gross weight, axle weight, and first responder weight.

4.4.9 Interviewee Number 9 (City in Central Texas)

Overall conditions off-system bridges

- Within our city, we take responsibility for the ownership and maintenance of approximately 8 to 9 off-system bridges.

- Typically, our bridges remain in good condition, except during floods when we often encounter overtopping, leading to the temporary closure of some bridges.

- Erosion in the vicinity of headwalls and scouring poses one of the primary challenges associated with our bridges.

Building codes for developers

- When it comes to the design, construction, and maintenance of off-system bridges, we rely on engineering firms who are obligated to adhere to the design manuals provided by TxDOT and AASHTO.

- During the initial plan review process, our development review committee effectively communicates the design requirements to developers.

Submission of Plans

- As part of the design process, developers are typically expected to submit preliminary plans for our review, and we provide them with feedback and comments. Once we are satisfied with the design following one or two rounds of review, we will issue a letter of approval.

- In certain cases, we may grant contingent approval and await confirmation from TxDOT regarding the plan's approval.

- Typically, we maintain hard copies of plans during the construction phase for distribution to the construction team. Once the construction is finished, we request developers to provide the as-built plan in PDF format.

- Typically, we do not directly submit the plans to TxDOT. If TxDOT requires the plans, we redirect them to the developers to obtain the necessary documentation.

Recommendations and Suggestions

- It is recommended that cities/counties establish communication with TxDOT to provide updated contact information for receiving the inspection reports. This ensures that TxDOT can send inspection reports to the appropriate personnel. In some cases, outdated contact information may result in reports being sent to individuals who are no longer in charge, leading to the potential loss of these reports.

- Given that our engineering team lacks expertise in bridge maintenance, it would be advantageous if TxDOT could offer us repair methods and options. This would enable us to effectively communicate and address bridge-related issues with our maintenance crew.

- It is recommended to establish a procedure for notifying TxDOT about newly annexed bridges within our city. This ensures that we receive inspection reports for these bridges. Currently, there have been instances where we do not receive inspection reports for newly annexed bridges.

4.4.10 Interviewee Number 10 (City in Southern Texas)

Overall conditions off-system bridges

- Our city implemented a significant bond program in 2007 to replace and rehabilitate most of the bridges that were experiencing issues.

- Due to the success of the initial bond program, our voters approved the implementation of a similar bond program every five years.

- Bridge replacement and rehabilitation are prioritized based on the bridge inspection reports provided by TxDOT.

Building codes for developers

- When it comes to the design, construction, and maintenance of off-system bridges, we adhere to the codes and standards set by TxDOT as our reference.

- If we intend to employ a design option that falls outside TxDOT's prescribed options, we will collaborate and coordinate with TxDOT. In this process, we will present our calculations to demonstrate the viability and support of the chosen design option.

- Additionally, we have established specific local criteria for bridges, particularly in relation to hydraulic concerns. When it comes to drainage and hydraulic conveyance, we utilize a 100-year flood standard, which differs from the approach employed by TxDOT.

Submission of Plans

- For older bridges, we retain hard copies of the plan set, while for newer bridges, we store the electronic version (i.e., PDF) within our city's records.

- We are currently converting the hard-copy plans into electronic versions as part of our digitization efforts.

Recommendations and Suggestions

- It would be advantageous if the inspection reports could be transformed into a public-friendly format, allowing us to make them easily accessible to the public or developers. Currently, we need to coordinate with TxDOT before sharing the reports with developers or the public to ensure that we do not disclose sensitive information, which can be time-consuming.

- I recommend cities or counties designate a dedicated staff member as a bridge liaison with TxDOT. Having this individual identified in advance significantly facilitates the flow of information between the state and municipalities, streamlining the communication process.

- I suggest that municipalities allocate a budget, even if it is small, for bridge maintenance on an annual basis. This practice guarantees that if TxDOT notifies about any issues with bridges, there is sufficient funding available to address them promptly.

- Enhanced communication from the state to municipalities, particularly regarding the federal highway bridge program (HBP) for off-system bridges, would serve as a catalyst

for municipalities to prioritize bridge-related matters and actively engage in bridge initiatives.

4.4.11 Interviewee Number 11 (City in Eastern Texas)

Overall conditions off-system bridges

- The overall conditions of our off-system bridges are good and we rarely encounter bridge problems.
- The main concern for bridge rehabilitation and construction in our city is securing funding for that.

Building codes for developers

- We require developers to follow AASHTO and TxDOT manuals.
- Our local government has specific hydraulic design requirements in place.

Submission of Plans

- We maintain electronic copies of bridge plans and have dedicated staff members responsible for managing the records. Whenever we require these plans, we simply reach out to the designated person, and they provide us with the requested documents.

Recommendations and Suggestions

- It would be advantageous to have our inspectors present during the inspection conducted by TxDOT on the off-system bridges, as it allows us to obtain precise information about the issues in our bridges.
- It is recommended that municipalities pay attention to local needs in addition to the requirements mentioned in the state and national design codes. For example, in our city, an additional lane for bikes necessitates considering extra width for bridges during the design phase.

4.4.12 Interviewee Number 12 (County in Central Texas)

Overall conditions off-system bridges

- Our county has about 73 off-system bridges, and they are in overall good condition.
- Most of our bridges were constructed in the 1980s and 1990s and are not very old.

Building codes for developers

- We specifically require developers to conduct hydraulic analysis to demonstrate water surface elevations during potential flooding scenarios.
- Our subdivision design guidelines mandate developers to adhere to specific hydraulic analysis requirements. As for structural design, we rely on established engineering practices delivered by engineering firms.

Submission of Plans

- We maintain engineering plans in both online and hard-copy formats. Currently, we are in the process of digitizing the hard-copy versions to create electronic copies.

Recommendations and Suggestions

- It is advisable to obtain detailed bridge plans from developers. Based on past experiences where we lacked such plans to determine the depth of the bridge pier, it presented significant challenges during the bridge repair process.
- It is of interest provide guidelines for the maintenance of bridges and requirements for pre-construction notification, particularly for scour and erosion protection. In the past, we encountered conflicting reviews from the Corps of Engineers and TxDOT, leaving us uncertain about the appropriate course of action in such situations.
- It would be advantageous if the state could disseminate information regarding the funding opportunities available to local governments for off-system bridges. Many local

governments may not be familiar with these funding opportunities, and providing such information would be highly beneficial.

4.4.13 Interviewee Number 13 (Engineering Consulting Firm in Northern Texas)

Experience with designing off-system bridges

- We have extensive experience in designing and constructing various bridge projects in the state of Texas.
- We implement AASHTO and TxDOT manuals for the design and construction of off-system bridges.

Recommendations and Suggestions for Local Governments

- It would be great if local governments could consider adopting the procedures used by TxDOT for bridges since many engineering firms involved in TxDOT projects are already familiar with these procedures.

Recommendations and Suggestions for TxDOT

- TxDOT could raise awareness of its design manual for bridges among local governments, enabling cities and counties to better understand the available design requirements for bridges.

4.4.14 Interviewee Number 14 (City in Northern Texas)

Overall conditions off-system bridges

- Our bridges are in good overall condition, and we have experienced no significant problems with them in recent years.

Building codes for developers

- Our engineering department is responsible to communicate with the contractors to ensure compliance with the bridge design requirements.

Submission of Plans

- We maintain records of engineering plans. Over time, certain hard copies of these plans have been lost, and we are currently in the process of digitizing the remaining paper copies to store them electronically.

Recommendations and Suggestions

- It is crucial for local governments to promptly address even minor bridge issues. Past experiences have shown that postponing such problems can lead to their escalation and result in more significant issues.

4.5 Conclusion

The interviews presented in this report highlight the state of practice in the design, construction, and maintenance of off-system bridges within local governments. Additionally, it provides recommendations aimed at improving the procedures involved in the maintenance and management of off-system bridges. Following the interviews, the research team selected five case studies to provide an overview of the current state of practice in the design, construction, and maintenance of off-system bridges. These case studies aim to provide valuable recommendations for implementing best practices in this field.

Chapter 5
CASE STUDIES

5.1 Introduction

This chapter presents five (5) case studies to summarize the procedures that local governments follow to design, construct, and maintain off-system bridges within their jurisdiction. Following the completion of follow-up interviews, the participants were requested to provide comprehensive details regarding the design, construction, and maintenance procedures of off-system bridges in their respective jurisdictions, which could be presented as case studies. The research team identified the most illustrative case studies based on the findings from interviews and surveys. These case studies have been presented in the following sections.

5.1.1 Case Study 1

The first case study pertains to a small city in the southern region of Texas.

Off-system Bridge Conditions

The frequency of bridge deficiencies within the city jurisdiction was very rare. The locations of deficiencies were in the following order based on their frequency of occurrence:

1. Superstructure
2. Substructure
3. Deck
4. Bridge Railing
5. Signs

The reported bridge deficiencies were attributed to the following contributing factors, listed in order of their importance:

1. Lack of maintenance
2. Hydraulic issues
3. Re-occurring vehicular damage
4. Construction error
5. Design error
6. Overload

Bridge Codes and Standards

The city requires developers to follow state-level manuals (TxDOT manuals) for the design, construction, and maintenance of off-system bridges. The state-level manuals include the following:

- TxDOT Bridge Design Manual-LRFD
- TxDOT Bridge Design Guide
- TxDOT Hydraulic Design Manual
- TxDOT Bridge Railing Manual
- TxDOT Bridge Railing Identification Guide
- TxDOT Bridge Detailing Guide
- TxDOT CAD Standards for Bridges
- TxDOT Bent (pier) Protection Guide
- TxDOT Quality Control and Quality Assurance Guide
- TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges
- TxDOT Preferred Practices for Steel Bridge Design, Fabrication, and Erection

Table 5-1 summarizes the existing practices pertaining to off-system bridges in the first case study.

Table 5-1 State of practice for the design, construction, and maintenance of off-system bridges in case study one.

Subject	Response	
	Yes	No
Approval of the plans by a Professional Engineer	✓	-
Submission of Preliminary layouts for internal review	✓	-
Familiarity with the TxDOT PBLR process	-	✓
Submission of Preliminary layouts for TxDOT review	-	✓
Submission of the final plan set to TxDOT	✓*	-
Following the TxDOT bridge inspection report	✓	-

**Only for bridges with state or federal fund*

A typical bridge plan set for a bridge project in case study 1 includes the following items:

- Bridge Hydraulic Data Sheets,
- Bridge Geotechnical Report (e.g., boring logs, boring location plan, and subsurface profile)
- Bridge Layout and Profile,
- Detailed Quantity Summary,
- Railing Details
- Utility Details
- Framing Details
- Foundation Plan
- Abutment Details
- Bent Details
- Slab Details
- Girder Details

- Standards

Recommendations and Suggestions

According to the interview findings from case study 1, one approach to enhance the local government's knowledge and enforcement of building design codes and standards for off-system bridges is for TxDOT to organize training workshops or educational courses for city/county engineers. This would empower them with the necessary understanding to effectively enforce the available requirements. Furthermore, establishing more effective communication channels between TxDOT and local governments regarding off-system bridge design requirements, such as the Preliminary Bridge Layout Review (PBLR) process and submission of bridge plans, would ensure that city/county engineers are well-informed and comply with the necessary guidelines. Additionally, TxDOT could improve inspection reports by incorporating visual aids such as pictures and diagrams, enabling more precise identification of deterioration and bridge deficiencies. Furthermore, providing detailed definitions and examples in these reports would enhance comprehension and interpretation by the relevant parties.

5.1.2 Case Study 2

The second case study pertains to a rural county in the eastern region of Texas.

Off-System Bridge Conditions

The frequency of bridge deficiencies within the county jurisdiction was very rare. The locations of bridge deficiencies were in the following order based on their frequency of occurrence:

1. Signs
2. Bridge railing
3. Deck
4. Substructure
5. Superstructure

The reported bridge deficiencies were attributed to the following contributing factors, listed in order of their importance:

1. Re-occurring vehicular damage
2. Hydraulic issues
3. Lack of maintenance
4. Overload
5. Construction error
6. Design error

Bridge Codes and Standards

The county does not require developers to follow any specific manual or standard for the design, construction, and maintenance of off-system bridges and relies on the current engineering practice employed by engineering firms.

Table 5-2 summarizes the existing practices pertaining to off-system bridges in the second case study.

Table 5-2 State of practice for the design, construction, and maintenance of off-system bridges in case study two.

Subject	Response	
	Yes	No
Approval of the plans by a Professional Engineer	✓	-
Submission of Preliminary layouts for internal review	✓	-

Familiarity with the TxDOT PBLR process	✓	-
Submission of Preliminary layouts for TxDOT review	✓*	-
Submission of the final plan set to TxDOT	✓*	-
Following the TxDOT bridge inspection report	✓	-

**Only for bridges with state or federal fund*

A typical bridge plan set for a bridge project in case study 2 includes the following items:

- Bridge Hydraulic Data Sheets,
- Bridge Geotechnical Report (e.g., boring logs, boring location plan, and subsurface profile)
- Bridge Layout and Profile,
- Detailed Quantity Summary,
- Railing Details
- Framing Details
- Foundation Plan
- Abutment Details
- Bent Details
- Slab Details
- Girder Details
- Standards

Recommendations and Suggestions

When planning and designing bridge projects, it is crucial to consider the specific needs of the local community and rural areas. This includes ensuring that the bridge width is suitable for agricultural equipment to pass through without causing damage to the guardrails. For instance, the county built a culvert that met the width requirements set by TxDOT. However, the distinct features of the rural environment were overlooked, which has led to the guardrail consistently being damaged by farming equipment.

5.1.3 Case Study 3

The third case study pertains to a large city in the southern region of Texas.

Off-System Bridge Conditions

The frequency of bridge deficiencies within the city jurisdiction was occasionally. The locations of deficiencies were in the following order based on their frequency of occurrence:

1. Superstructure
2. Bridge railing
3. Deck
4. Substructure
5. Signs

The reported bridge deficiencies were attributed to the following contributing factors, listed in order of their importance:

1. Lack of maintenance
2. Hydraulic issues
3. Re-occurring vehicular damage
4. Construction error
5. Overload
6. Design error

Bridge Codes and Standards

The city requires developers to follow a combination of state-level and national-level manuals and standard specifications for the design, construction, and maintenance of off-system bridges. These manuals and standard specifications include the following:

- AASHTO Bridge Design Specifications-LRFD
- FHWA Evaluating Scour at Bridges (HEC-18)
- National Cooperative Highway Research Program (NCHRP) Report 350— related to bridge railings and safety
- AASHTO Standard Specifications for Highway Bridges
- AASHTO LRFD Guide Specifications for the Design of Pedestrian Bridges
- TxDOT Bridge Design Manual-LRFD
- TxDOT Bridge Design Guide
- TxDOT Hydraulic Design Manual
- TxDOT Bridge Railing Manual
- TxDOT Bridge Railing Identification Guide

- TxDOT Bridge Detailing Guide
- TxDOT CAD Standards for Bridges
- TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges

Table 5-3 summarizes the existing practices pertaining to off-system bridges in the third case study.

Table 5-3 State of practice for the design, construction, and maintenance of off-system bridges in case study three.

Subject	Response	
	Yes	No
Approval of the plans by a Professional Engineer	✓	-
Submission of Preliminary layouts for internal review	✓*	-
Familiarity with the TxDOT PBLR process	✓	-
Submission of Preliminary layouts for TxDOT review	✓**	-
Submission of the final plan set to TxDOT	-	✓
Following the TxDOT bridge inspection report	✓	-

**At 30%, 60%, and 90% completion stages*

***Only for bridges with state or federal fund*

A typical bridge plan set for a bridge project in case study 3 includes the following items:

- Bridge Hydraulic Data Sheets,
- Bridge Geotechnical Report (e.g., boring logs, boring location plan, and subsurface profile)
- Bridge Layout and Profile,
- Detailed Quantity Summary,
- Railing Details
- Utility Detail
- Framing Details
- Foundation Plan
- Abutment Details
- Bent Details
- Slab Details
- Girder Details
- Standards

Recommendations and Suggestions

Local government entities would greatly benefit from training sessions offered by TxDOT concerning their standards and guidelines, as many individuals within the local governments may lack the necessary knowledge and experience in working with TxDOT manuals and guidelines. To enhance the inspection report, it would be helpful to provide more thorough explanations and information regarding bridge problems and issues. This is particularly important because individuals in local governments, who may not have a background in bridge engineering, often

struggle to comprehend the problems outlined in the bridge inspection report, which can lead to the73ecisionn to disregard the report. Local governments would benefit from TxDOT organizing follow-up meetings for face-to-face discussions regarding bridge issues. Additionally, maintaining multiple copies of engineering plans in the offices of local governments would be advantageous. This precautionary measure ensures the availability of alternative versions in situations where unforeseen events like flooding occur and result in the loss of plans.

5.1.4 Case Study 4

The fourth case study pertains to a county in the central region of Texas.

Off-System Bridge Conditions

The frequency of bridge deficiencies within the county jurisdiction was occasionally. The locations of deficiencies were in the following order based on their frequency of occurrence:

1. Signs
2. Substructure
3. Superstructure
4. Deck
5. Bridge railing

The reported bridge deficiencies were attributed to the following contributing factors, listed in order of their importance:

1. Lack of maintenance
2. Re-occurring vehicular damage
3. Hydraulic issues
4. Overload
5. Design error
6. Construction error

Bridge Codes and Standards

The city requires developers to follow state-level manuals and standards for the design, construction, and maintenance of off-system bridges. These manuals or standards include:

- TxDOT Bridge Design Manual-LRFD
- TxDOT Bridge Design Guide
- TxDOT Hydraulic Design Manual
- TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges

Table 5-4 summarizes the existing practices pertaining to off-system bridges in the fourth case study.

Table 5-4 State of practice for the design, construction, and maintenance of off-system bridges in case study four.

Subject	Response	
	Yes	No
Approval of the plans by a Professional Engineer	✓	-
Submission of Preliminary layouts for internal review	✓	-
Familiarity with the TxDOT PBLR process	-	✓
Submission of Preliminary layouts for TxDOT review	-	✓
Submission of the final plan set to TxDOT	✓	-
Following the TxDOT bridge inspection report	✓	-

A typical bridge plan set for a bridge project in case study 4 includes the following items:

- Bridge Hydraulic Data Sheets,
- Bridge Scour Data Sheet
- Bridge Geotechnical Report (e.g., boring logs, boring location plan, and subsurface profile)
- Bridge Layout and Profile,
- Detailed Quantity Summary,
- Railing Details
- Utility Detail
- Framing Details
- Foundation Plan
- Abutment Details
- Bent Details
- Slab Details
- Girder Details
- Standards

Recommendations and Suggestions

The engineering department of local governments lacks expertise in bridge design. It would greatly benefit them if TxDOT could offer training sessions or classes to educate the local governments' design team on the bridge design procedures and the software they use for bridge design. Similarly, the construction team in local governments lacks experience in building bridges, and additional training opportunities to help them better understand bridge plans and execute construction would be helpful. Including appropriate bridge repair options and methods in the inspection report would be highly advantageous, as it would provide local governments with valuable guidance on addressing and rectifying any problematic bridge components. Furthermore, local governments would benefit from receiving more guidance on load posting, as there is currently a lack of instructions regarding the proper installation locations for these signs. Additionally, clear instructions are needed regarding the required information they should display, such as gross weight, axle weight, and first responder weight.

5.1.5 Case Study 5

The fifth case study pertains to an engineering consulting firm based in the central regions of Texas.

Bridge Codes and Standards

The engineering consulting firm follows a combination of state-level, national-level, and local-level manuals and standards for the design, construction, and maintenance of off-system bridges. These manuals or standards include:

- TxDOT Bridge Design Manual-LRFD
- TxDOT Bridge Design Guide
- TxDOT Geotechnical Design Manual
- TxDOT Detailing Guide
- AASHTO Bridge Design Specifications-LRFD

Table 5-5 summarizes the existing practices pertaining to off-system bridges in the fifth case study.

Table 5-5 State of practice for the design, construction, and maintenance of off-system bridges in case study five.

Subject	Response	
	Yes	No
Approval of the plans by a Professional Engineer	✓	-
Submission of final bridge plans to local governments	✓	-

A typical bridge plan set for a bridge project in case study 5 includes the following items:

- Bridge Hydraulic Data Sheets,
- Bridge Scour Data Sheet
- Bridge Geotechnical Report (e.g., boring logs, boring location plan, and subsurface profile)
- Abutment Details
- Bent Details
- Slab Details
- Bridge Layout and Profile,
- Detailed Quantity Summary,
- Railing Details
- Framing Details
- Foundation Plan
- Girder Details
- Standards
- Column and Shaft Sizes Reinforcement Detail and Elevation

Recommendations and Suggestions

Considering the substantial engagement of engineering consulting firms in multiple TxDOT projects, they have developed a strong familiarity with the TxDOT manual. To foster a standardized design process and minimize confusion among engineering firms, it would be greatly advantageous for local governments to adopt the TxDOT manuals. This would ensure consistent practices and facilitate effective collaboration. As for recommendations and suggestions to TxDOT, organizing workshops or training sessions aimed at familiarizing local governments with the TxDOT manuals and applicable standards for bridge projects is highly recommended. This measure would enable local governments to gain a comprehensive understanding of the guidelines and procedures, promoting smoother collaboration and adherence to the required standards.

Chapter 6
CRITICAL ANALYSIS OF RESULTS AND RECOMMENDATION OF THE BEST PRACTICES

6.1 Critical Analysis

The data collected from the literature review, survey questionnaire, interviews, and case studies were analyzed in this chapter. Through an extensive literature review, a detailed understanding was obtained of the procedures followed for the design, construction, and maintenance of off-system bridges in Texas. By conducting three surveys (one for local governments, one for engineering consulting firms, and one for TxDOT districts), responses were collected from forty-nine (49) local governments, ten (10) engineering consulting firms, and three (3) TxDOT personnel with bridge experience. The surveys were followed by interviews with interested respondents from local governments and engineering consulting firms. Upon conducting a critical analysis of the results from interviews and surveys, the best practices for the design, construction, and maintenance of off-system bridges in Texas were identified. The following section provides these recommendations and suggested guidelines.

6.2 Recommendations and Best Practices

Following the evaluation of the procedures involved in the design, construction, and maintenance procedures of off-system bridges in Texas local governments, the following best practices and recommendations were identified:

- It is recommended that local governments adopt TxDOT manuals and guidelines for bridges to promote standardized design procedures and alleviate confusion among engineering firms in Texas.

- It is recommended that bridge design manuals incorporate supplementary requirements to address specific local needs, such as ensuring sufficient width to accommodate farming equipment in rural areas. This will ensure that the design process adequately considers and meets the unique demands of the local environment.

- It is recommended to organize training workshops or educational courses specifically designed for city/county engineers. This initiative would greatly enhance local governments' knowledge and understanding of the building design codes and standards applicable to off-system bridges, thereby fostering improved expertise in this field.

- It is recommended to establish a standard communication and coordination guideline for local governments and TxDOT to streamline communication of essential requirements concerning off-system bridges, encompassing the Preliminary Bridge Layout Review (PBLR) process and the requirement of submitting final bridge plans to TxDOT. This will ensure that city/county engineers are well-informed about the necessary prerequisites for this aspect.

- It is recommended that local governments develop comprehensive guidelines for developers, providing them with clear information about the necessary procedures, including the applicable design codes, to be followed during the design, construction, and maintenance of off-system bridges within the local government's jurisdiction.

- It is recommended to enhance the clarity and comprehension of TxDOT bridge inspection reports for city/county engineers. This can be achieved by incorporating additional visual aids, such as pictures and diagrams, in the reports to clearly illustrate the precise locations of deterioration and deficiencies. Furthermore, enriching the reports with comprehensive definitions and examples would contribute to a better understanding of the content.

- It is recommended to provide repair options and maintenance guides for the issues identified in the inspection report. By incorporating these repair options or maintenance

guides, cities/counties can effectively address and rectify the identified problems, enabling them to implement appropriate measures for resolution.

- It is recommended that local governments require developers to coordinate with TxDOT to obtain bridge numbers for the off-system bridges they design or construct. This proactive measure ensures proper documentation and accurate tracking of off-system bridges within the inventory system, facilitating efficient management and maintenance processes.

- It is recommended that local governments store multiple copies of engineering plans (hard copies and electronic copies) in their offices to ensure preparedness for unforeseen events, such as flooding, which could result in the loss of important plans. This precautionary measure guarantees the availability of alternative versions, reducing the impact of plan loss.

- It is recommended that TxDOT arrange follow-up meetings with local governments to facilitate face-to-face discussions concerning bridge issues outlined in inspection reports. This proactive step would be advantageous for local governments, as it allows for direct engagement on matters related to bridges.

- It is recommended that less experienced local governments consider emulating the procedures employed by neighboring larger cities when it comes to the design, construction, and maintenance of bridges. Learning from neighboring cities' approaches can enhance the effectiveness and efficiency of bridge-related processes in smaller or less experienced municipalities.

- It is recommended that local governments' inspectors be present during routine bridge inspections conducted by TxDOT, as this would provide a valuable educational opportunity for cities to enhance their knowledge and understanding of bridge inspection practices.

- It is recommended to provide guidance on load posting, as the current lack of instructions regarding appropriate sign installation locations poses a challenge. Additionally, there is a need for explicit instructions on the essential information these signs should include, such as gross weight, axle weight, and first responder weight.

- It is recommended that cities/counties establish communication with TxDOT to provide updated contact information for receiving the inspection reports. This ensures that TxDOT can send inspection reports to the appropriate personnel. In some cases, outdated contact information may result in reports being sent to individuals who are no longer in charge, leading to the potential loss of these reports.

- It is recommended to establish a procedure for notifying TxDOT about newly annexed bridges within our city. This ensures that we receive inspection reports for these bridges. Currently, there have been instances where we do not receive inspection reports for newly annexed bridges.

- It is recommended that cities/counties designate a dedicated staff member as a bridge liaison with TxDOT. Having this individual identified in advance significantly facilitates the flow of information between the state and municipalities, streamlining the communication process.

- It is recommended that municipalities allocate a budget, even if it is small, for bridge maintenance on an annual basis. This practice guarantees that if TxDOT notifies about any issues with bridges, there is sufficient funding available to address them promptly.

- It is recommended that various entities, such as the Corps of Engineers and TxDOT, coordinate with each other while providing reviews about off-system bridges. This collaboration aims to ensure non-conflicting assessments and evaluations.

- It is recommended to disseminate information regarding the funding opportunities available to local governments related to off-system bridges. This approach assists them in becoming acquainted with these funding options and utilizing them effectively.

- It is recommended that local governments adopt and implement the appropriate hydraulic design criteria specified in the state's (e.g., TxDOT Hydraulic Design Manual) and the national's (e.g., HEC-18) design codes to mitigate the potential risks associated with flooding or scour.

6.3 Conclusion

The comprehensive analysis of data collected from the literature review, surveys, interviews, and case studies provided a detailed understanding of the procedures and best practices for the design, construction, and maintenance of off-system bridges in Texas. Through the process of conducting surveys, interviews, and case studies, valuable insights were gained regarding effective maintenance practices for off-system bridges and the potential challenges encountered by local governments in this regard. The findings of this research effort provide recommendations that can enhance the management and maintenance of off-system bridges in Texas, leading to improved infrastructure and increased public safety. This set of recommendations offers potential advantages to the Texas Department of Transportation and local governments, encompassing both qualitative and economic benefits; qualitative benefits pertain to those aspects that are challenging to measure

precisely, like safety improvements (Ashuri et al., 2014), while economic benefits are measurable, such as the savings achieved through reduced maintenance costs after implementation (Shahandashti et al., 2017).

References

American Association of State Highway and Transportation Officials (AASHTO), (2020). "AASHTO Bridge Specifications," 9th Edition.

Ashuri, B., Shahandashti, M., & Tavakolan, M. (2014). *STC synthesis of best practices for determining value of research results* (No. LTRC Project No. 12-3PF). Louisiana Transportation Research Center.

Bani-Hani, A., Baral, A., & Shahandashti, M. (2023). Synthesis of State of Practice on Bridge Deck Drains. In *International Conference on Transportation and Development 2023* (pp. 393-404).

Brazoria County Subdivision Rules and Regulations, (2006). Available at: https://www.brazoriacountytx.gov/home/showpublisheddocument/78/63586052121883000. Retrieved in September 2022

City of Arlington Design Criteria Manual, (2020). Available at: https://cdn5-hosted.civiclive.com/UserFiles/Servers/Server_14481062/File/City%20Hall/Depts/PublicWork%20Transportation/Engineering/DCM/Arlington_Design_Criteria_Manual.pdf. Retrieved in September 2022.

City of Austin Drainage Criteria Manual, (2022). Available at: https://library.municode.com/tx/austin/codes/drainage_criteria_manual. Retrieved in September 2022.

City of Austin Transportation Criteria Manual, (2022). Available at: https://library.municode.com/tx/austin/codes/transportation_criteria_manual. Retrieved in September 2022.

City of Austin, (2022). Standard Specifications Manual. https://library.municode.com/tx/austin/codes/standard_specifications_manual. Retrieved in August 2022.

City of Corpus Christi Infrastructure Design Manual, (2022). Available at: https://www.cctexas.com/sites/default/files/IDM-final-version.pdf. Retrieved in September 2022.

City of Dallas Street Design Manual, (2019). Available at: https://dallascityhall.com/departments/public-works/DCH%20Documents/Public%20Works/pdf/Street%20Design%20Manual_091219.pdf. Retrieved in September 2022

City of Denton Transportation Design Criteria Manual, (2018). Available at: https://www.cityofdenton.com/DocumentCenter/View/4807/Transportation-Criteria-Manual-March-2018pdf. Retrieved in September 2022.

City of Fort Worth Transportation Engineering Manual, (2019). Available at: https://www.fortworthtexas.gov/files/assets/public/tpw/documents/cfw-transportation-engineering-manual.pdf. Retrieved in September 2022

City of Garland Technical Standard Manual, (2020). Available at: https://www.garlandtx.gov/DocumentCenter/View/459/Technical-Standards-Manual-PDF?bidId=. Retrieved in September 2022

City of Houston Infrastructure Design Manual, (2022). Available at: https://www.houstonpermittingcenter.org/news-events/2022-infrastructure-design-manual-announcement. Retrieved in September 2022

City of Lubbock Standard Specifications, available at https://www.abilenetx.gov/DocumentCenter/View/3064/420-1-PDF. Retrieved in September 2022.

City of McAllen Standard Design Guide for Public Infrastructure Improvements, (2021). Available at: https://www.mcallen.net/docs/default-source/engineering-files/standard_design_guide_july_2021.pdf?sfvrsn=2. Retrieved in September 2022

City of McKinney Engineering Design Manual, (2018). Available at: https://www.mckinneytexas.org/DocumentCenter/View/16490/McKinney-Engineering-Design-Manual-Rev-4?bidId=. Retrieved in September 2022.

City of Mesquite Engineering Design Manual. Available at: https://www.cityofmesquite.com/DocumentCenter/View/13132/Sections-1-9?bidId=. Retrieved in September 2022

City of Midland Engineering Design and Development Manual, (2021). Available at: https://www.midlandtexas.gov/1003/Engineering-DesignDevelopment-Manual. Retrieved in September 2022.

City of Pharr Standard Manual, (2006). Available at: https://pharr-tx.gov/wp-content/uploads/2020/04/city-of-pharr-standards-manual.pdf. Retrieved in September 2022.

City of San Antonio Design Guidance Manual, (2017). Available at: https://www.sanantonio.gov/PublicWorks/Current-Vendor-Resources/Design-Guidance-Manual. Retrieved September 2022.

City of San Antonio Unified Development Code, (2022). Available at: https://library.municode.com/tx/san_antonio/codes/unified_development_code. Retrieved in September 2022.

Cook, W. (2014). Bridge failure rates, consequences, and predictive trends. Utah State University.

Denton County Planning Department Subdivision Process (2009). Available at: https://www.dentoncounty.gov/DocumentCenter/View/1567/Subdivision-Rules-and-Regulations-PDF. Retrieved in September 2022.

Galveston County Rules, Regulations, and Requirements Relating to the Approval and Acceptance of Improvements in Subdivisions or Re-Subdivisions, (1997). Available at: https://www.galvestoncountytx.gov/home/showpublisheddocument/4408/637371357492070000. Retrieved in September 2022

Harris County Toll Road Authority. (2017). Standard Specification for Highway for Construction and Maintenance of Highway, Streets, and Bridges.

Harris County Guideline, (1988). Design Guideline. Available online at https://www.eng.hctx.net/Portals/33/Publications/capital-improvements/guidelines/1988-Guidelines-repro-PDG.pdf. Retrieved in August 2022.

Hu, Y., Chen, J., Zou, F., He, M., Mao, J., Liu, X., ... & Yuan, Z. (2021). A comparative study of temperature of mass concrete placed in August and November based on on-site measurement. Case Studies in Construction Materials, 15, e00694.

Hurt, M. A., & Schrock, S. D. (2016). Highway bridge maintenance planning and scheduling. Butterworth-Heinemann.

Lee, G. C., Mohan, S., Huang, C., & Fard, B. N. (2013). A study of US bridge failures (1980-2012). Buffalo, NY: MCEER.

Montgomery County Subdivision Rules and Regulations, (1984). Available at: https://cms1files.revize.com/montgomerycountytx/Montgomery%20County%20Subdivision%20Rules%20and%20Regulations%201984%20rev%202021.pdf. Retrieved in September 2022.

Russo, F. M., Wipf, T. J., & Caliber, F. W. (2003). Cost-effective Structures for off-system bridges. Transportation research record, 1819(1), 397-404.

Shahandashti, M., Ashuri, B., & Tavakolan, M. (2017). Synthesis of Methods and Measures for Determining Value of Transportation Research. *Journal for the Advancement of Performance Information & Value*, *78*.

Shahandashti, M., Chao, S. H. S., Fang, N., Bani-Hani, A., & Baral, A. (2021). *Synthesis: Bridge Deck Drains* (No. FHWA/TX-21/0-7092-1). Texas. Dept. of Transportation. Research and Technology Implementation Office.

Shipman, C. L. (2014). Finding maximum moment: Determining Hl-93 truck position on simple spans. Journal of Bridge Engineering, 19(6), 06014003.

Texas Department of Transportation, (2009). Local Government Project Procedures for Bridges (Module 10). Available online at: https://ftp.dot.state.tx.us/pub/txdot-info/cst/mods/mod10.pdf. Retrieved in August 2022.

Texas Department of Transportation, (2014). Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges. Available online at: https://ftp.txdot.gov/pub/txdot-info/des/spec-book-1114.pdf. Retrieved in August 2022.

Texas Department of Transportation, (2017). PS&E Preparation Manual. Available online at: https://www.txdot.gov/inside-txdot/division/construction/txdot-specifications/local-government.html. Retrieved in August 2022.

Texas Department of Transportation, (2019). Bridge Facts. Available at: https://ftp.txdot.gov/pub/txdot-info/library/pubs/bus/bridge/facts-19.pdf. Retrieved in March 2022.

Texas Department of Transportation, (2020a). Report of Texas Bridges. Available at: https://ftp.txdot.gov/pub/txdot-info/library/reports/gov/bridge/fy20.pdf. Retrieved in September 2022.

Texas Department of Transportation, (2020b). Geotechnical Manual. Available online at: http://onlinemanuals.txdot.gov/txdotmanuals/geo/geo.pdf.

Texas Department of Transportation, (2020c). Bridge Railing Manual. Available online at: http://onlinemanuals.txdot.gov/txdotmanuals/rlg/rlg.pdf.

Texas Department of Transportation, (2021a). Bridge Design Manual- LRFD. Available online at: http://onlinemanuals.txdot.gov/txdotmanuals/lrf/lrf.pdf. Retrieved in August 2022.

Texas Department of Transportation, (2021b), Local Government Project Management Guide, available at: https://ftp.txdot.gov/pub/txdot/lgp/procedures/guide.pdf. Retrieved in September 2022

Texas Department of Transportation, (2022a). Engineering software. Available online at: https://www.txdot.gov/business/resources/engineering-software.html. Retrieved in August 2022.

Texas Department of Transportations, (2022b). Bridge Detailing Guide. Available at: https://ftp.txdot.gov/pub/txdot-info/brg/design/bridge-detailing-guide.pdf. Retrieved in September 2022.

Texas Department of Transportation. (2018). Report on Texas Bridges. Available at: https://ftp.txdot.gov/pub/txdot-info/library/reports/gov/bridge/fy18.pdf. Retrieved in March 2022.

The Federal Highway Administration, (2006). Soils And Foundations Reference Manual. Available at: https://www.fhwa.dot.gov/engineering/geotech/pubs/nhi06088.pdf. Retrieved in August 2022.

The Federal Highway Administration, (2014). Standard Specifications. Available at: https://highways.dot.gov/federal-lands/specs. Retrieved in August 2022.

Travis County Code, Available online at: http://online.encodeplus.com/regs/traviscounty-tx/index.aspx. Retrieved in September 2022.

U.S. Census Bureau. (2017). "2017 Census of Government-Organization". Retrieved in February 2022.

Williamson County Subdivision regulations, (2021). Available at: https://agenda.wilco.org/docs/2021/COM/20210727_1619/27107_2021-07-22_-_Subdivision_Regulations_%282021-B_Update%29_-_CLEAN.pdf. Retrieved on in September 2022

APPENDIX A

SURVEY QUESTIONNAIRE FOR LOCAL GOVERNMENTS

Synthesis: Develop Guidance for Local Government Building Codes for Bridge

CONTACT INFORMATION

Please provide the following contact information.

Name	*Name*
Position	*Position*
Local Government (City/County)	*Local Government*
E-mail	*E-mail*
Phone	*Phone*

GENERAL INFORMATION

1. Are there any off-system bridges owned and maintained by your local government?

"Off-system bridge is defined as a vehicular bridge owned and maintained by a county, city, or other local or regional governmental unit, and not on the TxDOT-designated highway system. Culverts with a clear opening of more than 20 feet, measured along the center of the roadway between the inside of end walls are designated a bridge class culvert."

☐ Yes

☐ No *(if no, the survey terminates)*

2. What is the frequency of bridge deficiencies in the off-system bridges that are owned and maintained by your local government?

"Deficiencies is referred to the incapacity of a bridge, or its components, to perform as specified by its design and construction requirements."

☐ Never
☐ Very Rarely
☐ Rarely
☐ Occasionally
☐ Frequently

3. Where do deficiencies within bridges typically occur? Please rank them in order of frequency (1 most frequent and 6 least frequent)

☐ Deck ____1_____

☐ Superstructure (e.g., girders, bearing pads) ____2_____
"Superstructure is that part of a bridge structure covered on the span details, or above the bridge seats."

☐ Substructure (e.g., piers, foundations) ____3_____
"Substructure is that part of a bridge structure covered on bent details, or below the bridge seats including backwalls and wingwalls at abutments."

☐ Bridge railing ____4_____
☐ Signs (on or above structure) ____5_____
☐ Other ____6_____

4. What are the most common causes of bridge deficiencies/poor performance in your local government? Please rank them in order of importance (1 most and 7 least)

☐ Hydraulic issues ____1_____

- ☐ Re-occurring vehicular damage ____2_____
- ☐ Overload ____3_____
- ☐ Construction error ____4_____
- ☐ Design error ____5_____
- ☐ Lack of maintenance ____6_____
- ☐ Other ____7_____

5. Does your local government require developers to follow any specific manuals, guidelines, or standard specifications to design and construct bridges?
   - ☐ Yes *(if yes, go to question 6)*
   - ☐ No *(if no, go to question 10)*

Requirements for Developers

6. What kind of manuals (i.e., National Level, State level, or Local Level) does your local government require developers to follow for the design and construction of off-system bridges? Please select all that apply.
   - ☐ National Level (e.g., AASHTO Bridge Design Specifications)
   - ☐ State Level (e.g., TxDOT Bridge Design Manual)
   - ☐ Local Level (e.g., Local Government's Design Manual)

7. What National design manuals or standards does your local government require developers to follow for the design and construction of off-system bridges? Please select all that apply. *(Show this question if national-level codes were checked in question 6)*
   - ☐ AASHTO Bridge Design Specifications-LRFD
   - ☐ National Cooperative Highway Research Program (NCHRP) Report 350— related bridge railings and safety
   - ☐ AASHTO Manual for Assessing Safety Hardware (MASH)— related bridge railings and safety
   - ☐ AASHTO Standard Specifications for Highway Bridges

- ☐ AASHTO LRFD Guide Specifications for the Design of Pedestrian Bridges
- ☐ Other (Please Specify) ☐

8. What State design manuals or standards does your local government require developers to follow for the design and construction of off-system bridges? Please select all that apply.
(Show this question if State level codes were checked in question 6)

- ☐ TxDOT Bridge Design Manual- LRFD
- ☐ TxDOT Hydraulic Design Manual
- ☐ TxDOT Bridge Railing Identification Guide
- ☐ TxDOT CAD Standards for Bridges
- ☐ TxDOT Quality Control and Quality Assurance Guide
- ☐ TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges
- ☐ TxDOT District Requirements
- ☐ TxDOT Preferred Practices for Steel Bridge Design, Fabrication, and Erection
- ☐ TxDOT Bridge Design Guide
- ☐ TxDOT Bridge Railing Manual
- ☐ TxDOT Bridge Detailing Guide
- ☐ TxDOT Bent (pier) Protection Guide
- ☐ TxDOT Geotechnical Manual
- ☐ TxDOT Corrosion Protection Guide
- ☐ Other (Please Specify) ☐

9. Which aspects of bridge design and construction are subject to additional provisions in your local government's manuals? *(Show this question if Local level codes were checked in question 6)*

- ☐ Hydraulic Design
- ☐ Structural Design
- ☐ Geotechnical Design
- ☐ Standard Specifications
- ☐ CAD Standards and Detailing Guide
- ☐ Bridge Railing
- ☐ Other (Please Specify) ☐

Preparation and Submission of Bridge Plan Sets

10. Does your local government require that a professional engineer sign and seal the bridge plan sets?
    - ☐ Yes
    - ☐ No

11. Does your local government require developers to submit the preliminary layouts during the design process for your internal review and approval?
    - ☐ Yes
    - ☐ No

12. Is your local government familiar with TxDOT preliminary bridge layout review (PBLR) process and the design requirements embedded in it?
    - ☐ Yes
    - ☐ No

13. Does your local government submit the preliminary layouts for TxDOT's review and approval during the design process?
    - ☐ Yes (for all projects)
    - ☐ Yes (only for projects on the state highway, projects with state or federal funds, or projects off the state highway but connecting to or crossing a state highway)
    - ☐ No

14. Does your local government archive the final bridge plan sets after the project is completed?
    - ☐ Yes (for all bridge projects)
    - ☐ Yes (only for projects on the state highway, projects with state or federal funds, or projects off the state highway but connecting to or crossing a state highway)

- No

15. What items are typically included in a bridge plan set in your local government?

- ☐ Bridge Hydraulic Data Sheets,
- ☐ Bridge Geotechnical Report (e.g., boring logs, boring location plan, and subsurface profile)
- ☐ Bridge Layout and Profile,
- ☐ Slab Details
- ☐ Girder Details
- ☐ Standards
- ☐ Bent Details
- ☐ Bridge Scour Data Sheet
- ☐ Detailed Quantity Summary,
- ☐ Railing Details
- ☐ Utility Details
- ☐ Framing Details
- ☐ Foundation Plan
- ☐ Abutment Details
- ☐ Other (Please Specify) ☐

Bridge Inspection

16. Does your local government follow the recommendations outlined in the TxDOT bridge inspection report that is prepared for the off-system bridges in your local government?

"TxDOT is responsible to perform initial inspections (on new bridges or when existing bridges are first entered into a database) and routine inspections (every 24 months) on all on-system and off-system bridges."

- ☐ Yes
- ☐ No

Further Information

17. Our follow-up interview is designed to acquire practical information about the state of practice on building codes that cities and counties have in place for developers, as well as the practices to acquire those plans after construction is complete. Are you willing to share your insight in a follow-up interview?

- ☐ Yes
- ☐ No

Thank you for participating in this survey.

If you like to provide follow-up information or if you are interested in receiving notification once

the final report is completed, please contact Dr. Mohsen Shahandashti, P.E., at mohsen@uta.edu or call directly at 817-271-0440.

APPENDIX B

SURVEY QUESTIONARY FOR ENGINEERING CONSULTING FIRMS

Synthesis: Develop Guidance for Local Government Building Codes for Bridge

CONTACT INFORMATION

Please provide the following contact information.

Name:	*Name*
Position:	*Position*
Engineering Consulting Firm:	*Engineering Consulting Firm*
City/Town:	*City/Town*
E-mail:	*E-mail*
Phone:	*Phone*

GENERAL INFORMATION

1. Is your engineering consulting firm actively involved in the design, construction, or maintenance of off-system bridges in Texas?

"Off-system bridge is defined as a vehicular bridge owned and maintained by a county, city, or other local or regional governmental unit, and not on the TxDOT-designated highway system. Culverts with a clear opening of

more than 20 feet, measured along the center of the roadway between the inside of end walls are designated a bridge class culvert."

- ☐ Yes
- ☐ No *(if no, the survey terminates)*

2. What engineering services does your firm offer regarding the off-system bridges in Texas? Please select multiple if it applies.

- ☐ Design
- ☐ Construction and Maintenance

BRIDGE CODES AND STANDARDS

3. Does your engineering consulting firm follow any specific design manuals or guidelines to design and construct off-system bridges in Texas?
   - ☐ Yes
   - ☐ No *(If no, go to question 6)*

4. What kind of design manuals (e.g., national level, state level, local level) do you follow in your engineering firm to design and/or construct off-system bridges in Texas? Please select multiple if it applies.
   - ☐ National Level Design Manuals (e.g., AASHTO Bridge Design Specifications)
   - ☐ State Level Design Manuals (e.g., TxDOT Bridge Design Manual)
   - ☐ Local Level Design Manuals (e.g., Local Government's Design Manual, TxDOT District Requirements)

5. Please select the codes and standards that your engineering firm follow to design and/or construct off-system bridges in Texas. *(According to answers for questions 2 and 4, related manuals will be listed)*

- ☐ TxDOT Bridge Design Manual- LRFD
- ☐ TxDOT Hydraulic Design Manual
- ☐ TxDOT Bridge Railing Identification Guide
- ☐ TxDOT CAD Standards for Bridges
- ☐ TxDOT Quality Control and Quality Assurance Guide
- ☐ TxDOT Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges
- ☐ TxDOT Preferred Practices for Steel Bridge Design, Fabrication, and Erection
- ☐ TxDOT Bridge Design Guide
- ☐ TxDOT Bridge Railing Manual
- ☐ TxDOT Bridge Detailing Guide
- ☐ TxDOT District Requirements
- ☐ TxDOT Bent (pier) Protection Guide
- ☐ TxDOT Geotechnical Manual
- ☐ TxDOT Corrosion Protection Guide
- ☐ AASHTO Bridge Design Specifications-LRFD
- ☐ AASHTO Manual for Assessing Safety Hardware (MASH)— related bridge railings and safety
- ☐ AASHTO Standard Specifications for Highway Bridges
- ☐ National Cooperative Highway Research Program (NCHRP) Report 350— related bridge railings and safety
- ☐ AASHTO LRFD Guide Specifications for the Design of Pedestrian Bridges
- ☐ Other (Please Specify) ☐

PREPARATION AND SUBMISSION OF BRIDGE PLAN SETS

6. Does your engineering firm require a professional engineer to approve the bridge plan set after the design is completed? *(Show question if design service was selected in question 2)*

- ☐ Yes
- ☐ No

7. Does your engineering firm submit the final bridge plan sets to local governments after the design is completed? *(Show question if design service was selected in question 2)*

- ☐ Yes
- ☐ No

8. Does your engineering firm approve the final as-built plan set by a professional engineer after the construction or rehabilitation is completed? *(Show question if Construction service was selected in question 2)*

- ☐ Yes

☐ No

9. Does your engineering firm submit the final bridge plan sets (as-built plans) to local governments after the construction or rehabilitation is completed? *(Show question if Construction service was selected in question 2)*

☐ Yes

☐ No

10. What items are typically included in a bridge plan set prepared by your engineering consulting firm?

☐ Bridge Hydraulic Data Sheets,
☐ Bridge Geotechnical Report (e.g., boring logs, boring location plan, and subsurface profile)
☐ Bridge Layout and Profile,
☐ Slab Details
☐ Girder Details
☐ Standards
☐ Bent Details
☐ Bridge Scour Data Sheet
☐ Detailed Quantity Summary,
☐ Railing Details
☐ Utility Details
☐ Framing Details
☐ Foundation Plan
☐ Abutment Details
☐ Other (Please Specify) ☐

Further Information

11. Our follow-up interview is designed to acquire practical information about the state of practice on building codes that cities and counties have in place for developers, as well as the practices to acquire those plans after construction is complete. Are you willing to share your insight in a follow-up interview?

☐ Yes

☐ No

Thank you for participating in this survey.

If you like to provide follow-up information or if you are interested in receiving notification once the final report is completed, please contact Dr. Mohsen Shahandashti, P.E., at mohsen@uta.edu or call directly at 817-271-0440.

APPENDIX C
SURVEY QUESTIONARY FOR TXDOT

Synthesis: Develop Guidance for Local Government Building Codes for Bridge

CONTACT INFORMATION

Please provide the following contact information.

Name	*Name*
Position	*Position*
District	*District*
Address	*Address*
City/Town	*City/Town*
State	*State*
E-mail	*E-mail*

GENERAL INFORMATION

1. Is there a specific local government or engineering consulting firm that should be contacted to learn more about their building codes for off-system bridge design, construction, and maintenance, as well as their practices to acquire plans after construction is completed?

- ☐ Yes
- ☐ No *(if no, survey terminates)*

2. Please provide the name and possible contact information for the local government or engineering consulting firm that should be contacted to learn about their current practices for the design and construction of off-system bridges.

Note: If there are multiple local governments, you can upload a list file in the next question of this survey.

- Name of Local government or engineering consulting firm. _____
- Name of Representative (if any): _____
- Position: _____
- Email: _____
- Phone: _____

3. If you have a list of local governments or engineering consulting firms that we should contact to learn about their current practices for design and construction of off-system bridges, please upload it below.

Upload file

Thank you for participating in this survey.

If you like to provide follow-up information or if you are interested in receiving notification once the final report is completed, please contact Dr. Mohsen Shahandashti, P.E., at mohsen@uta.edu or call directly at 817-271-0440.