Texas Freight Network Technology and Operations Plan

Safety Warning Detection System Concept of Operations
Texas Department of Transportation, Freight Planning Branch

Final: December 2020
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<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AADT</td>
<td>Average Annual Daily Traffic</td>
</tr>
<tr>
<td>AASHTO</td>
<td>American Association of State Highway Transportation Officials</td>
</tr>
<tr>
<td>ATHWLD</td>
<td>Average of the Ten Heaviest Loads Daily</td>
</tr>
<tr>
<td>ATIS</td>
<td>Advanced Traveler Information System</td>
</tr>
<tr>
<td>ATMS</td>
<td>Advanced Traffic Management System</td>
</tr>
<tr>
<td>C2C</td>
<td>Center-to-Center</td>
</tr>
<tr>
<td>CapMetro</td>
<td>Capital Metropolitan Transit Authority</td>
</tr>
<tr>
<td>CAT</td>
<td>Cooperative Automated Transportation</td>
</tr>
<tr>
<td>CCTV</td>
<td>Closed-Circuit Television</td>
</tr>
<tr>
<td>CMV</td>
<td>Commercial Motor Vehicle</td>
</tr>
<tr>
<td>ConOps</td>
<td>Concept of Operations</td>
</tr>
<tr>
<td>CRIS</td>
<td>Crash Records Information System</td>
</tr>
<tr>
<td>CTEEC</td>
<td>Combined Transportation &amp; Communications Center</td>
</tr>
<tr>
<td>CTRMA</td>
<td>Central Texas Regional Mobility Authority</td>
</tr>
<tr>
<td>CTT</td>
<td>Comparative Travel Time</td>
</tr>
<tr>
<td>CV</td>
<td>Connected Vehicle</td>
</tr>
<tr>
<td>DART</td>
<td>Dallas Area Rapid Transit</td>
</tr>
<tr>
<td>DMS</td>
<td>Dynamic Message Sign</td>
</tr>
<tr>
<td>ESALs</td>
<td>Equivalent Single Axle Loads</td>
</tr>
<tr>
<td>FHWA</td>
<td>Federal Highway Administration</td>
</tr>
<tr>
<td>FNTOP</td>
<td>Freight Network Technology and Operations Plan</td>
</tr>
<tr>
<td>GIWW</td>
<td>Gulf Intracoastal Waterway</td>
</tr>
<tr>
<td>HCRS</td>
<td>Highway Conditions Reporting System</td>
</tr>
<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
</tr>
<tr>
<td>IRI</td>
<td>International Roughness Index</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>ITS</td>
<td>Intelligent Transportation Systems</td>
</tr>
<tr>
<td>LAN</td>
<td>Local Area Network</td>
</tr>
<tr>
<td>METRO</td>
<td>Metropolitan Transit Authority of Harris County</td>
</tr>
<tr>
<td>MPO</td>
<td>Metropolitan Planning Organization</td>
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<tr>
<td>MUTCD</td>
<td>Manual on Uniform Traffic Control Devices</td>
</tr>
<tr>
<td>NESC</td>
<td>National Electrical Safety Code</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>Operations &amp; Maintenance</td>
</tr>
<tr>
<td>OEMs</td>
<td>Original Equipment Manufacturers</td>
</tr>
<tr>
<td>OS/OW</td>
<td>Oversize/Overweight</td>
</tr>
<tr>
<td>PAAC</td>
<td>Port Authority Advisory Committee</td>
</tr>
<tr>
<td>PII</td>
<td>Personally Identifiable Information</td>
</tr>
<tr>
<td>RIMS</td>
<td>Regional Incident Management Systems</td>
</tr>
<tr>
<td>ROI</td>
<td>Return on Investment</td>
</tr>
<tr>
<td>ROW</td>
<td>Right of Way</td>
</tr>
<tr>
<td>SOPs</td>
<td>Standard Operating Procedures</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
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</tr>
<tr>
<td>STARS II</td>
<td>Statewide Traffic Analysis and Reporting System</td>
</tr>
<tr>
<td>STRATIS</td>
<td>South Texas Regional Advanced Transportation Information System</td>
</tr>
<tr>
<td>SWRI</td>
<td>Southwest Research Institute</td>
</tr>
<tr>
<td>TCDS</td>
<td>Traffic Count Database System</td>
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<tr>
<td>TFMP</td>
<td>Texas Freight Mobility Plan</td>
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<tr>
<td>THFN</td>
<td>Texas Highway Freight Network</td>
</tr>
<tr>
<td>TMC</td>
<td>Traffic Management Center</td>
</tr>
<tr>
<td>TMFN</td>
<td>Texas Multimodal Freight Network</td>
</tr>
<tr>
<td>TMUTCD</td>
<td>Texas Manual on Uniform Traffic Control Devices</td>
</tr>
<tr>
<td>TPP</td>
<td>Transportation Planning and Programming</td>
</tr>
<tr>
<td>TSMO</td>
<td>Traffic Systems Management &amp; Operations</td>
</tr>
<tr>
<td>TTI</td>
<td>Texas A&amp;M Transportation Institute</td>
</tr>
<tr>
<td>TxDOT</td>
<td>Texas Department of Transportation</td>
</tr>
<tr>
<td>TxDPS</td>
<td>Texas Department of Public Safety</td>
</tr>
<tr>
<td>TxFAC</td>
<td>Texas Freight Advisory Committee</td>
</tr>
<tr>
<td>USDOT</td>
<td>United States Department of Transportation</td>
</tr>
<tr>
<td>WAN</td>
<td>Wide Area Network</td>
</tr>
<tr>
<td>WIM</td>
<td>Weigh-in-Motion</td>
</tr>
<tr>
<td>XML</td>
<td>Extensible Markup Language</td>
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1.0 Introduction
The Freight Network Technology and Operations Plan (FNTOP) is anticipated to be the most comprehensive freight technology planning effort among state Departments of Transportation (DOTs) in the U.S. The FNTOP intends to outline potential strategies to guide technology- and operations-related investments on the Texas Multimodal Freight Network (TMFN). The FNTOP includes a review of current and future transportation challenges, opportunities, and the development of user needs informed by focused public and private sector engagement. The FNTOP is anticipated to be an invaluable resource to help public agencies and the private sector effectively plan for future deployments of freight technologies, working in partnership across all modes of freight transportation.

This document—titled Concept of Operations—discusses key information for the Safety Warning Detection System strategy, which was one of the strategies identified in the FNTOP and recommended by stakeholders for advancement to the ConOps phase. The objective of a ConOps is to describe the operation of the proposed system in a non-technical and easy-to-understand manner. How the system is to be used and its anticipated benefits is described from multiple stakeholder viewpoints as a way to provide a bridge between the needs that motivated the project and the specific technical requirements.

1.1 Project Overview
The primary goal of the FNTOP is to develop a comprehensive plan advising TxDOT on deploying technology based operational strategies to improve freight transportation safety and mobility in Texas. The main objectives of this project include:

- Identify and assess technological and operational strategies being used on the TMFN or could be used in the future to improve safety, mobility, and facilitate economic competitiveness;
- Identify and assess the Texas Department of Transportation’s (TxDOT) needs, challenges, and opportunities in terms of physical Intelligent Transportation System (ITS) hardware (e.g., traffic detectors, closed-circuit television (CCTV) cameras, dynamic message signs (DMS), connected vehicle (CVs) roadside units, etc.) and related infrastructure, digital framework and related infrastructure, operations, staffing and expertise, and statewide, corridor, urban, and rural needs and partnerships;
- Assess the TMFN’s current and future technological and operational needs, as well as its readiness and adaptability potential associated with the impacts of existing and emerging technologies;
- Develop strategies, policies, programs, and projects to address technological and operational needs; and
• Develop an Implementation Plan and a set of Concept of Operations documents, with each focused on a near-term freight network technology “early win” deployment concept.

The FNTOP and Concepts of Operations would guide Texas’s strategic development and deployment of innovative multimodal freight transportation technologies, techniques, research, and methods.

1.2 Project Reports
The FNTOP is based on a detailed assessment of current and future needs, challenges, gaps, and opportunities that inform strategies and a standalone Implementation Plan. These assessments are compiled in the following technical reports:

- **Goals and Objectives Report.** Developed goals and objectives for the FNTOP in alignment with existing and ongoing planning efforts and stakeholder input.

- **State of the Practice Assessment Report.** Assessed the state of the practice regarding freight-related groups, policies, and initiatives in Texas, in addition to existing and emerging domestic and international freight technological and operational developments.

- **Inventory of Existing Conditions Report.** Identified ITS assets, applications, and programs that exist on the TMFN, as well as summarized operational and management processes related to TxDOT and partner use of technology infrastructure.

- **Stakeholder Outreach Summary Report.** Summarized discussions and feedback collected at Texas public agency meetings, deeper-dive discussions with various TxDOT Divisions, Cooperative Automated Transportation (CAT) meeting, Port Authority Advisory Committee (PAAC) meeting, FNTOP regional stakeholder meetings, TxDOT stakeholder webinar workshop, FNTOP briefing with private and public sector stakeholders, as well as the set of one-on-one stakeholder interviews conducted.

- **User Needs Assessment Report.** Identified and assessed the technological and operational needs of the TMFN based on public and private sector stakeholder feedback, which were combined with initial research efforts to establish a set of FNTOP User Needs.

- **Strategies and Conceptual Framework Report.** Documented FNTOP identified strategies that are relevant to the goals and objectives of the FNTOP and based on documented FNTOP User Needs. Identified details of the FNTOP identified strategies, including how they are prioritized and how they could fit together as part of a larger conceptual framework that builds upon the existing Texas ITS program.
• **Concepts of Operations.** Developed in-depth concepts of desired operations and maintenance requirements for the six FNTOP recommended strategies selected for Concept of Operations (ConOps) development.

• **Implementation Plan.** Identified near-term, medium-term, and long-term actions, in addition to considerations necessary for the rollout of each of the 10 FNTOP recommended strategies as they are transitioned from planning to design.

• **Freight Network Technology and Operations Plan.** Will summarize the entire plan development tasks, as well as incorporate the technical and stakeholder engagement tasks completed throughout this project in a final plan.

In an effort to keep up with technology trends, TxDOT is separately developing its CAT Strategic Plan. This statewide plan looks at strategies and opportunities for advancing emerging technologies, such as Connected Vehicles (CVs), Automated Vehicles (AVs), and electric vehicles (EVs). With a number of goals that relate to the TMFN, the plan aims to put Texas at the forefront of innovation. Although the CAT Strategic Plan is separate from the FNTOP, it has overlapping goals and objectives that have been used to help inform the FNTOP’s efforts and identified strategies.

### 1.3 Stakeholder Engagement

The FNTOP began with research on existing freight initiatives at TxDOT to gain a better understanding of the current challenges faced by the Texas freight community. TxDOT then reached out to a diverse group of stakeholders with a goal to solicit feedback and opinions on the current state of freight operations in Texas and the vision for the application of technology to support future freight operations. The stakeholder interviews verified and supported many of the issues identified by the FNTOP, while also informing the prioritization of potential strategies to address deficiencies in the system.

This outreach included public sector stakeholders (internal and external to TxDOT; federal, state, and local) and private sector stakeholders. A brief overview of the full FNTOP outreach effort is provided below:

- **TxDOT Stakeholder Groups (Division Offices)** – This effort included key personnel from many TxDOT Divisions, including the Transportation Planning and Programming Division, Information Technology Division, Traffic Safety Division, Travel Information Division, Right of Way Division, Rail Division, Maintenance Division, Maritime Division, and Strategic Planning Division.

- **Freight Network Technology Regional Outreach** – This effort included discussing the FNTOP at the TxDOT CAT Meeting, PAAC Meeting, Houston (TranStar) Stakeholder Meeting, Dallas/Fort Worth Stakeholder Meeting, a dedicated breakout session at the 2019 Texas Mobility Summit in San Antonio, a stakeholder webinar workshop, and a FNTOP briefing with private and public sector stakeholders. At each meeting or session,
moderators collected feedback regarding challenges and opportunities associated with technology-based operational strategies to improve freight transportation safety and mobility in Texas.

- **Public/Private Sector Stakeholder Outreach** – This effort consisted of one-on-one phone and in-person interviews (total of 58) with stakeholder representatives in multiple freight modes, freight companies, railroads, original equipment manufacturers (OEMs), startups, industry groups, telecommunications companies, research institutes, MPOs, cities, federal government, and others. A breakdown by type of stakeholder, based on the 58 interviews, is shown in Exhibit 1.

**Exhibit 1: Distribution of Stakeholder Types for Public/Private Sector Outreach**

![Pie chart showing distribution of stakeholder types]

1.4 **Texas Multimodal Freight Network**

The TMFN consists of the state’s freight assets that are most important for moving the largest volumes of freight and that serve the state’s key freight intensive industries. Per the 2018 TFMP\(^1\), these assets cover:

- **Highways**: Highways are the predominant mode for freight movement within the state, providing first and last mile connections to rail facilities, maritime ports, airports, and pipelines, as well as serving long haul trips destined throughout the state and beyond.

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\(^1\) Texas Department of Transportation, *Texas Freight Mobility Plan 2018*, March 7, 2018.
Texas has over 313,000 miles of public roadways – making it the state with the most extensive highway network. 21,861 miles are on the THFN, with 745 miles designated as Critical Rural Freight Corridors and another 372 miles designated as Critical Urban Freight Corridors. In 2016, trucks accounted for 54 percent of total tonnage moved in Texas. Intrastate trucking tonnage is anticipated to grow significantly as more residents, businesses, and freight locate within the state.

- **Railroads:** With 10,539 track miles (all on the TMFN), Texas has more miles of rail and more railroad employees than any other state. Texas contains five of the seven rail crossings between the U.S. and Mexico, providing critical connections for trade between the two countries. Texas’ 49 shortline railroads serve as first or last mile railroads for Texas’ three Class I railroads (BNSF Railway, Kansas City Southern Railway Company, and Union Pacific Railroad), Texas’ maritime ports, and many of the state’s rail-served industries.

- **Ports and Waterways:** Texas handles the second highest volume of total maritime tonnage of any state in the nation with 21 maritime ports and the Gulf Intracoastal Waterway (GIWW) system and is the leading state for international maritime tonnage. Maritime port and waterway access are necessary to attract and support many businesses, including the petrochemical sector, one of the state’s most important industries. Nine of Texas’ 12 deepwater ports, and one of its nine shallow-draft ports are included on the TMFN. Texas’ 379-mile portion of the GIWW, referred to as Marine Highway 69 (M-69), is also a part of the TMFN. M-69 handles two-thirds of the waterway’s traffic, moving approximately 86 million short tons of cargo annually.

- **Airports:** In 2016, six of the top 50 cargo airports in the U.S. (in terms of landed weight) were located in Texas. Out of Texas’ 24 commercial airports, seven are included on the TMFN. Air cargo tonnage is expected to grow at a higher rate than any other mode due to market changes such as the increase in e-commerce and the associated expectations for one- or two-day shipping.

- **Pipelines:** Texas has the most extensive pipeline network in the nation, with 426,000 total miles (59 percent intrastate and 41 percent interstate), carrying 826.6 million tons of cargo in 2016.

- **International Border Crossings:** Texas’ 20 commercial international border crossings are also all on the TMFN. Of those, 15 are commercial vehicle crossings, and the other five are rail crossings.

Exhibit 2 provides an overview of the assets designated as a part of the TMFN – namely key roadways, railroads, maritime ports and waterways, airports, and international border crossings. Exhibit 3 maps out where these assets are located in Texas. The TMFN is important because it includes the key corridors that facilitate the efficient and safe movement of goods in Texas and are the most critical for focused investment.
### Exhibit 2: Overview of Texas Multimodal Freight Network Assets

<table>
<thead>
<tr>
<th>Asset Description</th>
<th>Total</th>
<th>Transporting</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadway Centerline Miles</td>
<td>313,000</td>
<td>1.2 billion tons</td>
<td>Texas Department of Transportation, Texas Freight Mobility Plan 2018 – Executive Summary, March 7, 2018.</td>
</tr>
<tr>
<td>Texas Highway Freight Network</td>
<td>21,661</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical Rural Freight Corridor</td>
<td>745</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical Urban Freight Corridor</td>
<td>372</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Railroads on the TMFN</td>
<td>10,539</td>
<td>441 million tons</td>
<td></td>
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<tr>
<td>Class I Railroads</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class III or Shortline Railroads</td>
<td>49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Port System and the Gulf Intracoastal Waterway System</td>
<td>21</td>
<td>598 million tons</td>
<td></td>
</tr>
<tr>
<td>Deepwater Ports</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Included on TMFN</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shallow Draft Ports</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Included on TMFN</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miles of GINW, all on TMFN</td>
<td>379</td>
<td></td>
<td></td>
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<tr>
<td>Commercial Airports</td>
<td>24</td>
<td>1.8 million tons</td>
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<tr>
<td>Air Cargo Airports on TMFN</td>
<td>7</td>
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<tr>
<td>Pipeline Miles</td>
<td>426,000</td>
<td>837 million tons</td>
<td></td>
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<tr>
<td>Interstate</td>
<td>59%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intrastate</td>
<td>41%</td>
<td></td>
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<tr>
<td>Commercial International Border Crossings, all on the TMFN</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial Vehicle Crossings</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail Crossings</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Facilitating**: 73.5 million tons
Exhibit 3: The Texas Multimodal Freight Network

The Texas Multimodal Freight Network

Legend
- Texas Highway Freight Network
- Primary Highway Freight System
- Critical Urban Freight Corridor
- Critical Rural Freight Corridor
- Class I Railroad
- Shortline Railroad
- Truck Border Crossing
- Rail Border Crossing
- Intermodal Airports
- Deep Draft Port
- Shallow Draft Port
- Gulf Intracoastal Waterway

Source: Texas Department of Transportation, Texas Freight Mobility Plan 2018 – Executive Summary, March 7, 2018.
The 2018 TFMP identified eight goals and associated objectives that help inform and articulate TxDOT’s freight investment priorities, help define freight system investment needs, and identify the desired future performance of the TMFN. Exhibit 4 summarizes these goals, some of which will be utilized later in this document to identify deficiencies in the existing system and justify deployment of the identified strategy.

**Exhibit 4: 2018 TFMP Goals**

<table>
<thead>
<tr>
<th>2018 TFMP Goals</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Improve multimodal transportation safety</td>
</tr>
<tr>
<td>Economic Competitiveness</td>
<td>Improve the contribution of the Texas freight transportation system to economic competitiveness, productivity and development</td>
</tr>
<tr>
<td>Asset Preservation and Utilization</td>
<td>Maintain and preserve infrastructure assets using cost-beneficial treatments</td>
</tr>
<tr>
<td>Mobility &amp; Reliability</td>
<td>Reduce congestion and improve system efficiency and performance</td>
</tr>
<tr>
<td>Multimodal Connectivity</td>
<td>Provide transportation choices and improve system connectivity for all freight modes</td>
</tr>
<tr>
<td>Stewardship</td>
<td>Manage environmental and TxDOT resources responsibly and be accountable in decision-making</td>
</tr>
<tr>
<td>Customer Service</td>
<td>Understand and incorporate citizen feedback in decision-making processes and be transparent in all TxDOT communications</td>
</tr>
<tr>
<td>Sustainable Funding</td>
<td>Identify sustainable funding sources for all freight transportation modes</td>
</tr>
</tbody>
</table>

Source: Texas Department of Transportation, Texas Freight Mobility Plan 2018

### 1.5 Summary of Existing Conditions and User Needs

The FNTOP reviewed the existing ITS program in Texas, which represents the vast majority of TxDOT’s real-time traffic management applications that serve roadway user needs, including freight. TxDOT utilizes Traffic Management Centers (TMC) as one of the key tools to operate and manage its road network. TxDOT is a participant in several advanced mobility initiatives, including an Integrated Corridor Management (ICM) program, a freight signal priority project, and several Connected Vehicle initiatives; that said, the vast majority of the ITS and traffic management program resides in major metropolitan areas, with limited coverage or response capabilities in rural areas. Relevant ITS programs in the context of this strategy are discussed later in Section 2.2. Further details on these programs and others can be found in the FNTOP State of the Practice Assessment Report and FNTOP Inventory of Existing Conditions Report.
User Needs for the FNTOP were informed by the FNTOP Goals and Objectives, the FNTOP State of the Practice Assessment Report, the FNTOP Inventory of Existing Conditions Report, and input from stakeholders. Relevant user needs that apply to this ConOps are presented in Section 2.5 to aid with traceability of features described later in the document. A full list of FNTOP User Needs can be found as part of the FNTOP User Needs Assessment Report.

1.6 Summary of Strategies and Conceptual Framework Report

The FNTOP developed a series of technological strategies for improving freight operations in Texas. The strategies developed as part of the FNTOP consider the range of existing and emerging solutions available, based on traceability of the solutions to identified user needs prepared as part of the FNTOP User Needs Assessment Report. Exhibit 5 summarizes the potential strategies proposed to guide technology- and operations-related investments on the TMFN. Based on internal discussion and coordination with TxDOT, 10 of the 12 FNTOP strategies were advanced based on favorable feedback regarding direct relevance/importance to freight needs, uniqueness as a standalone strategy, and value as an application. The two strategies not advanced represented an infrastructure solution (Fiber Optic Expansion) and a strategy deemed to be too similar to another strategy (Freight Integrated Corridor Management).

Key public and private stakeholders were engaged to obtain feedback on the 10 strategies, including suggested refinements, and priorities. Through outreach efforts, stakeholders were asked to rank the recommended strategies based on the following questions:

- Does the strategy add value to the Texas Multimodal Freight Network?
- Is the strategy likely to succeed in Texas?

A total of six strategies were recommended to advance to Concept of Operations development. There was consistent agreement among TxDOT and its stakeholders that these strategies had high scores for adding value to the TMFN and were likely to succeed in Texas. The other strategies developed as part of this effort were either underway as part of a separate effort or deferred due to another TxDOT initiative. Exhibit 5 reflects the final recommendations for each strategy.
### Exhibit 5: Summary of Proposed FNTOP Strategies

<table>
<thead>
<tr>
<th>Identified Strategy</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck Parking Availability System</td>
<td>Underway&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>High-Resolution Freight Traveler Information System</td>
<td>Advanced to Concept of Operations</td>
</tr>
<tr>
<td>Centralized Data Repository for Freight Applications</td>
<td>Deferred&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>AV Infrastructure, Connected Signing, and Data</td>
<td>Advanced to Concept of Operations</td>
</tr>
<tr>
<td>Safety Warning Detection System</td>
<td>Advanced to Concept of Operations</td>
</tr>
<tr>
<td>Smart Freight Connector</td>
<td>Advanced to Concept of Operations</td>
</tr>
<tr>
<td>Blocked Rail Crossing Traffic Management System</td>
<td>Advanced to Concept of Operations</td>
</tr>
<tr>
<td>Smart Work Zone Information System</td>
<td>Underway&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Statewide Traffic Operations Center</td>
<td>Advanced to Concept of Operations</td>
</tr>
<tr>
<td>Binational Traffic Operations Center</td>
<td>Deferred&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Freight Integrated Corridor Management</td>
<td>Not Advanced&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fiber Optic Cable System Expansion</td>
<td>Not Advanced&lt;sup&gt;4&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup>Included in other TxDOT ongoing initiatives  
<sup>2</sup>Better fulfills goals and objectives of other TxDOT initiatives  
<sup>3</sup>Not advanced due to similarities with Smart Freight Connector strategy  
<sup>4</sup>Not advanced due to being an infrastructure-focused commodity instead of a technological or operational application.

An overall technology framework was developed to demonstrate how the proposed FNTOP strategies could work together as an integrated statewide system. The framework helps illustrate the relationships between the FNTOP strategies and any overlapping opportunities that might allow for easier deployment. All strategies have the potential to be implemented together in functional groups or as stand-alone systems.

Exhibit 6 shows the relationship among integrated services and strategies.
Exhibit 6: Potential Integrated Services and Strategies

Regional TMC(s)

ATMS

Real Time Traffic Data
Notifications

Centralized Operations

Statewide Traffic Operations Center

Centralized Data Repository for Freight Applications

Real Time Data & Notifications

AV, Signing & Data

Safety
Road User Information
Autonomous Vehicles
Notifications (conditions, incidents, closures...)

AV Infrastructure

AV Infrastructure, Connected Signing, and Data

Binational Traffic Operations Center

High-Resolution Freight Traveler Information System

Notifications

Real Time Traffic Data
Notifications

Partner Agencies
Nav/Map/Traffic Services
Other Stakeholders
Media Outlets
Gov Auth/ Emerg Serv
Data Subscribers
DriveTexas ATIS

Truck Parking Availability System

Safety Warning Detection System

Smart Freight Connector

Blocked Rail Crossing Traffic Management System

Smart Work Zone Information System
1.7  Purpose of the Concept of Operations Document

The development of a Concept of Operations (ConOps) document is the next critical step necessary for each of the six strategies selected for advancement to create implementable solutions as part of the FNTOP. The objective of a ConOps is to describe the operation of the proposed system in a non-technical and easy-to-understand manner. How the system is to be used and its anticipated benefits is described from multiple stakeholder viewpoints as a way to provide a bridge between the needs that motivated the project and the specific technical requirements. Each required functionality must be traceable back to documented user needs prepared as part of the FNTOP User Needs Assessment to ensure that the ITS project addresses real-world issues. The ConOps document is used to collect feedback from the system users and other stakeholders and to validate key assumptions built into the system concept (e.g., who is responsible for what). By building support, gathering feedback, and refining the proposed concept, the ConOps document serves as a high-level guide for subsequent design efforts (e.g. System Requirements, High-Level Design, Detailed Design). It helps advance the strategy into these subsequent phases by reducing the risk of the strategy failing or being delayed due to a lack of agreement or understanding of the proposed concept.

The establishment of priorities informed TxDOT’s selection of the six strategies that advanced to a ConOps. The development of FNTOP strategies, from proposal to ConOps, is outlined in Exhibit 7.

Exhibit 7: Formulation of Strategies from Proposal to Final Texas Freight Network Technology and Operations Plan

Projects that engineer systems—whether the project is a simple ITS deployment or a complex commercial airliner—follow what is called the Systems Engineering Process. This process identifies and outlines procedural steps of how the system is incrementally developed, how the system is incrementally validated by stakeholders, and how the system is to be
measured and accepted. The “V” Development Model,² shown in Exhibit 8, is a visualization of one such process. This model was developed based on Systems Engineering industry standards and is part of U.S. Department of Transportation’s (USDOT) best practices for ITS projects. The development processes outlined in the model help transportation agencies use common, consistent, and well-established systems engineering tools and processes to:

- Improve the quality of Intelligent Transportation Systems;
- Reduce the risk of cost and schedule overruns;
- Gain wide stakeholder participation;
- Maintain, operate, and evolve the Intelligent Transportation System;
- Maintain consistency with the regional and state ITS architectures;
- Provide flexibility in procurement options for the agencies; and
- Keep current with the rapid evolution of technology.

Exhibit 8: Systems Engineering V-Model

Development of the ConOps document is the first major step of the Decomposition and Definition phase of the V-Model, where ITS project concepts become more defined. It helps establish the simple expectations of the system so that stakeholders can understand what the project intends to do and understand how it will be later validated when complete.

² Federal Highway Administration California Division and Caltrans, Systems Engineering Guidebook for ITS Version 3.0 Website
1.8 Safety Warning Detection System Overview

This ConOps is focused on a Safety Warning Detection System, which was one of the priority strategies identified in FNTOP development and recommended by stakeholders for advancement to the ConOps phase. At a high level, the Safety Warning Detection System is a notification system that alerts truckers and other road users of situations when a vehicle is operating beyond a safety threshold, such as being too tall, too heavy, or too fast. The goals of this system are to improve freight safety by providing greater awareness of potential safety issues, as well as improve asset preservation by reducing damage to infrastructure caused by unsafe operational behavior.

Exhibit 9 provides an illustrative example of the Safety Warning Detection System strategy that was previously discussed in the FNTOP Strategies and Conceptual Framework Report. It is comprised of the following four safety warning applications, which are discussed in greater detail later in this ConOps:

- **Overweight Detection Systems** – These systems detect if a truck exceeds a predetermined weight, usually in advance of a posted bridge crossing or a truck route with a lower permitted weight limit.

- **Overspeed Detection Systems** – These systems detect if a vehicle—either truck or passenger car—exceeds a certain travel speed, usually in an environment where reduced speed is strongly advised, such as horizontal curves or hills with poor sight lines.

- **Intersection Conflict Warning** – These systems detect if a vehicle is crossing through an intersection that may be occluded by poor sight lines or some other restriction and provide notification to other approaching vehicles.

- **Overheight Detection Systems** – These systems detect if a truck exceeds a predetermined height, usually in advance of a bridge underpass. It also may include collision detection systems on the physical bridge infrastructure to notify and alert TxDOT of a detected strike.
Exhibit 9: Illustrative Example of the Safety Warning Detection System Strategy

Key objectives—collected through stakeholder outreach and other FNTOP efforts—identified to frame what this system shall ultimately do include:

- Reduce incidences of bridge strikes caused by overheight vehicles, which can cause extended closures for costly repairs, sometimes even forcing prolonged lane closures;
- Improve the preservation of infrastructure assets by reducing the number of overweight vehicles on critical facilities;
- Reduce the incidences of speed-related crashes by freight vehicles where lower travel speeds are advised;
- Reduce the incidences of crashes between freight vehicles and other vehicles at intersection locations, particularly in rural areas where stop control and poor sight distance are prevalent;
- Increase the situational awareness of the traffic management centers (TMCs) as the events in the field occur;
Increase the responsiveness of TxDOT in repairing infrastructure damage by using real-time notifications to more quickly initiate inspections, which reduces the potential for further damage and helps reduce the risk of failure;

Provide real-time notifications of potential hazards ahead so that freight vehicles can divert onto an alternative route; and

Archive and analyze notification data to report on the effectiveness of the system in improving the safety of freight operations and increasing the life of infrastructure.

1.9 Organization of the Report

This document is one of the deliverables as defined under Task 2.6: Develop Concept of Operations from the scope of work for Cambridge Systematics, Inc.’s project number 160058.006 named Texas Freight Network Technology and Operations Plan. The scope of work document is TxDOT Work Authorization No. 6, Contract No. 50-6IDP5011. This ConOps covers the topic areas outlined in ANSI/AIAA-G-043 and IEEE Standard 1362\textsuperscript{3}, as recommended by the FHWA for ConOps development.

The remainder of this document is organized into the following sections:

\begin{itemize}
  \item **Section 2 – The Current Situation in Texas.** This section describes current systems and technologies utilized by stakeholders and how each is being used, deficiencies of the existing systems, desired changes to the systems and priorities, and assumptions and challenges.
  
  \item **Section 3 – Concept for the Proposed Safety Warning Detection System.** This section contains a description of the desired system and high-level requirements, how it will address the concerns outlined in Section 2, how it will operate, and how users will interface with the system.
  
  \item **Section 4 – Benefits, Impacts, and Alternatives of the Safety Warning Detection System.** This section describes the expected operational and organizational benefits and impacts of the essential features of the new system, the potential impacts during development, disadvantages and limitations of the proposed system, and alternatives and tradeoffs considered while developing the system concept.
  
  \item **Section 5 – Operational Scenarios.** This section identifies potential real-world situations for the system. Each scenario describes how stakeholders respond to and benefit from the implementation and operation of the new system.
\end{itemize}

\textsuperscript{3} ANSI refers to the American National Standards Institute, AIAA refers to the American Institute of Aeronautics and Astronautics, and IEEE refers to the Institute of Electrical and Electronics Engineer. All three are standards-setting organizations.
- **Section 6 – Next Steps.** This section outlines the next steps of the Texas FNTOP following the development of the Concept of Operations documents, including the near-term development of the Implementation Plan.

- **Section 7 – References.** This section lists all references used in the creation of this document.
2.0 The Current Situation in Texas

The purpose of this section is to highlight the current situation in Texas in the context of the 2018 TFMP goals and the existing traffic management and traffic data systems that are currently in operation. It then highlights the deficiencies in the current situation that could be addressed by the recommended strategy. It later discusses the user classes that could apply to this ConOps document and the User Needs that support motivations to pursue a new Safety Warning Detection System.

2.1 Description of the Current Situation

The 2018 TFMP provides a comprehensive multimodal freight transportation plan for Texas, which is based on a decade of multimodal strategic planning and stakeholder collaboration at the statewide, regional, and local levels to facilitate continued economic growth and goods movement throughout the state. The TFMP and its related recommendations support the USDOT National Multimodal Freight Policy and national freight goals; it also includes state-specific recommendations to explore technology options as part of policy and planning to enhance freight transportation system safety, management, operations, and asset preservation. In the context of implementing solutions that would offer real-time notification of safety issues along the THFN, there are several TFMP goals as shown in Exhibit 10 that support this strategy. Key existing conditions associated with the impacts of freight on highway safety and asset preservation are discussed in the following subsections.

Exhibit 10: Texas’ Freight Mobility Plan Goals and Objectives Related to the Highway Mode

<table>
<thead>
<tr>
<th>2018 TFMP Goals</th>
<th>Description</th>
<th>Objectives Related to the Highway Mode</th>
</tr>
</thead>
</table>
| Safety          | Improve multimodal transportation safety. | • Increase the resiliency and security of the state’s freight transportation system in response to multi-hazard threats, including natural disasters and man-made threats.  
• Support the deployment of innovative technologies to enhance the safety and efficiency of the Texas Multimodal Freight Network. |
| Asset Preservation and Utilization | Maintain and preserve infrastructure assets using cost beneficial treatments. | • Leverage and utilize the Texas Multimodal Freight Network.  
• Utilize technology to provide for the resiliency and security of the TMFN in response to multi-hazard threats, including natural disasters and man-made threats. |

Source: Texas Department of Transportation, Texas Freight Mobility Plan 2018 – Executive Summary, March 7, 2018
2.1.1 Safety
Between 2013 and 2017, there were almost 3 million crashes on Texas roadways, with approximately 190,000 crashes involving commercial motor vehicles (CMVs) as documented in TxDOT’s Crash Records Information System (CRIS). The data revealed that CMV-related crashes have a greater impact on safety resulting in a greater probability of serious injuries. During the reporting period, non-CMV-related crashes reported an average of 0.03 serious injuries per incident, while CMV-related crashes reported an average of 0.04 serious injuries.

Exhibit 11 shows the number of CMV-related crashes each year and the number of CMV-related crashes that reported serious injuries or fatalities. During the five-year period, total CMV-related crashes grew at an average rate of 5 percent per year. Crashes involving serious injuries and fatalities combined represents 5 percent of the total CMV-related crashes. The number of serious injury and fatality-involved crashes combined grew at an average rate of 3 percent per year, which is lower than the growth rate observed for non-serious CMV-related crashes.

Exhibit 11: CMV-Related Crashes on Texas Roads (2013 to 2017)

Exhibit 12 shows the numbers of CMV-related crashes occurring at intersections and curves. Between 2013 and 2017, almost a quarter of CMV-related crashes—or approximately 43,000 crashes—occurred at intersections, and 1 percent of those crashes involved a fatality. Crashes of this type resulted in a similar rate of serious injuries compared to all CMV-related crashes, at an average of 0.04 serious injuries per crash. During the reporting period, 13 percent of CMV-related crashes—or approximately 25,000 crashes—occurred on
curves, and 2 percent of those crashes involved a fatality. Crashes of this type resulted in a higher number of serious injuries compared to all crashes, with an average of 0.05 serious injuries per crash.

**Exhibit 12: CMV-Related Crashes at Intersections and Curves (2013 to 2017)**

2.1.2 Asset Preservation and Utilization

The 2018 TFMP took a comprehensive look at asset preservation needs, including bridges with low vertical clearances, poor condition, or load restrictions, as well as pavement-rated needs such as poor condition. Exhibit 13 shows bridge issues and poor pavement conditions on the THFN. The TFMP reported that 85 percent of total lane miles on the THFN in 2016 were deemed “fair” or better, according to a scoring of pavement conditions based on the IRI. Of the 20,778 bridges on the THFN, 76 bridges were rated in poor condition; 13 bridges were restricted to loads of 80,000 pounds or less; and 291 bridges had a vertical clearance of less than 15 feet (as of 2017).

Bridges with a vertical clearance of less than 15 feet can be especially problematic, resulting in dangerous and costly bridge strikes by oversized vehicles. In 2017, TxDOT implemented a new vertical clearance standard that calls for a minimum clearance height of 18 feet and 6 inches (18’-6”) for all bridges and other overhead structures located on the THFN. The updated standard applies to new bridge construction or reconstruction projects that are let after September 2020. According to the CRIS data, there were a total of 178
CMV-related crashes from 2013 to 2017 that involved freight vehicles striking the top of an underpass or tunnel.

**Exhibit 13: Bridge Issues and Poor Pavement Conditions on the Texas Highway Freight network**

Source: Texas Freight Mobility Plan 2018
2.2 **Existing Systems**

This section discusses the existing traffic management systems in Texas, highlighting systems on the highway network that could overlap with and support this strategy. It is important to understand what systems and functionalities have already been deployed, so that the concept for the proposed system described in Section 3.0 can utilize relevant existing systems to support implementation activities. Refer to the FNTOP Inventory of Existing Conditions Report for additional information on the majority of the existing systems included in this section.

### 2.2.1 ITS Field Devices

TxDOT operates an extensive network of ITS field devices as part of its traffic management programs. Most ITS deployments are located near major urban areas or along highly traveled routes, as the largest benefit to road users (passenger cars, freight, etc.) is often captured by focusing investments in these areas. For example, ITS programs to help manage incidents are often deployed in urban areas, as roadway incidents can very quickly lead to propagating system delays due to the high traffic flows in those areas. Since much of the early ITS program focused on incident management, this approach to deployment has resulted in high concentrations of ITS assets in certain areas.

Some of the ITS equipment highlighted as an existing system that could support or function alongside a roadway safety notification system include:

- Overheight Detection Systems
- Closed-Circuit Television (CCTV) Cameras
- DMS
- Traffic Detectors
- Weigh-in-Motion (WIM)/Permanent Count Stations

#### 2.2.1.1 Overheight Detection Systems

Overheight detection systems monitor the height of trucks that pass by to determine if they exceed a certain height threshold, usually determined by a bridge clearance or other height restriction downstream from the monitoring device. Upon detection of a vehicle that is too tall, the system would relay an alert to the driver, warning them that they are overheight, either through a DMS, static sign with flashing beacons (i.e., “Overheight Vehicle When Flashing”), or other communications method.

Overheight detection systems in Texas are deployed as spot treatments along key freight corridors such as I-10 in Houston and I-35 in Austin that experience recurring bridge strikes. Exhibit 14 provides a summary of the number of existing and planned overheight detection systems by District. Across the state, the systems are operational at 23 sites; the Atlanta District has the most installations with 10 sites. The Odessa District, which has a high
concentration of energy sector industries and the highest statewide concentration of OS/OW vehicles, will have the most systems in operations once construction is completed for 25 sites along I-20 and I-30.

**Exhibit 14: Overheight Vehicle Detection Deployments Statewide**

<table>
<thead>
<tr>
<th>District</th>
<th>Roadways</th>
<th>Status</th>
<th>Number of Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlanta</td>
<td>US 259, SH 11, SH 49, FM 1997, FM 31</td>
<td>Operational</td>
<td>10</td>
</tr>
<tr>
<td>Austin</td>
<td>I-35 (southbound)</td>
<td>Operational</td>
<td>3</td>
</tr>
<tr>
<td>Corpus Christi</td>
<td>US 77</td>
<td>Operational</td>
<td>1</td>
</tr>
<tr>
<td>Dallas</td>
<td>I-635</td>
<td>Operational</td>
<td>2</td>
</tr>
<tr>
<td>Fort Worth</td>
<td>SH 121 (southbound)</td>
<td>Operational</td>
<td>1</td>
</tr>
<tr>
<td>Houston</td>
<td>I-10</td>
<td>Operational</td>
<td>2</td>
</tr>
<tr>
<td>Laredo</td>
<td>I-35 (southbound)</td>
<td>Operational</td>
<td>1</td>
</tr>
<tr>
<td>Odessa</td>
<td>I-20, I-30</td>
<td>Under Construction</td>
<td>25</td>
</tr>
<tr>
<td>Pharr</td>
<td>I-30</td>
<td>Operational</td>
<td>1</td>
</tr>
<tr>
<td>San Angelo</td>
<td>LP 306</td>
<td>Operational</td>
<td>1</td>
</tr>
<tr>
<td>Yoakum</td>
<td>I-10</td>
<td>Operational</td>
<td>1</td>
</tr>
</tbody>
</table>

The overheight detection systems operate locally in the field to provide notifications for a freight vehicle that could not pass underneath a bridge safely. Most of the sites are outfitted with infrared or laser detection sensors that measure vehicle heights ahead of a low clearance bridge. The system installed on I-10 in the Yoakum District is unique in its use of an overhanging cable suspended over the road for overheight vehicle detection.

Once an overheight vehicle is detected, a flashing beacon sign is activated to alert the vehicle operator to exit the highway at the next off-ramp location. At this time, the systems are not integrated with LoneStar; the systems in the Houston District communicates with the TMC by sending an alert email with an image of the vehicle.

Exhibit 15 shows the flashing beacon sign for the overheight detection system located on I-35 southbound towards downtown Austin.
Exhibit 15: Overheight Flashing Beacon Warning Sign (I-35 in Austin, TX)

2.2.1.2 Closed-Circuit Television Cameras
CCTV cameras provide visual coverage of locations along traveled roadways. For highway applications, CCTV cameras are often strategically placed on high-volume corridors and near locations with high concentrations of crashes that require incident management and response. Video feeds are transmitted back to the TxDOT District for real-time viewing; where TMCs are present, operators may keep these video feeds on in the background for passive monitoring and early detection of non-routine congestion. During incidents, CCTV cameras provide a high degree of visual clarity of how the incident is progressing, which allows for better management of the event and accurate dissemination of information to the public. In other uses, CCTV cameras can be utilized to provide situational awareness of a remote asset, such as viewing an area where an ITS device has activated an alarm (e.g. flooding detection, overheight vehicle, cabinet intrusion, etc.).

Across the state of Texas, TxDOT operates over 2,700 CCTV cameras. Details on their locations can be found in the FNTOP Inventory of Existing Conditions Report.

2.2.1.3 Dynamic Message Signs
DMS are electronic roadside signs that can broadcast changeable messages to road users, which may include public safety, traveler information, incident, or other key information. In comparison to static signs, DMS can be changed from a remote location in response to real-time events, which allows road users to make informed travel decisions to help improve
their safety or mobility. Most DMS are the large electronic signs that appear over Texas highways, but smaller equivalents can be found on other routes. In the Austin District, there are a few DMS that are classified as Comparative Travel Time (CTT) signs, which are static sign panels with changeable matrix boards that provide travel time information for fixed routes. While most DMS in Texas are large boards utilized to broadcast messages on freeways, smaller DMS can be used to activate specific messages, such as notification of high-water at specific locations.

TxDOT operates over 980 DMS. Details on their locations can be found in the FNTOP Inventory of Existing Conditions Report.

2.2.1.4 Traffic Detectors
Road detectors, or sensors, are devices that detect vehicles passing or arriving at a certain point. In the context of a traffic signal, they monitor for vehicle counts and vehicle presence at the stop bar to determine if a green phase should be called. In the context of a highway, they are used to evaluate flow, density, speed, and (depending on the type) vehicle classification. Detectors can be one of many types, including loop detectors, microwave radar, magnetometers, and video detection. Traffic-related data is often summarized in discrete intervals, such as 30-second blocks, and transmitted back to the appropriate District in real-time for use in TMCs. These detectors are used for real-time operations management, as opposed to other data collection devices like WIM or permanent count stations (discussed in the following sections) that generally provide annualized data to support trend analyses and planning work. For smaller safety-related systems, these traffic detectors can be used to measure speed and support the generation of safety alerts to inform drivers to take corrective action.

TxDOT operates over 2,500 detectors in Texas; this quantity includes only those devices used for real-time data collection for traffic management purposes and are permanently installed (as opposed to short-term temporary deployments). Details on their locations can be found in the FNTOP Inventory of Existing Conditions Report.

2.2.1.5 Weigh-In-Motion/Permanent Count Stations
Texas Department of Public Safety (TxDPS) operates and provides staff for WIM and permanent count stations around the state that are used to collect data on overweight vehicles for planning purposes. In particular, WIM is a technology that estimates vehicle weights of at-speed trucks to:

- Inventory the percentage of overweight vehicles at a given location;
- Collect and classify traffic volume data for planning activities; and
- Provide notification of a potentially overweight vehicle for law enforcement to investigate.
Many WIM or permanent count stations are permanent in-field devices to collect annual data, although TxDOT often supplements these stations with temporary device stations to collect partial-year data at specific locations and then annualize the data over the year. TxDOT is currently reviewing the existing WIM and permanent count system under a separate planning effort to identify where the system should be expanded to improve coverage.

TxDOT operates over 41 WIM stations and over 400 permanent count stations in Texas. Details on their locations can be found in the FNTOP Inventory of Existing Conditions Report.

### 2.2.2 Traffic Management Centers

TxDOT utilizes TMCs as one of the key tools to operate and manage its road network. These TMCs utilize the ITS assets available in the District to improve traffic flow, respond to incidents, and provide public safety information at a widespread and coordinated level. TxDOT currently operates seven regional TMCs, which tend to be strategically placed near the urban areas where traffic volumes and road incidents are generally more frequent. These TMCs typically provide services to state-owned roads and often manage the ITS assets for an adjacent District that may not have a TMC. Exhibit 16 summarizes each of the seven TMCs. Further details on their operations can be found in the FNTOP Inventory of Existing Conditions Report.

#### Exhibit 16: TxDOT Traffic Management Centers

<table>
<thead>
<tr>
<th>TxDOT Traffic Management Centers</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austin Combined Transportation, Emergency &amp; Communications Center (CTECC)</td>
<td>Austin CTECC serves as the TMC for the Austin area, but also serves other centralized public safety operations. It involves a partnership between TxDOT, Travis County, the City of Austin, and the Capital Metropolitan Transit Authority (CapMetro).</td>
</tr>
<tr>
<td>Dallas DalTrans</td>
<td>Dallas DalTrans serves as the TMC for the Dallas area. It involves a partnership between three agencies including the City of Dallas, TxDOT, and Dallas Area Rapid Transit (DART).</td>
</tr>
<tr>
<td>El Paso TransVista</td>
<td>El Paso TransVista serves as the TMC for the El Paso area. Housed within the TxDOT El Paso District, this TMC provides traffic and emergency management information for the region.</td>
</tr>
<tr>
<td>Fort Worth TransVision</td>
<td>Fort Worth TransVision serves as the TMC for the Fort Worth area. It is managed and operated by the TxDOT Fort Worth District and provides traffic and emergency management information for the Fort Worth area and Tarrant County.</td>
</tr>
</tbody>
</table>
TxDOT Traffic Management Centers

<table>
<thead>
<tr>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Houston TranStar</td>
<td>Houston TranStar serves as the TMC for the greater Houston area. It involves a partnership between the City of Houston, Harris County, TxDOT, and the Metropolitan Transit Authority of Harris County (METRO).</td>
</tr>
<tr>
<td>Laredo South Texas Regional Advanced Transportation Information System (STRATIS)</td>
<td>Laredo STRATIS serves as the TMC for the Laredo area. It is managed and operated by the TxDOT Laredo District and works in collaboration with the City of Laredo’s Traffic Management Center.</td>
</tr>
<tr>
<td>San Antonio TransGuide</td>
<td>San Antonio TransGuide serves as the TMC for the San Antonio region. It is managed and operated by the TxDOT San Antonio District and works in collaboration with local agencies.</td>
</tr>
</tbody>
</table>

Some TxDOT Districts that do not have a formal TMC—typically those in rural parts of the state that are not near an urban center with a TxDOT TMC—have the capability to manage and operate the ITS devices within their specific region, typically through a smaller workstation with client software to handle special events or emergencies, as opposed to a real-time traffic management system.

### 2.2.3 TxDOT Real-Time Traffic Management

All TxDOT TMCs operate their ITS programs using Advanced Traffic Management System (ATMS) software. The ATMS software integrates multiple ITS devices into a single platform for easy operator use and management within each TMC. Previously, the legacy ITS program utilized vendor-specific software for each device, which was cumbersome for an operator to cycle through when attempting to manage an incident, such as concurrently viewing a camera and posting a message to a DMS. Modern ATMS platforms allow for several systems to work collaboratively at the single press of a button or entry of a specific event type.

TxDOT utilizes LoneStar for its TMCs, which is based on the ActiveITS system developed by the Southwest Research Institute (SWRI). ActiveITS is also used under different names in other states. An exception to LoneStar’s use is in the Houston TranStar facility, which utilizes the RIMS (Regional Incident Management System) ATMS Platform, developed by the Texas Transportation Institute (TTI). While the ATMS may encompass the majority of the ITS devices that are controlled by a TMC, there are often certain devices that are operated under a separate software platform at the same facility, which can lead to gaps in data visibility under a single platform.

### 2.2.4 Statewide Traffic Analysis and Reporting System

TxDOT’s Transportation Planning and Programming (TPP) Division publishes a public-facing data analysis and reporting database called the Statewide Traffic Analysis and Reporting System (STARS II). The STARS II website includes detailed traffic data and statistics, as well
as Average Annual Daily Traffic (AADT) data and other reported traffic data for transportation planning purposes. The Traffic Count Database System (TCDS), included within STARS II, further details count data that has been collected around the State. An example of STARS II is shown in Exhibit 17.

**Exhibit 17: TxDOT STARS II Website**

![Exhibit 17: TxDOT STARS II Website](image)

Source: TxDOT

### 2.2.5 DriveTexas

DriveTexas serves as the online, public-facing database that provides real-time highway conditions and other traveler information throughout Texas. This data can include construction projects, road closures, and other delays, as well as real-time traffic and future construction projects. It is available as a web platform for browser users. DriveTexas receives and publishes data feeds from HCRS (Highway Condition Reporting System), as well as provides links to TxDOT's ITS pages to show data from LoneStar. An example of statewide information is shown in Exhibit 18.
2.3 **Deficiencies of the Current Situation**

The FNTOP State of the Practice Assessment Report and input from FNTOP stakeholders identified several common deficiencies in the existing system.

- **Highway Safety** - There was a total of over 190,000 CMV-related crashes between 2013 and 2017, which represents 6.3 percent of all crashes statewide according to an analysis of CRIS data. CMV-related crashes have a greater rate of serious injuries per incident compared to non-CMV-related crashes. Almost a quarter of the CMV-related crashes occurred at intersections and 13 percent of the CMV-related crashes occurred on curves. During the reporting period, 178 of the CMV-related crashes involved a freight vehicle striking the top of an underpass or tunnel.

- **Infrastructure Gaps** – The state highway network has limited detection coverage to monitor OS/OW vehicles on freight routes across Texas. A total of 41 WIM and 125 permanent count stations are distributed across the 25 TxDOT Districts. More coverage is needed in areas with rapidly increasing freight activity such as the Permian Basin. Additionally, a proportion of the WIM and permanent count stations are identified as inactive or offline according to TxDOT GIS inventory data, likely due to needed maintenance or replacement. Deployment of overheight vehicle detection stations is limited across the state, with a handful of demonstration sites along I-35 and I-10 in the Austin and Houston Districts, respectively.

- **Lack of Real-time Information** – Under the current operating model, TxDOT is not automatically notified of infrastructure damage. In fact, TxDOT only finds out about a
collision with infrastructure if it is reported or if it is discovered during routine maintenance, which can result in additional deterioration.

- **Limited ATMS Notification Capabilities** – System detectors are currently integrated into the LoneStar/RIMS ATMS platform and provide TMC operators with real-time information on traffic conditions (link speed, volume, and occupancy). WIM and permanent count station data is archived for reporting only. Currently, the ATMS lacks the ability to generate notification messages based on data from the detection subsystem, which would be needed when OS/OW vehicles operating outside of desirable parameters are detected.

- **Exposure to Direct and Indirect Costs** – Infrastructure damage by OS/OW vehicles is cumulative and recurring, which leads to deteriorating pavement and bridge conditions on the highway network. In the case of overheight vehicles for example, certain bridges experience multiple strikes within a year. Each bridge strike costs taxpayers an average of $200,000 to $300,000 in repairs, and often the cost is not recouped from the vehicle driver or owner.\(^4\) In addition to the direct cost of infrastructure repairs, indirect costs in delays and productivity losses are incurred due to road closures and secondary crashes.

### 2.4 Profiles of User Classes

The following provides a profile of users and stakeholders that would be involved with the Safety Warning Detection System strategy.

#### 2.4.1 TxDOT Divisions

TxDOT Divisions handle a wide range of services for the agency. For various TxDOT initiatives, these Divisions coordinate internally to serve as stakeholders and—depending on the topic—lead the initiative.

Several Divisions would be relevant to this strategy. TxDOT’s TPP Division—which oversees statewide traffic data collection and reporting to supports District project planning and development efforts—would be a key stakeholder for weight-monitoring systems deployed as part of the Safety Warning Detection System. In particular, it would benefit from the data collection program by expanding the WIM data coverage area. The Traffic Safety Division would also be a key stakeholder, as this strategy would expand the existing ITS program and require development of new standards and practices. The Traffic Safety Division is also currently reviewing potential Overheight Detection Systems with the Districts and may have experience that can be utilized to advance this strategy. Other Divisions would collaborate on this strategy, based on its relevance to their initiatives.

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\(^4\) Roads and Bridges, Safety: TxDOT Using High Tech to Prevent Truck Crashes.
2.4.2 TxDOT Districts
TxDOT Districts have local responsibility over building and maintaining state-owned roads and other applicable transportation infrastructure within their Districts, including ITS devices and systems. The Districts would be key stakeholders and owners responsible for installing, operating, and maintaining the field devices and components associated with the Safety Warning Detection System.

2.4.3 Traffic Management Centers
The core business of the seven Texas TMCs is managing traffic and incidents using data collected from field devices such as traffic sensors, DMS, and CCTV cameras. The Safety Warning Detection System devices and components deployed in the field would expand this capability to better monitor and manage speed and OS/OW related incidents. The TMC operators would be end-users of the notification alerts generated by the system. While most of the alert features would occur in the field for the truckers themselves, the TMC would benefit from receiving certain real-time notifications, such as alerts regarding bridge strikes, device failures, or a high recurrence of a certain activity (e.g., consistent speeding at a dangerous curve).

2.4.4 Texas Department of Public Safety
Goals of TxDPS focus on enhancing highway and public safety, as well as coordinating statewide emergency management. TxDPS would be a key stakeholder involved in identifying where safety issues are a concern, and may serve in the role of aiding in asset preservation by enforcing regulations and conducting investigations on infrastructure damage. WIM and CCTV cameras would provide TxDPS with data to support enforcement activities.

2.4.5 Truckers
Truckers would be the main end-users of this system. Real-time alerts of potential hazards, along with clearly defined alternative routes, would help encourage compliance with regulations and protect both the truck and infrastructure from damage. Additionally, a system that identifies violators for use by enforcement agencies would help discourage bad behavior.

2.5 User Needs
As part of the FNTOP, the User Needs Assessment developed a comprehensive list of user needs identified through a gap assessment and ongoing stakeholder engagement. The specific needs and gaps from the FNTOP User Needs Assessment that the Safety Warning Detection System strategy addresses are summarized in Exhibit 19. The assessment prioritized these needs based on relevance, plausibility, and alignment with the 2018 TFMP goals and objectives. The user needs were divided among seven high-level freight technology areas that were established in the FNTOP State of the Practice Assessment Report:
- Traffic Management;
- Advanced Traveler Information Systems;
- Dynamic Route Guidance;
- Data (I)ntegration and Analytics;
- Enforcement and Inspection;
- Connected and Automated Vehicles; and
- Intermodal Terminal Operations.

The naming convention for the user need ID includes the letter code listed above identifying the freight technology area to which it belongs to. For example, in Exhibit 19, UN-T4 represents the fourth User Need for the Traffic Management freight technology area. Each User Need is associated with one or more goals from the TFMP and is prioritized as follows:

- **High** – The need is a “must-have” and should be considered essential to the development of the FNTOP.
- **Medium** – The need is a “should-have” or desirable capability for which there is considerable interest, but is not necessarily critical to TxDOT.
- **Low** – The need is a “nice-to-have” or not viable in the near-term.

More information about the FNTOP User Needs and how this strategy can address them is available in the FNTOP User Needs Assessment Report, as well as FNTOP Strategies and Conceptual Framework Report.

**Exhibit 19: Affiliated User Needs for Safety Warning Detection System**

<table>
<thead>
<tr>
<th>ID</th>
<th>Preliminary User Needs</th>
<th>Texas Freight Mobility Plan 2018 Goals</th>
<th>Priority</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Management Freight Technology Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UN-T4</td>
<td>Need to develop the Houston-Dallas-San Antonio triangle with new smart technologies to improve operations.</td>
<td>Safety, Economic Competitiveness, Asset Preservation and Utilization, Mobility and Reliability</td>
<td>Medium</td>
<td>Stakeholder Interviews</td>
</tr>
<tr>
<td>UN-T7</td>
<td>Need for rural ITS in high-traffic freight areas to help support operations.</td>
<td>Economic Competitiveness, Mobility and Reliability</td>
<td>Medium</td>
<td>Inventory of Existing Conditions, Stakeholder Interviews</td>
</tr>
<tr>
<td>ID</td>
<td>Preliminary User Needs</td>
<td>Texas Freight Mobility Plan 2018 Goals</td>
<td>Priority</td>
<td>Source</td>
</tr>
<tr>
<td>----</td>
<td>----------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------</td>
<td>----------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>UN-A3</td>
<td>Need for more Dynamic Message Signs (DMS) on primary freight corridors to relay traffic information.</td>
<td>Safety, Asset Preservation and Utilization, Mobility and Reliability</td>
<td>High</td>
<td>Inventory of Existing Conditions, Stakeholder Interviews</td>
</tr>
<tr>
<td>UN-A10</td>
<td>Need for better advanced notice of height and weight restrictions on roads to improve safety.</td>
<td>Safety, Asset Preservation and Utilization, Mobility and Reliability</td>
<td>Medium</td>
<td>Stakeholder Interviews</td>
</tr>
<tr>
<td>UN-A11</td>
<td>Need for more advanced notice of safety danger spots with high crashes, severe curves, or steep grades to warn drivers.</td>
<td>Safety, Asset Preservation and Utilization, Mobility and Reliability</td>
<td>Medium</td>
<td>Stakeholder Interviews</td>
</tr>
<tr>
<td>UN-E2</td>
<td>Need to deploy more WIM and automated vehicle classification stations in Texas for increased freight inspection and planning capabilities.</td>
<td>Safety, Economic Competitiveness, Mobility and Reliability</td>
<td>High</td>
<td>Inventory of Existing Conditions, Stakeholder Interviews</td>
</tr>
<tr>
<td>UN-E4</td>
<td>Need for more advanced remote monitoring equipment to detect and uniquely identify vehicles over allowable limits on Texas roadways to increase freight compliance to roadway laws by robustly identifying offenders.</td>
<td>Safety, Economic Competitiveness</td>
<td>Medium</td>
<td>Stakeholder Interviews</td>
</tr>
</tbody>
</table>
### 2.6 Assumptions and Challenges

Several key assumptions and challenges would apply to a system that issues safety notifications and advance alerts. These assumptions and challenges are identified in the following sections.

#### 2.6.1 Assumptions

- **Scope of Field Device Operations** – All safety warning applications would function remotely in the field and provide immediate notifications to freight vehicle operators of potential hazards ahead, such as through the use of flashing beacon signs or DMS. Some of these systems may report real-time alerts to the TMC. All of these systems would capture detection event data and report this data to a repository.

- **Scope of Real-time Notifications** – The intersection conflict and overspeed detection systems are not expected to transmit real-time alerts to the TMCs. These systems would trigger too many alarms during the day. The detection events for these systems would be archived for data analysis and reporting. The overheight and overweight detection systems, as well as the bridge collision detection system, however, are expected to send automatic alerts to the TMC given that damage caused by OS/OW vehicles could be extensive and require road closures.

- **Use of Standard Detection Technologies** – Field detectors are expected to initially use standard detection technologies that are already deployed and operated by TxDOT. New device standards and specifications would be defined by the Traffic Safety Division as necessary to support project development and implementation across the state.

- **Scope of ATMS Integration and Enhancements** – New systems would be integrated into the ATMS platform, either for real-time alerts, device status alarms, or data collection. The new system would communicate with field devices and components using TxDOT ITS.
standards and protocols. Additionally, TMC standard operating procedures (SOPs) would be updated and training for TMC staff provided to incorporate new systems into TMC processes for managing the transportation system.

- **Data Archiving and Reporting** – All new devices and notifications would be archived in a relational database system for performance reporting purposes.

- **Collection of Information for Law Enforcement Investigations** – Depending on the policies at TxDOT, this system may be instrumented—directly or indirectly—with components to aid with law enforcement in response to infrastructure damage, such as a camera to take photos of detected overheight vehicles. These components would not be used for direct enforcement (like an automated red-light camera), but rather provide evidence to aid in a police investigation in response to infrastructure damage. Since Districts do not currently record video from their CCTV camera system, this would require policy modifications or collaboration with another agency that can operate an adjacent system.

- **Data Sharing with TxDPS** – The system would be designed to share alerts regarding possible infrastructure damage with TxDOT, but could also be relayed to TxDPS to respond more quickly to a public safety concern. In the event of reported infrastructure damage (like a bridge strike reported automatically), TxDOT would be able to work with TxDPS to dispatch Highway Patrol vehicles to the site for verification of immediate infrastructure damage and possible vehicle/driver injury. All available information could be shared with TxDPS to aid in an investigation.

- **Safety systems would not be limited to the freight community** – Since the road is utilized by other users, these safety systems would not be limited to notifying only freight vehicles of potential safety concerns. For example, a speeding car that approaches a curve would receive a similar warning as a speeding truck.

- **Some existing systems could be used as part of the strategy** – Some existing ITS devices could be repurposed to aid in this strategy, depending on their capabilities and geographic location.

### 2.6.2 Challenges

- **Cost of ITS equipment needed to implement the strategy** – Field equipment can be costly, depending on how many sites for each system are deployed. Additionally, there would be ongoing operations and maintenance (O&M) costs associated with each system scaled to the number of sites deployed. An inventory of spare parts would be needed to replace components that break down or reach end of life, which can be a challenge if there is no formal plan or a lack of dedicated funding to support upkeep and expansion of this strategy.

- **Staff Training** – TxDOT end-users, such as maintenance staff and TMC operators, would need training to familiarize themselves with the new devices and ATMS enhancements that would be deployed as part of the system. Maintenance staff would need training to
perform preventative maintenance on field devices and other components. Staff would also need to learn new procedures on troubleshooting and resolving issues in the field. TMC operators would need training on the new Safety Warning Detection System subsystem and tools in the ATMS console in order to respond to notifications. Division staff would need to be trained on data reporting and how to retrieve performance metrics.

- **Actively Managed TMCs are Limited** – Seven of the 25 Districts have an actively managed TMC with operators onsite to monitor traffic conditions on a continuous basis. Following a critical event such as a bridge strike, a staffed TMC would have the centralized resources and capabilities to manage road closures in coordination with TxDPS, disseminate updated traveler information, and dispatch personnel to the site to inspect damage. This would not be the case in some possible locations.

- **Statewide ATMS Integration and Deployment** – While most of the District TMCs use the LoneStar platform for their ATMS, there are implementations of LoneStar that have been tailored to the specific needs of the District. Deploying and integrating the new Safety Warning Detection System would require statewide coordination to ensure consistent functionality and outputs.

- **System Reliability** – The effectiveness of the safety warning applications is dependent on the reliability of the system detectors. Inductive loop detectors for example, are widely used, but are susceptible to failure and require routine preventative maintenance in order to perform reliably. Field-to-center communications is another potential point of failure that could impact the critical delivery of notification messages to the TMC.

- **TxDOT Maintenance of ITS Assets that are Off the Freeway Network** – Existing TxDOT maintenance contracts may not be set up for staff to maintain ITS assets that are located off of the traditional freeway network where most ITS assets are currently located. This may require modifications to funding for personnel to service remote assets outside of a defined maintenance area.

- **Driver Compliance** – Alerts and notifications are designed to facilitate informed decision-making, but some drivers may elect not to comply with the system generated instruction. Stakeholders have identified driver compliance to safety messages as a concern.
3.0 Concept for the Safety Warning Detection System
This section describes the proposed system. It provides an overview of the objectives; discusses ConOps essential features, capabilities and functions; and outlines the system-level operational environment, processes, and necessary support. The level of detail presented is intended to explain how the proposed system is envisioned to fulfill the user needs and requirements.

3.1 Objectives
The Safety Warning Detection System is intended to provide truckers with real-time notifications of potential hazards ahead so that drivers make informed decisions in response. The Safety Warning Detection System is intended to improve safety and asset preservation for the Texas freight community. This section outlines the current needs and challenges within Texas, and the desired capabilities that are motivating the proposed system.

As detailed in the crash analysis in Section 2.0, the safe operation of trucks on key infrastructure elements like curves, bridges, and intersections is a primary concern that the Safety Warning Detection System is designed to address. Trucks have an increased number of points of conflict with existing roadway infrastructure due to their size, weight, and inherent momentum that makes responding quickly to unexpected events more difficult. These increased points of conflict lead to more severe impacts when incidents occur, either due to a direct crash or an indirect impact to the existing infrastructure (e.g. bridge damage due to overheight vehicle strikes, pavement degradation due to excessive weight, etc.). The input from stakeholders and previous FNTOP research highlights the challenges and issues associated with having limited real-time notification systems for identifying safety issues, limiting the ability of TxDOT and its partners to promptly detect, monitor, respond to, and investigate infrastructure damage.

Exhibit 20 provides an illustrative example of the Safety Warning Detection System strategy that was discussed in the FNTOP Strategies and Conceptual Framework Report.
The Safety Warning Detection System is comprised of the four applications:

1. **Overweight Detection Systems** – These systems detect if a truck exceeds a pre-determined weight, usually in advance of a posted bridge crossing or a truck route with a lower permitted weight limit. These systems would be installed in advance of a key route decision point, where an alternate truck route with a higher weight capacity is available. These systems would utilize WIM technologies in real-time and provide notification to drivers via a roadside sign—either a DMS or a warning sign with flashing beacons—and direct them to use an alternate route. In addition to the real-time weight monitoring, these WIM sites could serve as enforcement tools or historical data points, similar to what is currently done as part of the TxDOT WIM and permanent count station program. The goal is to reduce the number of overweight vehicles on critical facilities, helping to extend the life of the asset. Depending on policies adopted in Texas, this system could also capture image snapshots of offending vehicles to help with investigations into damage caused by overweight vehicles.
2. **Overspeed Detection Systems** – These systems detect if a vehicle—either freight or passenger car—exceeds a certain travel speed, usually in an environment where reduced speed is strongly advised, such as horizontal curves or hills with poor sight lines. These systems would be installed at locations with a history of speed-related crashes or an evident geometric restriction that has an advisory speed with poor compliance. These detection systems would notify the driver of excessive speed by activating a roadside sign—either a DMS or warning sign with flashing beacons—that would advise of excessive speed and instruct the driver to slow down. The goal is to reduce the number of speed-related crashes in these areas, which have the potential to disrupt freight mobility during incidents.

3. **Intersection Conflict Warning** – These systems detect if a vehicle is crossing through an intersection that may be occluded by poor sight lines or some other restriction and provide notification to other approaching vehicles. Such systems are used primarily in rural locations at two-way stop-controlled intersections with poor sight lines. On the main approach, the driver is notified of a potential conflict via an activated roadside sign with flashing beacons. This system would be advantageous for freight at intersections where a truck may cross at a slower speed due to its size, which not all motorists appropriately recognize from a distance. The goal is to reduce the number of angle crashes in these areas.

4. **Overheight Detection Systems** – These systems detect if a truck exceeds a pre-determined height, usually in advance of a bridge underpass. These systems would be installed in advance of an alternate truck route. Upon an overheight detection, the driver is notified of being too tall by a roadside sign—such as from a DMS, a warning sign with flashing beacons, or (as CV is rolled out) a dashboard alert through CV-enabled applications—and directed to use an alternate route. This system would be applicable to urban, suburban, and rural locations, including those on truck routes that are not classified as limited access facilities. The goal is to reduce the number of bridge strikes due to overheight vehicles, which can shut down the route altogether until the bridge is repaired. Depending on policies adopted in Texas, this system could also capture image snapshots of offending vehicles to help investigate after collisions have occurred. It also may include collision detection systems on the physical bridge infrastructure to notify and alert TxDOT of a detected strike.

Data collected from these strategies could be used in real-time and historic contexts, such as for safety evaluations, historic truck weight measuring, or enforcement screening. In addition to the real-time alerts and notifications, this type of information would be valuable for project planning and development processes, as well as life cycle maintenance. Additionally, this strategy could also instrument infrastructure with collision detection systems to help report bridge strikes to the local District to allow for prompt response and evaluation.
3.2 Description of ConOps Essential Features, Capabilities, and Functions

This section describes the proposed system and proposed improvements, based on the components identified earlier. The descriptions are provided at a high-level, indicating the operational features and functionalities without specifying design details or technology-specific solutions.

The main features and functions of the Safety Warning Detection System are shown in Exhibit 21, mapped to FNTOP User Needs.

**Exhibit 21: Safety Warning Detection System Features and Functions**

<table>
<thead>
<tr>
<th>Features</th>
<th>Main Functions</th>
<th>User Need(s) Addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real-Time Notifications on Bridge Strike Events</td>
<td>TMC operators would receive a notification in the ATMS when the detection sensor in the field is triggered by an overheight vehicle. The information could be used to dispatch TxDOT District personnel for immediate inspection and repair, as well as inform law enforcement immediately to initiate an investigation.</td>
<td>UN-T4, UN-T7, UN-A10</td>
</tr>
<tr>
<td>Advanced Warning on Potential Hazards</td>
<td>The overspeed, overweight, intersection conflict, and overheight detection systems would immediately alert vehicles by using a flashing beacon warning sign or messages posted on DMSs. The vehicle operator could then exit safely onto an alternative route ahead of a low clearance or load restricted bridge. The operator could also take corrective action ahead of an intersection or curve.</td>
<td>UN-T4, UN-T7, UN-A3, UN-A10, UN-A11, UN-C1, UN-C5</td>
</tr>
<tr>
<td>Roadside Camera to Aid Enforcement</td>
<td>The optional use of roadside cameras could provide information for law enforcement to pursue violators and offenders. Upon detection, a camera would take a photo of the offending vehicle.</td>
<td>UN-E2, UN-E4</td>
</tr>
</tbody>
</table>
Weigh-in-Motion Systems

WIM systems would be installed in advance of bridge crossings or other strategic road assets to notify of overweight conditions. The stations would provide advisory information to trucks and collect information that could aid enforcement. The deployment of the system would add coverage to more freight routes across the state and address the need for more sources of WIM and permanent count station data for planning.

Since this system relies on technological processes, the general framework follows the requirements for a successful ITS program. At a high level, a successful ITS program requires 1.) a means to collect data, 2.) a means to process the data, and 3.) a means to distribute that data to the targeted user group. As long as this process is followed, this system would have the necessary building blocks to succeed.

Although the process is straightforward, the means and methods to implement these requirements can vary widely. Texas has a few initiatives underway for certain Safety Warning Detection Systems, but they are isolated improvements that were deployed in response to a major concern, such as alternate route travel time when I-35 was reconstructed in the Temple area, or bridge strikes in the heavily traveled Austin and Houston highway networks. Although TxDOT has some standards to support deployment of these systems, there currently is not a statewide planning effort to widely deploy these systems as a proactive effort.

The following sections examine several key strategies to consider as part of the Safety Warning Detection System. The intent is not to define one strategy as the sole approach for all components, but rather outline the key characteristics so that a given strategy can be correctly applied to a situation. The strategies are discussed in the following sections:

- Data Collection
- Data Processing
- Information Distribution
3.2.1 Data Collection

Data collection methods for this system aim to collect information regarding:

1. If a vehicle exceeds a certain height,
2. If a vehicle exceeds a certain weight,
3. If a vehicle exceeds a certain speed,
4. If a vehicle has been present in a specific location for a certain amount of time, and
5. If infrastructure is subject to excessive loading, usually correlating to a strike from a vehicle.

Not all components are required at the same time to provide a safety system. Various components to support some or all of these goals are discussed in the following sections. These components are conceptual in order to illustrate certain general ideas, but other options could feasibly serve the same role.

3.2.1.1 Height Detection

This type of component would detect and report data on whether a vehicle has exceeded a certain height threshold. These detection units would typically cover a single point of a road where the device is installed, usually in advance of a height-restricted geometric issue like a low bridge. Preferably, this detection is installed prior to an alternative route to prevent a vehicle from having to stop and perform a U-turn.

Various options exist for collecting this information. The component may be a detector unit, such as an electronic eye, a laser, or a sway bar, that is activated when an overheight vehicle passes the detector. The preferred technology for collecting this information would depend on available right of way (ROW), easements, and layout of the road.

3.2.1.2 Weight Detection

This type of component would detect and report data on whether a vehicle has exceeded a certain weight threshold. These detection units would typically cover a single point of a road where the device is installed, usually in advance of a weight-restricted geometric issue like a bridge with a loading restriction. Preferably, this detection is installed prior to an alternative route to prevent a vehicle from having to stop and perform a U-turn.

Various options exist for collecting this information. The component may be a WIM station that records weight in real-time when the overweight vehicle drives over the detector. The preferred technology for collecting this information would depend on available ROW, easements, and layout of the road.

3.2.1.3 Speed Detection

This type of component would detect and report data on whether a vehicle has exceeded a certain speed threshold. These detection units would typically cover a single point of a road
where the device is installed, usually in advance of a speed-constrained geometric issue like a sharp curve or winding segment.

Various options exist for collecting this information. The component may be a detector unit, such as microwave radar, loop detector, or video processing, that evaluates the vehicle’s speed as it passes the detector. The preferred technology for collecting this information would depend on available ROW, easements, and layout of the road.

3.2.1.4 Presence Detection
This type of component would detect and report data on whether a vehicle is present within a certain zone for a period of time that exceeds a certain threshold. These detection units would typically cover a single point of a road where the device is installed, usually at a location where a dwelling vehicle could present a conflict for another approaching vehicle due to a poor sight line.

Various options exist for collecting this information. The component may be a detector unit, such as microwave radar, lidar, or video processing, that evaluates the presence of a vehicle in an area as it passes the detector. The preferred technology for collecting this information would depend on available ROW, easements, and layout of the road.

3.2.1.5 Collision Detection
This type of infrastructure health monitoring component would detect and report data whether infrastructure is subjected to an atypical loading, usually corresponding to an impact from a vehicle. Generally, these detection units would be installed on or within the infrastructure itself and would be placed in one or several strategic locations based on structurally sensitive points.

Collecting this information would be done through sensors that measure stress and strain on the infrastructure. Several systems are installed within the bridge itself as part of new bridge construction in the industry, although options to install sensors on the exterior of the structure is a common alternative. The preferred technology for collecting this information would depend on the design of the infrastructure in question.

3.2.2 Data Processing
Data processing methods for this system aim to process information regarding whether a defined threshold has been violated, such as an overheight detection, an overweight detection, an overspeed detection, a presence detection that exceeds the time limit, or an atypical force loading on a piece of infrastructure. Components to support some or all of these goals are discussed in the following section. These components are conceptual in order to illustrate certain general ideas, but other options could feasibly serve the same role.
3.2.2.1 Field Processing Component
Field processing would occur in the field to provide a timely notification to motorists. A field processor would manage all data received from the sensors and determine if a response is required based on the defined parameters programmed by TxDOT. It would connect with data collection and data dissemination elements through a closed-loop system, and would utilize a TxDOT network connection in order to report notifications, alerts, and data logs to a central system. These notifications and alerts could be utilized by District personnel, TxDPS, and other stakeholders who would benefit.

3.2.3 Information Distribution
Information distribution methods for this system aim to distribute information to end-users regarding 1.) whether a vehicle exceeds a certain threshold and should take corrective action, and 2.) whether infrastructure has likely been subjected to an atypical loading event. These components are conceptual in order to illustrate certain general ideas, but other options could feasibly serve the same role.

3.2.3.1 Roadside Sign with Activated Flashing Beacons
This component would be a low-cost notification static sign that indicates a vehicle has violated an operating restriction and should take corrective action, such as taking an alternate route or slowing down (see Exhibit 15 earlier in this document for an example of an existing sign with flashing beacons). Flashing beacons would be installed on the static sign to convey a sense of urgency of a real-time event occurring, consistent with other warning signs used in Texas, such as for “High Water” flood warnings. An example of these signs could include “Overheight Vehicle Detected When Flashing. Turn right on Meyers Road to Bypass Low Bridge.”

This component would be best installed at a sufficient distance upstream of where a corrective action is required, so as to allow the driver time to read, recognize, and respond to the message. It would also need to be installed reasonably downstream from the detection unit, so as to provide enough time for the field processor to identify the issue but not so far as to impact credibility. As the USDOT CV initiative is formally rolled out, these roadside signs could be equipped with CV equipment to issue a digital notification to CV-equipped vehicles near the sign.

3.2.3.2 Dynamic Message Signs
This component would consist of customizable DMS that activate when a vehicle has violated an operating restriction and should take corrective action, such as taking an alternate route or slowing down. Flashing beacons may be used on the DMS to capture driver attention but are not required. The DMS would store standard messages for certain types of detections, activating only when a defined issue is detected. Examples could be “Overheight Vehicle Detected. Turn Right on Meyers Road to Bypass Low Bridge.” As an
added benefit, TxDOT would be able to customize the messages in the future if a different message is found to yield greater compliance.

Similar to the static sign, this component would be best installed at a sufficient distance upstream of where a corrective action is required, so as to allow the driver time to read, recognize, and respond to the message. It would also need to be installed reasonably downstream of the detection unit, so as to provide enough time for the field processor to identify the issue but not so far as to impact credibility. As was the case with the static sign, CV equipment could be eventually installed on the DMS to issue a digital notification to CV-equipped vehicles near the DMS.

### 3.2.3.3 Alerts and Notifications
This component would reside within TxDOT, integrated as part of the ATMS, to receive alerts regarding events, log data, and identify system-related issues. This system would require a network communications connection to the field processor to receive the data. Any data reported to advanced traveler information systems (ATIS), like DriveTexas, would pass through this component.

The component could provide TMC users with the ability to locate detection sites on a map, obtain detector status and view automated notification messages triggered by the system. The TMC users would have the ability to retrieve images captured by a roadside camera identifying the vehicle triggering the detection event.

### 3.2.3.4 Roadside Camera
This component would be an optional feature that would be deployed to aid in investigative efforts after infrastructure damage has occurred. It is envisioned to be a simple camera that records several photos or a video clip of vehicles that trigger the overheight and overweight detection sites. The goal would be to log which vehicles were deemed overheight or overweight around the time of the incident, which allows law enforcement to conduct further investigation to see if they were involved in the damage.

This device could either be part of the TxDOT system—if TxDOT policies allow photos to be taken for certain systems, or it could be part of another agency’s system that sits adjacent to the TxDOT system. While some states with video recording prohibitions are allowing it as part of new Wrong-Way Detection Systems, restrictions do exist regarding the ability to record images. If another agency is involved, this camera system would simply tie into the TxDOT system in a closed-loop circuit and, upon receiving a detection alert from the TxDOT system, the other agency’s camera would immediately capture the picture.

### 3.3 Conceptual High-Level System Architecture
The physical elements of the Safety Warning Detection System are shown in the systems diagram in Exhibit 22. The diagram illustrates how the system elements such as roadside
devices are integrated with the ATMS environment and interconnected with the systems operated by the agencies that are stakeholders or end-users.

The sensors for the roadside overheight, overspeed, intersection conflict, and overweight detection systems would transmit data from the field to the new Safety Warning Detection System subsystem in the ATMS platform. The new subsystem would provide a software interface that transmits alert notifications to the TMC operators when a detection sensor is triggered by an overheight or overweight vehicle. System logs, detector status, and notification events are archived in the ATMS database system for reporting purposes. The intersection conflict and overspeed detection systems would not issue automatic notifications to the TMC, but rather log events as historical data for retrieval. The notifications from the overweight and overheight detection systems would be shared with partner agencies such as TxDPS and the local TMCs that are affiliated with the District TMCs. The WIM and permanent count station count data would be archived in the TCDS and accessible through the STARS II website. With increased awareness of critical events in the field, the TMC could provide timely traveler information through the DriveTexas website on road closures resulting from extensive infrastructure damage caused by OS/OW vehicles.

Exhibit 23 illustrates the information flows from the field elements to the conceptualized Safety Warning Detection System, which would operate centrally from the District TMCs. The users associated with the agency stakeholders involved in the operations of the safety warning applications are identified in the diagram, as well as the dissemination methods to provide notification alerts to freight vehicle operators and the traveling public.
Exhibit 22: Systems Diagram for the Safety Warning Detection System

Data Sharing Partners
- DriveTexas
- STARS II
- TxDPS
- TxDOT TMCs
- Local TMCs

TxDOT District ATMS
- Lonestar/RIMS User Interface (UI) and Map
- Center-to-Center (C2C) Interfaces
- Reporting and Data Archiving

Alarms and Notification Subsystem
- Event Management Subsystem
- Traffic Sensor Subsystem
- CCTV Subsystem
- DMS Subsystem

Roadside Controller Units
- Overheight Vehicle Detector
- Overweight Vehicle Detector
- Intersection Conflict Detector
- Overspeed Detector
- Roadside Camera
- Bridge Collision Detection System
- Flashing Beacon Warning Signs
- Dynamic Message Signs (DMS)

Existing System
New System
Hardwired Communications
Wi-Fi/Cellular Communications

Field Deployments
Exhibit 23: Data Flow Diagram for the Safety Warning Detection System

Users

- TxDOT
- TxDPS
- STARS II
- Traveling Public
- TMC Operators
- Freight Vehicle Operators

Data Sources

- Roadside Camera
  - Device status, still images and recorded video
  - Status request
- Bridge Collision Detection System
  - Detector status, collision alarms
  - Status request
- Intersection Conflict Detection System
  - Detector status
  - Status request
- Overspeed Vehicle Detection System
  - Detector status
  - Status request
- Overweight Vehicle Detection System
  - Detector status, overweight vehicle alarms, vehicle counts, classification, speed, axle weights
  - Status request
- Overheight Vehicle Detection System
  - Detector status, overheight vehicle alarms
  - Status request

System Concept/ATMS Integration

Safety Warning Detection System

Dissemination Methods

- SLOW DOWN
- INTERSECTION AHEAD
- TURN HERE
- DMS
- Website
- Mobile App
3.4 **Modes of Operations**

Four modes of operation for the Safety Warning Detection System are identified and described in this section:

- Normal Operational Mode
- Routine Maintenance Mode
- System Failure Mode
- Notification Mode

The primary mode of operation for the Safety Warning Detection System is the **Normal Operational Mode**. In the field, the roadside detection elements for the four safety warning applications (overweight, overheight, intersection conflict, and overspeeding) would function remotely and monitor all vehicles ahead of a potential hazard. The detection sensors would transmit status signals periodically to the TMC where operators could use the ATMS console to view information on detector health. TxDOT Districts without TMCs would receive automated email alerts when a device status goes offline, so as to inform their maintenance groups. Data on axle weights and vehicle classification captured by the overweight detection sensors deployed at WIM station sites would be archived in the TCDS and accessible through the STARS II website. The WIM and permanent count station data is used by Division staff (TPP and Traffic Safety) for corridor planning, pavement design, and crash safety analysis.

In the **Routine Maintenance Mode**, the roadside elements for the intersection conflict, overheight, overweight, and overspeed detection systems would be maintained by District personnel. District maintenance personnel would conduct preventative maintenance based on a defined schedule according to TxDOT specifications and requirements. Preventative maintenance would be performed to clean DMS and flashing beacon signs, test, and calibrate detection sensors and inspect communication devices.

In the **System Failure Mode**, a break in communications or a malfunctioning detection sensor would trigger an error message that alerts the TMC operator. If the failure only affects communications between the roadside controller and the TMC, the detection sensors and the DMS and flashing signs would continue to function locally and provide notifications to the freight vehicle operator, but would not be able to update the TMC. Upon detecting a system failure, the TMC operator would initiate troubleshooting according to SOPs.

In the **Notification Mode**, the detection sensors are triggered by a vehicle that is: 1) traveling too fast heading into a curve; 2) approaching an intersection where oncoming traffic could be a conflict; 3) transporting cargo that is too tall to clear a low clearance; or 4) transporting cargo that is too heavy for an upcoming bridge or road segment that is load restricted. Upon
detection, the roadside controller would display alerts on DMS or flashing beacon signs to provide advance warning to the truck driver approaching a potential hazard. At the same time, the controller would transmit a signal to the TMC where the ATMS would display a notification alerting the TMC operator and/or log the event in the data repository. Depending on the report, the TMC operator may initiate SOPs to verify and monitor the OS/OW event and initiate incident response, clearance and enforcement operations as required, in coordination with TxDPS and local officials. In the event of a reported bridge strike for example, the TMC operator would notify applicable District staff, and TxDPS could retrieve a snapshot photo (depending on system design) of previous detected vehicles that set off the system in order to begin an investigation.

### 3.5 Support Environment

This section identifies major elements in the information technology (IT) environment that would support the operations of the Safety Warning Detection System. The expected resources (e.g., hardware, software, networking, and business processes, etc.) are described as follows:

- Application services and interfaces to manage the detection systems in the field would reside in the new Safety Warning Detection System subsystem in keeping with the modular structure of the ATMS platform. TMC application servers and ATMS software clients would be hosted on the Districts’ local area networks (LAN) and wide area networks (WAN).

- TMC operators could leverage existing ATMS subsystems (e.g., CCTV, DMS, and traffic sensors) where appropriate to manage incidents arising from a crash at an intersection or curve, or an OS/OW related event resulting in extensive damage that requires road closures.

- Persistent data such as device configuration parameters and network addresses would be archived in the existing ATMS database system. Data backups would be maintained in accordance with enterprise IT policies on data retention.

- The new Safety Warning Detection System subsystem would utilize existing Extensible Markup Language (XML) protocols to exchange requests, responses, and messages with other subsystems and applications within the ATMS.

- User security would be administered using the security features in the ATMS. TMC operators and other ATMS users would be assigned accounts and password protected access in accordance with existing IT security policies and procedures that are applicable to the IT environment at the TMC.

- Tools and methods to secure data such as encryption would be done so in accordance with enterprise IT policies on information security.
The new Safety Warning Detection System subsystem would utilize existing center-to-center (C2C) interfaces in the ATMS to share data with TxDOT and external partner agency systems.

- District IT administrators would maintain servers, applications, and networks associated with the operation of the ATMS. Preventative maintenance would be performed at scheduled intervals and technical support provided to TMC operators and other users in accordance with organizational IT policies and procedures.

- Traffic Safety Division would support system development efforts to integrate the new Safety Warning Detection System subsystem into the ATMS. In coordination with ITD, the Division would utilize systems engineering processes to manage software development, testing, and roll-out of updates and enhancements to the ATMS. The Division would publish device standards and specifications to support project development and procurement.

- Division and District personnel would coordinate responsibility for maintaining and troubleshooting issues affecting the overspeed, overheight, overweight, and intersection conflict detection systems.

- The TCDS and the STARS II website would provide a data archiving, analytics, and reporting platform to access the WIM and permanent count station data collected at the overweight detection system sites.
4.0 Benefits, Impacts, and Alternatives of the Safety Warning Detection System

The purpose of this section is to identify the benefits and impacts created with the deployment of the Safety Warning Detection System strategy. This section also identifies alternative options to this strategy and notes their respective drawbacks relative to the strategy proposed in this ConOps.

4.1 Benefits

This subsection summarizes the key benefits that TxDOT should expect from deployment of the Safety Warning Detection System strategy. From a benefits perspective, the implementation of this strategy would have the following impacts:

- **Increased Safety on State Highways** – The safety warning applications would provide notifications to trucks using DMS or flashing beacon warning signs. Vehicle operators would have the information to make informed routing decisions ahead of a potential hazard. The reduction in CMV-related crashes would help reduce the rate of serious injuries which are greater when freight vehicles are involved.

- **Increased Use of Real-time Information** – Access to timely information on critical events such as bridge strikes would increase the situational awareness of TMCs. This would allow the TMCs to better coordinate incident response and clearance operations by reducing the time needed to identify and verify events in the field. From a resource standpoint, there would be greater demands on the communications network with more transmission of field-to-center data.

- **Increased Availability of Freight Data** – Increased deployment of WIM stations for overweight vehicle detection and unsafe speed detection would increase the availability of data for freight planning, corridor project development, and safety analysis. Over time, TxDOT could access historical datasets for system asset planning and monitoring.

- **Increased Enforcement of Violators** – The overheight and overweight vehicle detection systems may have components such as roadside cameras that could capture information that could aid in law enforcement investigations. Additionally, the data collected by the systems could help TxDPS identify areas of the network where trucks operate outside of allowable parameters.

- **Increased Life of Infrastructure** – The system would help reduce the direct and cumulative effects of damage to bridges, pavement, and other infrastructure. For a critical event such as a bridge strike, TxDOT could immediately dispatch personnel for repairs and reduce further damage and the risk of failure.

- **Increased Cost Savings** – The system is expected to reduce the significant costs of repairs and maintenance over time by reducing the damage by OS/OW vehicles to bridges, pavement and other infrastructure. Complete road closures required for bridge repairs for example, could be avoided.
4.2 Impacts
This subsection describes the impacts that TxDOT and its stakeholders should expect as a result of the strategy’s deployment. First, impacts to the operational and institutional policies and constraints are highlighted, which TxDOT should review as part of the planning process for this strategy. It then highlights the operational and organizational impacts that TxDOT should expect during deployment, as well as any impacts incurred as a result of development. Lastly, it documents the expected impacts to stakeholders identified earlier.

4.2.1 Policies
The following summarizes some of the key impacts to operational and institutional policies associated with system development:

- **Traffic Management and Incident Response** – The system shall be consistent with TxDOT SOPs for TMC activities and tasks. The system must not interfere with the operations of the TMC, and operator involvement must be minimal, such as confirming that the components are all online. Management of incidents and events detected by the system would be done so in a manner consistent with existing processes and procedures.

- **Data Sharing** – Information sharing would comply with TxDOT agreements for sharing data with partner agencies and other third parties.

- **Data Security and Privacy** – The system would comply with any legal requirements and TxDOT policy for the protection, security, and privacy of data provided by and shared with stakeholders and end-users. The system would not compromise any personally identifiable information (PII).

- **Operational Uptime** – Any system should be in operation 24 hours per day, seven days a week, 365 days per year, as time spent offline will decrease the users’ perceived value of the system.

- **Compliance with Design Standards** – The system must utilize infrastructure that is designed in compliance with any applicable design standards or guides, including the American Association of State Highway Transportation Officials (AASHTO) A Policy on Geometric Design of Highways and Streets, the AASHTO Roadside Design Guide, the Texas Manual on Uniform Traffic Control Devices (TMUTCD), the TxDOT Roadway Design Manual, the National Electrical Safety Code (NESC), applicable ITS and ITD security requirements, and other applicable Texas design guides.

- **Driver Distraction Laws** – Applications will be designed in a fashion that prevents potential safety hazards from distracted driving. For instance, any roadside signs will follow design standards established in the TMUTCD.

4.2.2 Constraints
The following summarizes some of the key operational constraints impacting system development:
- **Budget Constraints** – Funding is limited, which means the full concept may not be attainable as part of the initial deployment. Additional funds will be necessary to expand the system beyond the initial deployment.

- **Maintenance** – The system will have ITS hardware that will need maintenance and periodic replacement. This will require TxDOT staff or a TxDOT-funded maintenance contractor to dedicate time for system upkeep.

- **Network Communications** – Field-to-center network communications is recommended in order to have a comprehensive system. Many of the sites, however, are in remote locations where less-than-reliable wireless communication options are the most cost-effective solution. An expansion of TxDOT’s fiber optic cable network would increase the likelihood of reliable network communications being available.

- **Limitations on Alternative Freight Routes** – Coordination and collaboration with local agencies is necessary to confirm that the alternate routes and supporting operations would be beneficial to these communities. Some communities may have no options or may politically oppose routing freight into other areas.

- **Limited ROW** – This strategy may involve the placement of equipment at locations that are off TxDOT ROW.

- **Coordination Within TxDOT** – Maintenance of the devices and components would be performed primarily by TxDOT Districts. The Districts are responsible for operating and maintaining local ITS devices such as signals, safety warning beacons, CCTV cameras, DMS, and system detectors. TPP owns and operates the WIM stations where the overweight detection systems are deployed across the state.

- **Limited ITS Deployment** – ITS assets, such as CCTV cameras, can support efforts to remote monitor a situation as it unfolds, but most of these devices are deployed in parts of the highway network outside of urbanized areas with decreased coverage. It is likely that devices and components supporting the Safety Warning Detection System would not be near existing ITS assets.

- **ATMS Integration** – Devices for this system may not currently be integrated into the ATMS platform. TMC operators must be able to view notification messages within the ATMS console and access details to determine when and where the notification was triggered.

- **Conflicts with Private Sector Services** – Truckers have access to dynamic route guidance information that is predominantly a private-sector service. It is possible that an alert from the Safety Warning Detection System might be ignored if it conflicts with guidance from the private-sector route guidance system.

- **Veracity of Bridge Heights** – Marked bridge clearance may need to be verified by actual measurements in order to establish accurate height thresholds for the overweight detection system to operate properly.
4.2.3 Operational Impacts
From an operational perspective, the implementation of this strategy would have the following impacts:

- **Increased Demand for Real-Time Network Communications** – With increased ITS coverage, efficient and reliable communications would be needed to collect and monitor notifications of relevant events and potentially view CCTV video images.

- **New Training Requirements** – Maintenance personnel would require additional training to support new equipment that would be installed, likely over several Districts.

4.2.4 Organizational Impacts
From an organizational perspective, the implementation of this strategy would impact both the public and the private sector.

4.2.4.1 Public Sector

- **Increased System Preservation** – TxDOT would have increased awareness of critical damage to infrastructure with the notifications from the Safety Warning Detection System. This would increase the life of infrastructure by allowing inspections and repairs to be done more quickly, which reduces further damage. The system would also prevent or reduce the number of incidents that cause damage to the infrastructure. Over time, TxDOT could realize a ROI with the deployment of the system by reducing the frequency and severity of damage caused to bridges and pavement.

- **Increased Data for Crash Safety Analysis** – The Safety Warning Detection System would provide more data to TxDOT to assess safety issues across the highway network. The frequency and distribution of detection events could be analyzed spatially with the CRIS data to identify gap areas in the network where safety countermeasures might be needed to address unsafe freight vehicle operations and the safety of all vehicles at intersections and areas where a lower speed is advised.

- **Increased Data for Project Planning and Development** – The deployment of the overweight detection system would expand the availability of WIM and permanent count station data across the state. Project planning and design efforts would benefit from having the data to develop inputs needed for freight accommodations, traffic forecasting, schematic design, pavement design, and environmental studies. This would improve the functional performance of corridor projects.

- **Increased Support for Enforcement** – TxDOT could share information captured by the system to assist TxDPS with investigations on violators and offenders. This could improve site selection of locations in need of additional enforcement. This could also improve cost recovery for repairs, which is usually borne by taxpayers instead of the vehicle drivers or owners.
4.2.4.2 Private Sector
The Safety Warning Detection System is expected to benefit private sector trucking companies. With advance notification, trucks could adjust their speed ahead of an intersection or curve or exit the highway ahead of low clearance bridges and load restricted areas. Reductions in crashes would make freight operations safer and cheaper to operate. With awareness of the system deployment locations, trucking companies could make more informed route planning decisions, which increases operational efficiency.

4.2.5 Impacts During Development
The development of the Safety Warning Detection System is not expected to disrupt the operations of existing detection systems, including WIM and permanent count station stations or any safety warning devices deployed on Texas roads. Software development would be needed to integrate the detection systems into the ATMS platform, as well as updates to the UI to provide the TMC operators with the tools to access system notifications and manage devices. System development is not expected to disrupt day-to-day TMC operations. Using the systems engineering process as a planning and development framework, ATMS updates could be developed and released iteratively with acceptance test plans and procedures in place to verify that releases meet all requirements before system cutover to the production environment.

During field installations, mobility could be impacted by road closures to install and test roadway sensors. These impacts could be mitigated by scheduling construction for off-peak travel periods and deploying ITS devices to better manage traffic within the work zones.

4.2.6 Impacts to Stakeholders
Relevant stakeholders for the Safety Warning Detection System strategy are listed in Exhibit 24. Stakeholders are denoted by roles of owner, key stakeholder, and/or end-user. TxDOT Divisions would act as owner with the administrative responsibility of providing project planning and implementation support in coordination with the TxDOT Districts. The Districts would be responsible for operating and maintaining the systems installed on state-owned routes that are not part of a Division initiative, such as the WIM or permanent count stations. The Districts, their affiliated TMCs, and other public sector agencies would be key stakeholders in identifying where needs exist based on crash histories, infrastructure damage, and other considerations. End-users would primarily be TMC operators that act on the real-time notifications and the private sector truckers who would utilize the notifications to avoid safety hazards and take necessary actions to divert ahead of potential hazards.
<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Role</th>
<th>Strategy Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>TxDOT Divisions</td>
<td>Owner/Key Stakeholder/End-User</td>
<td>• Will help guide and recommend strategic placement of Safety Warning Detection System, based on strategic planning criteria.</td>
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<tr>
<td></td>
<td></td>
<td>• Will own and operate WIM stations where the overweight detection systems are deployed.</td>
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<tr>
<td></td>
<td></td>
<td>• Will utilize WIM data from existing and new sites to provide inputs to Districts for traffic forecasting, pavement design criteria, safety improvements, and for air &amp; noise studies.</td>
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<td></td>
<td></td>
<td>• Will support project implementation by developing standards and specifications for ITS devices and system components.</td>
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<td>• Will publish archived WIM data through the STARS II website.</td>
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<tr>
<td>TxDOT Districts</td>
<td>Owner/Key Stakeholder/End-User</td>
<td>• Will own, operate, and maintain any technological deployments as part of their ITS program, with the exception of any technology programs that fall under a TxDOT Division’s responsibility.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Will respond to reported bridge strikes or other incidents that involve their infrastructure.</td>
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<td></td>
<td>• Will help guide and recommend strategic placement of these Safety Warning Detection System, based on strategic planning criteria.</td>
</tr>
<tr>
<td>Traffic Management Centers</td>
<td>Key Stakeholder/End-User</td>
<td>• Will help guide and recommend strategic placement of these Safety Warning Detection System, based on strategic planning criteria.</td>
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<td></td>
<td></td>
<td>• Will be an end-user of the notification alerts generated by the detection systems.</td>
</tr>
<tr>
<td>Stakeholder</td>
<td>Role</td>
<td>Strategy Impact</td>
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<tr>
<td>Texas Department of Public Safety</td>
<td>Key Stakeholder/End-User</td>
<td>• Will use real-time notifications to monitor traffic conditions for possible incidents or damage to infrastructure caused by OS/OW vehicles.</td>
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<tr>
<td></td>
<td></td>
<td>• Will help guide and recommend strategic placement of these Safety Warning Detection System, based on strategic planning criteria.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• May utilize camera snapshots of offending vehicles to aid in investigations when a bridge strike has occurred.</td>
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<tr>
<td></td>
<td></td>
<td>• Highway Patrol vehicles in the field may use the notification alerts provided by the TMCs to consider enforcement of OS/OW violators.</td>
</tr>
<tr>
<td>Truck and Passenger Vehicle Drivers</td>
<td>End-User</td>
<td>• Will be the primary end-user of the notification alerts generated by the detection systems.</td>
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<tr>
<td></td>
<td></td>
<td>• Will utilize the alerts to divert onto an alternative route in advance of a restricted area or take precautions ahead of an intersection or curve.</td>
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</table>

### 4.3 Alternatives To This Strategy

The proposed ConOps for the Safety Warning Detection System strategy comes with many benefits and impacts, but it inherently comes with prerequisite requirements in order to be successful in the long-term. While it meets the goals and objectives defined in the FNTOP strategy, it is not the only option available. This subsection identifies the inherent disadvantages and limitations of this strategy, and then contrasts the strategy against candidate alternatives that would also satisfy the intent, but were rejected due to being less advantageous.

#### 4.3.1 Disadvantages and Limitations

The strategy in this ConOps is expected to have several disadvantages and limitations, which form prerequisite requirements that TxDOT will need to satisfy for it to fully succeed. Unlike the policy and constraint considerations identified earlier, these disadvantages and limitations will need to be continuously addressed.
- **System Maintenance and Upkeep of Field Devices** – The proposed system utilizes field assets, as opposed to alternatives that could utilize a type of geofenced map alert with significantly less field maintenance. Field assets, due to exposure to elements and deployment in remote locations, will inherently be more costly to maintain.

- **Compliance with Safety Warning Notifications** – The system is only effective if the truck driver heeds the warning on the DMS or flashing beacon sign. Driver inattentiveness or unfamiliarity with the signage could limit the effectiveness of the advanced notification provided. This could limit the ability of the system to divert vehicles ahead of a potential hazard such as a tight curve, an intersection with poor sight distance, a load restricted bridge, etc.

- **Privacy Concerns** – State and local regulations could limit the use of information that could uniquely identify the vehicle of an offender or violator that caused damage to the infrastructure. This could limit the ability of the state to enforce bad actors and potentially recover costs for infrastructure repairs.

- **Geographic Coverage** – Not every part of the highway network would be instrumented with the Safety Warning Detection System. Deployments would be done strategically to focus on locations near critical infrastructure and areas with high incidences of commercial vehicle crashes.

4.3.2 Alternatives and Tradeoffs Considered

Given the above disadvantages and limitations, alternative options and tradeoffs were examined in lieu of the strategy in its proposed form. The alternative options listed below explore different approaches to improving the availability and use of the Safety Warning Detection System. It is important to note that some of these alternatives may seem intuitively nonsensical, but they are worth noting to confirm that all options have been explored and rejected for the stated reasons.

4.3.2.1 **Alternative 1: “Do Nothing” Approach**

This alternative would maintain the current situation, which would require no changes to the existing program, no increases in costs, and no additional coverage. TxDOT’s existing traffic operations program would continue to provide the same types of service, with no improvements in safety notifications. TxDOT would expect to maintain the status quo, capturing none of the benefits outlined in Sections 4.1.

4.3.2.2 **Alternative 2: Utilize Crowdsourced Data Only**

This alternative would implement a crowdsourced method of reporting areas of concern in lieu of detection systems. Drivers would need to access this crowdsourced information prior to undertaking a trip to confirm whether areas of concern exist along their route, including the low bridges, sharper turns, etc. As mobile applications are further developed, some of this crowdsourced information could be integrated into navigation systems, providing...
crowdsourced notices and alerts of issues similar to how Waze reports crowdsourced traffic-related events and incidents.

Crowdsourcing effectively increases how much of the highway network is monitored. However, it relies on a community of active contributors to input correct information, which may be challenging in rural areas. Additionally, without a feedback system in place, crowdsourced reports of areas of concern are no different than the roadside signing that TxDOT currently puts up to report on bridge heights, curve speeds, facility maximum weights, and others. This alternative—while offering some potential in enhancing the availability of data from a planning perspective—is not recommended because it does not offer the rapid real-time notifications and alerts that the strategy proposes.

4.3.2.3 Alternative 3: Issue Alerts in Geofenced Area
This alternative would implement an alert system for onboard equipment for vehicles in lieu of in-field detection systems. Similar to the crowdsourced data, this system would need to digitally map where areas of concern are present and broadcast alerts to vehicles that may benefit from notification within that area. For example, the CV program would effectively do this, issuing a curve speed warning digitally to a CV-equipped vehicle that is going around a curve too quickly. If integrated with an onboard navigation system, these alerts could be done with a minimal amount of field equipment, relying instead on the navigation system’s basemap and the cellular communications network to issue updates.

While this would reduce overall infrastructure costs, this alternative is not recommended because it fails to provide the full potential described by this strategy. A geofenced alert can offer real-time feedback for certain alerts—primarily speed notifications or, in some cases, intersection alerts—but they fall short on overheight and overweight detection because no monitoring equipment is used to determine if the vehicle, in fact, is exceeding the allowable parameters. Drivers could potentially enter in their estimated heights and weights, but the margin of error is too great if they input the wrong parameters—intentionally or unintentionally. CV will likely be incorporated into this strategy in the future, but not in the manner in which this alternative describes. TxDOT will see some improvements if employing this alternative, but not nearly as many as the recommended strategy.
5.0 Operational Scenarios
This section presents five operational scenarios that describe situations in which the Safety Warning Detection System could significantly improve the safety of truckers delivering freight throughout Texas. Each operational scenario describes the users involved and the issues that are intended to be addressed, as well as the outcomes or benefits the users are expected to experience through the deployment of this strategy. The following operational scenarios do not address all of the desired Safety Warning Detection System improvements, nor do they represent a comprehensive set of use cases, but rather demonstrate some of the key situations that this system could help serve and improve. Exhibit 25 summarizes the operational scenarios presented in this section.

Exhibit 25: Summary of Operational Scenarios

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<thead>
<tr>
<th>#</th>
<th>Scenario</th>
<th>Stakeholder Perspective</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A truck driver triggers the speed advisory warning system.</td>
<td>Truckers/TxDOT TMC Operators/TxDPS</td>
</tr>
<tr>
<td>2</td>
<td>A truck driver triggers an overheight vehicle warning system and, upon an automated alert of a bridge strike, a TMC operator responds.</td>
<td>Truckers/ TxDOT TMC Operators/TxDPS</td>
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<tr>
<td>3</td>
<td>A truck driver triggers an overweight vehicle warning system.</td>
<td>Truckers</td>
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<td>4</td>
<td>A truck driver triggers the intersection conflict warning, approaching trucker slows down to avoid a conflict.</td>
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<td>5</td>
<td>TxDOT District looks at safety warning device data to help make planning decisions using performance measures.</td>
<td>TxDOT District</td>
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5.1 Speed Advisory Warning System Notification is Triggered
On a Monday morning at 9 a.m. Alice is driving her truck south on I-35, approaching Austin, Texas, to make her first freight delivery of the day. She is a local trucker delivering gravel from a quarry in Round Rock and is very familiar with this route. According to her in-cab navigation, she is on the best route and on time to arrive at the facility just after 10 a.m.

She is coming to an interchange south of downtown that is known to be challenging to truckers because of the large flyover ramp with tight horizontal curves. Truckers must reduce their speeds from 60 mph to 30 mph to maneuver the curve safely. The area is known to have frequent accidents where trucks have tipped over, usually due to driver inattention as they fail to slow down at the curve.
On this trip, Alice notices a brand new DMS that had been recently installed by TxDOT. It was blank as she approached it, but suddenly it shows a message “Sharp Curve Ahead. Slow Down.” She realizes that she had been going faster than desirable through the interchange and carefully slows down. Alice and the vehicles around her safely make it through the curve and merge onto the new highway.

About half a mile behind Alice, Adam is driving his truck. He is a long-distance trucker covering multiple states from the Midwest to Central Texas. He has made deliveries to the Dallas-Fort Worth area, but is making one today to a distribution center in San Antonio. He usually makes deliveries in Dallas, but has accepted a delivery in San Antonio. He is not familiar with this I-35 interchange or the sharp curve that is present, but he has his in-cab navigation to safely route him to his destination. Luckily, there is not much traffic and Adam is on time to make his delivery.

As Adam is driving, he sees the same DMS. He glances at it and sees a message of “Sharp Curve Ahead. Slow Down.” Adam realizes he has not been paying attention at all and immediately starts to brake, coming upon the curve that he had not noticed. He is able to navigate through the tight curve with minimal issue now that he has braked, but he realizes that going through the curve at full speed might have caused him to lose control.

A few miles away, at the Austin CTECC, operators are monitoring the freeway network. Since the speed advisory system does not issue alerts for each detection, operators are notified of incidents when a crash is reported through other sources; otherwise, they might receive many false alarms for each speeding vehicle. However, in the background, the ATMS is silently logging all reported sign activations for the historical record. TxDOT may review the record and determine if additional signing would help reduce the number of overspeed events at this curve or if a reconstruction of the curve is needed.

5.2 Overheight Vehicle Notification is Triggered
Mark and Paula both work for the same trucking company based in the Permian Basin region of Texas. It is 5 p.m. on a Friday and they have a busy afternoon ahead of them. Their dispatcher has tasked them with delivering two loads from Odessa to San Angelo. Mark and Paula have years of experience making deliveries in the Permian Basin, mainly off of the Interstate System. They have not driven to San Angelo in years. Based on reports of excessive delays on major routes due to a major highway construction project, they will need to take local state routes.

They load up their trucks and begin the drive to San Angelo. They start off on I-20, but then exit to a lesser-traveled state route that is recommended by their navigation system to avoid the construction delays on the Interstate. Mark is a few miles ahead of Paula and realizes that he is very unfamiliar with this route. Unbeknownst to Mark and Paula, this local state route has a bridge that is lower than the TxDOT standard and, despite being signed properly,
has been struck over the years by truckers whose trailers are too tall. Neither Mark nor Paula realize it, but their trailers have a height too tall for the bridge, but due to clerical errors, they have initiated the trip without awareness of this fact.

Given the bridge has a bad history of strikes, TxDOT has instrumented an overheight detection system in advance of the bridge, as well as a bridge strike monitoring system to facilitate a rapid response. As Mark passes the overheight detection system, the system identifies his truck as being too tall. A downstream DMS illuminates as Mark approaches, indicating “Truck is too tall. Will Strike Bridge Ahead. Turn Right onto Johnstown Rd to Bypass.” Mark immediately takes the next turn onto Johnstown Road and, despite being slightly longer, his in-cab navigation system figures out a new route. After a few miles on the alternate route, he is able to resume driving on the highway.

A few minutes later, Paula passes the same overheight detection system. It detects her height as too tall and posts the same notification message on the DMS, but Paula ignores it, confident that her trailer would clear the bridge. Adjacent to the overheight detection system is a TxDPS camera, which—upon activation of the overheight alert—takes several snapshots of her truck and logs them on the hard drive. Paula fails to turn onto Johnstown Road and drives under the bridge. To her horror, she hears a violent screech as her truck scrape the bottom of the bridge. Somehow, she manages to get to the other side and, in a panic, drives off.

The bridge strike detector immediately logs a surge of force at the moment of collision. The nearby TxDOT TMC is notified, where an operator receives a pop-up alarm in the ATMS software of a reported collision. The TMC operator calls the District Engineer to report the strike, which results in staff immediately being dispatched to the bridge. They discover that the bridge has been damaged, but are able to confirm that it is not at risk to the public. Repairs are immediately ordered to fix the damage.

TxDPS is notified that a collision has occurred, but the driver failed to report the incident. TxDPS reviews the snapshots taken and is able to note that Mark’s and Paula’s trucks passed the site right around the time of the collision. While not conclusive on its own, TxDPS tracks down Mark’s and Paula’s trucks and is able to quickly determine that Paula’s truck has sustained damage consistent with the bridge strike. Paula admits to the collision and TxDPS is able to take action to recoup costs for the damage to the bridge.

5.3 **Overweight Vehicle Notification is Triggered**

On a Wednesday morning at 10 a.m. Caroline is driving her truck on I-10, approaching Houston, Texas. She is delivering a large shipment for a distribution center near the Port of Houston when her in-cab navigation system suddenly reroutes her to a local road, avoiding congestion on the interstate. Caroline takes the alternate route and is still on time to arrive by 11 a.m. However, she is on a road she has never taken before.
A few miles ahead is a narrow bridge that prohibits use by semi-trucks due to its load capacity. Even though it is signed for heavy trucks to not use the bridge, signs frequently are stolen and truck drivers unknowingly drive their heavy vehicles across the bridge. Although the bridge is still within its safety tolerances, the excessive loading has caused regular damage that necessitates costly repairs from TxDOT.

As Caroline comes within a mile of the bridge, she unknowingly drives across a WIM that assesses her vehicle weight. The system identifies her truck as exceeding the weight limits of the bridge and activates the beacons on a static sign that read “Bridge ahead. Vehicle is overweight when flashing. Turn left onto Meyers Road.” Caroline immediately turns onto Meyers Road and her navigation system finds another route, adding only an extra 2 minutes to her estimated arrival time.

5.4 Intersection Conflict Notification is Triggered

It is 9 p.m. on a Wednesday night and a heavy thunderstorm is rolling through southwest Texas. Sherry is making her final delivery of the day for a large facility outside of Laredo, Texas. She is traveling on a rural, two-lane segment of U.S. 59. Aside from the extremely low visibility during the storm, Sherry is also concerned about the road’s lack of lighting. She always exercises extra caution when she drives at night.

She notices that most of the intersections she passes are two-way intersections, where she has the ROW and vehicles on the intersecting streets have stop signs. She is relieved that she does not have to stop and watch for incoming traffic during these bad weather conditions. She also observes that the traffic around her consists mainly of trucks.

As she continues driving, she approaches a large intersection. It looks clear to Sherry, however, as she gets closer, she notices a static sign with flashing beacons on top that warn “Vehicle Crossing When Flashing”. She immediately brakes to a slower speed, suddenly spotting a slow-moving truck that is struggling to get across the road ahead of her. The other truck driver had not seen Sherry coming while waiting at a stop sign and severely misjudged how fast he could accelerate. Sherry realizes that, without notification from the sign with flashing beacons, she would not have been aware of the crossing truck and would have had to brake very hard, possibly losing control and causing extra wear and tear on her truck. Sherry also realizes that, through an improved awareness of the intersection, TxDOT may see a reduction of intersection-related crashes, which would allow them to prioritize limited safety funds to other critical safety improvements.

5.5 Performance Reporting

A TxDOT District in west Texas has implemented the Safety Warning Detection System throughout its roadway network. They have specifically focused on installing overheight detection devices at select locations, citing a large number of rural roadways with low
clearance bridges. After the first year of operations, the District decides to analyze the data and plan for future infrastructure improvements. On average, the District experiences about eleven bridge strikes a year. During that first year of operations, the number of bridge strikes was reduced to two. To improve driver compliance and attentiveness, the District added additional signage at those two bridge locations.

The District shares its findings with the Traffic Safety Division and concludes that the system was effective in reducing the number of bridge strikes. Using the historical dataset, the District calculates the proportion of trucks diverted based on the total number of events logged by the system. The ROI showed that the cost of implementing the system was far lower than the average cost of $200,000-$300,000 in repairs for each bridge strike. The Traffic Safety Division is encouraged by the findings and recommends deploying the system to other low clearance bridges on the THFN where the system could provide safety benefits until the bridge is reconstructed to the current vertical clearance standard.
6.0 Next Steps

This Safety Warning Detection System ConOps is one of six ConOps documents to be prepared as part of the FNTOP. As noted earlier, these six strategies were chosen through a selection process that vetted a total of 10 identified strategies with key stakeholders. Each ConOps intends to further answer how each specific strategy would operate, which systems it would interface with, and how various user groups would be impacted by the introduction of the strategy. Based on this document, this strategy is ready for TxDOT to advance to implementation planning in the future, which would include the development of system requirements and high-level design (detailed further in the Implementation Plan as shown in Exhibit 26).

In addition to the ConOps development, the FNTOP is also developing an Implementation Plan that explores the near-, medium-, and long-term actions that will drive the successful implementation of the 10 FNTOP strategies. This will include an assessment of the readiness of each strategy. The goal is to inform the next steps beyond the FNTOP as these strategies are transitioned from planning to design. This will include outlining how the Safety Warning Detection System strategy would ultimately come to fruition, utilizing insights provided as part of this ConOps.

**Exhibit 26: Next Step in the Texas FNTOP**
7.0 References

The following is a list of relevant documents, standards, and references used in preparing this document:


- Texas Department of Transportation, Crash Records Information System (CRIS).