Executive Summary

The roadway system plays a central role in the movement of freight throughout Texas. However, much of this system was designed and built decades ago with design features that do not accommodate the quantity and operational needs of trucks traveling on the system today. This contributes to reduced mobility and higher safety risks, which decreases the competitiveness of the state’s transportation system. Even newly built roads, designed following the latest standards, might not optimally accommodate the needs of the freight sector now, let alone in the future.

The Freight Infrastructure Design Considerations (FIDC) study of the Texas Department of Transportation (TxDOT) seeks to identify practices in roadway design that improve the mobility and safe movement of trucks. This includes considering roadway geometrics, intersections, bridges and structures, pavements, traffic operations, and work zone traffic control. The recommendations of the FIDC study focus on the Texas Highway Freight Network (THFN), which was designated as part of the 2018 Texas Freight Mobility Plan to include the roadways that are most important for freight movement in the state.

STUDY GOALS

The purpose of this study is to address roadway functional design and operational issues related to the movement of freight in Texas. It has four principal goals:

- Recommend design considerations for incorporation into freight network design.
- Develop freight factors for consideration in update of the TxDOT Roadway Design Manual.
- Enhance safety, address congestion, increase efficiency and improve multimodal access on the Texas Multimodal Freight Network.
- Identify freight infrastructure design issues on the Texas Highway Freight Network.
APPROACH

The recommendations of the FIDC were developed based on an extensive review of design guidance across the U.S., an analysis of roadway characteristics and performance data in Texas, and input from various stakeholders, including industry and truck drivers. The roadway design attributes that are most relevant to freight operations were identified through a thorough review of the literature, input from TxDOT engineers, and a survey of freight stakeholders. TxDOT’s design practices for these key freight attributes, as described in the 2020 Texas Roadway Design Manual (RDM) and other documents, were compared to guidance from the federal government, national committees (such as American Association of State Highway and Transportation Officials), six peer states, and six adjacent states. The findings of key research studies were also considered, including from the recently published National Cooperative Highway Research Program (NCHRP) Report 943 that provides design recommendations for truck routes. The identified best practices informed the selection of minimum and optimal criteria for each of the key freight attributes studied.

An analysis was then conducted to identify deficiencies in the THFN relative to existing design guidance and the recommended minimum and optimal criteria. For some design attributes, data already existed, which allowed for the identification of deficiencies throughout the THFN. For the rest, a manual process was used to catalog the characteristics of 30 segments on the THFN, which were selected by scanning six major corridors in the state to represent conditions throughout the network (spanning different functional classifications and degree of urbanization). The results of this data collection were then used in a statistical analysis to identify correlations between design attributes and key mobility and safety measures. The results of this analysis informed the prioritization of design recommendations.

NEIGHBORING STATES: New Mexico, Oklahoma, Arkansas, and Louisiana.

STAKEHOLDER OUTREACH AND COORDINATION

Stakeholder-informed analysis is a TxDOT hallmark. Two broad constituencies were engaged extensively:

1. TxDOT divisions and private partners;
2. Private industry and truck drivers.

Key steps of outreach and coordination were:

- Regional public/private forums held in 19 locations across Texas, with total attendance by 339 participants in addition to TxDOT personnel.
- Industry needs survey of businesses, logistics operators, and truck drivers elicited 453 responses on roadway conditions and related topics.
- Webinars were conducted with TxDOT District Operations in groups covering the entire state.
- Truck drivers were surveyed about aspects of roadway design, resulting in 72 responses used in establishing priorities.
- Coordination with the TxDOT Design Division was critical and influenced identification of design attributes, prioritization of attributes, and definition of design values for consideration.
GEOMETRICS

The following recommendations will help design roads to better accommodate the large size and performance characteristics of trucks:

- **Acceleration Lane Length**: Consider increasing the length of acceleration lanes on roads that have significant truck traffic to reduce speed differentials with mainline traffic, which is associated with higher crash rates. Additional allowances are recommended for lanes on an upgrade or starting from ramp metering. Design values could be increased to match national best practices, which generally result in acceleration lanes that are longer than those recommended by the RDM. The THFN has a significant deficiency in this area, with over half of all the ramps studied not meeting existing RDM guidance, and a much higher proportion not meeting national best practices.

- **Outside Shoulder Width**: Consider increasing the width of outside shoulders to 12 feet for freeways and expressways, 10 feet for Rural Principal and Minor Arterials and Rural Major and Minor Collectors, and 8 feet for Urban Principal and Minor Arterials and Urban Major and Minor Collectors (with higher classification roads receiving priority). These changes would be significant increases relative to the current guidance on the RDM; however, they are intended to accommodate truck parking during emergencies. Currently, one percent of freeways, 32 percent of arterials and 70 percent of collectors do not meet the minimum requirements for outside shoulder width in the RDM.

- **Lane Width**: Consider increasing the minimum lane widths along the THFN to 12 feet, as recommended in the recently published NCHRP Report 943. The RDM recommends different lane widths depending on the functional classification of the roadway; however, trucks have difficulty operating on roads narrower than 11 feet, leading to encroachment into adjacent lanes and other safety risks. This change would fall in line with peer states that are increasing lane widths on roads with significant freight activity. A review of the THFN found that 70 percent of its mileage of principal and minor arterials and major and minor collectors are already 12 feet wide. On the other hand, this review also found that six percent of the mileage did not meet existing RDM recommendations.
KEY FREIGHT ATTRIBUTES WHERE MAJOR CHANGES ARE RECOMMENDED

- **Intersection Turning Radius**: Consider designating the WB-67 as the design vehicle on the THFN (see exhibit below), where practical, and where high truck-turning movements are known or expected. This would reduce encroachment onto other travel lanes, improving safety and reducing damage to curbs and the pavement surface. This change would fall in line with peer states that are making greater allowances for truck turning movements. Turning radii is an area of systematic deficiency throughout the THFN, with 79 percent of the intersections reviewed not meeting the turning radii recommended for the smaller WB-62 design vehicle recommended in the RDM.

- **Intersection Channelization**: Consider developing guidance on storage lengths and channel widths at intersections that see significant truck volumes, particularly during congested periods of the day, as is recommended by NCHRP Report 943. This change would fall in line with peer states that include specific guidance for accommodating truck movements through intersections. The RDM does not include guidance for intersection channelization.

- **Vertical Grades**: Consider lowering maximum vertical grades on arterials with significant truck traffic to five or six percent, from current guidance in the RDM of eight percent to nine percent, to prevent significant slowdowns for loaded trucks and higher variability of speeds in the traffic stream. This would align the design criteria with leading peer states that reduce the maximum vertical grade when roads have a high truck percentage. Exceptions could be created for travel through mountainous areas in West Texas, where ensuring lower grades is costly. No change is recommended to the maximum vertical grade on freeways, which is set at three to four percent in the RDM. In general, vertical grades were not found to be a pressing issue on the segments of the THFN analyzed (a small subset of the THFN).

- **Climbing Lane**: Consider expanding RDM guidance on climbing lanes so they are warranted in more locations throughout the THFN. Some peer states, particularly those in mountainous areas, have gone beyond the calculations recommended in national guidance to develop expanded criteria for the use of climbing lanes, in most cases prioritizing roads with significant freight volumes. TxDOT should study further the applicability of these recommendations to Texas.
KEY FREIGHT ATTRIBUTES WHERE MAJOR CHANGES ARE RECOMMENDED

WORK ZONES

The U.S. Department of Transportation has published extensive rules and guidance on designing roadway construction work zones; however, each state ultimately implements this guidance per local conditions and practices. In Texas, this guidance has been operationalized in the Texas Manual on Uniform Traffic Control Devices, Part 6, although this guidance does not include any significant consideration of truck traffic. TxDOT should consider including truck-specific guidance like several peer states have done. This could include maintaining 18.5-foot clearances, limiting the narrowing of lanes, preserving adequate shoulders, and other geometric recommendations mentioned previously, especially when high truck volumes are present. The needs of work zones will vary from project to project; however, statewide guidance on work zones involving high truck volumes would be useful. This echoes the recommendations of NCHRP Report 943. It is recommended that TxDOT continue deploying Intelligent Transportation Systems that warn truck drivers about disruptive work zone activities, as done in the I-35 Connected Work Zone Project.

KEY FREIGHT ATTRIBUTES WHERE NO MAJOR CHANGES ARE RECOMMENDED

The following design attributes were reviewed as part of the FIDC study, however no major changes were recommended because existing practices in Texas matched national guidance or leading practices. Minor recommendations are provided for some of these attributes.

GEOMETRICS

- **Deceleration Lane Length:** No specific changes are recommended. The design criteria in the RDM aligns with the national guidance and the guidance from peer states. While some older trucks might take significantly longer to come to a stop, especially when heavily loaded, most trucks have braking systems that allow them to slow down at comparable rates similar to passenger vehicles. However, a review of the THFN found that almost half of the deceleration lanes reviewed were shorter than recommended by the RDM, which could be causing issues for the operations of trucks and other vehicles.

- **Ramp Length:** No specific changes are recommended. Even though the RDM provides guidance only on the lengths of ramps that have a specific configuration, this is not uncommon relative to national guidance and peer states. Most ramps reviewed in the THFN were not of the configuration that had length guidance. Of the few that were, only four did not meet RDM guidance; therefore, this is not an area of significant deficiency on the THFN.

- **Critical Length of Grade:** No specific changes are recommended. Existing design criteria in the RDM are compatible with national guidance and are similar to peer states.

- **Passing Sight Distance & Passing/No-Passing Zones:** No specific changes are recommended. Existing design criteria in the RDM are compatible with national guidance and are similar or more conservative than peer states.

- **Intersection Sight Distance:** No specific changes are recommended, as the RDM already follows national guidance. However, TxDOT is encouraged to study further how the sight distances of trucks might differ from those of passenger vehicles, particularly on downgrade situations. Some peer states recommend truck-specific criteria in this area that go beyond national guidance. Of the intersections reviewed on the THFN, 11 percent do not appear to meet the minimum sight distance recommendations of the RDM. While not a systematic deficiency, this could elevate crash risks at deficient intersections.
Executive Summary

TxDOT Freight Infrastructure Design Considerations

PAVEMENT

The pavement design process in Texas is similar to that of peer states. While a structured process is in place, the ultimate decision about the type of pavement used and its technical characteristics is made by either local engineers in TxDOT’s districts or municipal governments. Statewide guidance provides a basis for design methods but leaves ultimate responsibility to the local level. Truck impacts are considered as a percentage of traffic through Equivalent Single-Axle Load calculations. In Texas, the decision whether to use flexible pavements (unreinforced asphalt on gravel) or rigid pavements (steel-reinforced concrete) does not appear to depend on the truck uses of the road, even though this has a critical impact on pavement performance and life-cycle costs. In general, flexible pavements deteriorate quicker under heavy axle loads, but withstand overweight trucks better, where the weight is distributed among many axles. Rigid pavements are more expensive to build initially but have a much longer service life.

The decision regarding pavement type could be made in a systematic way that reduces costs and improves freight serviceability on the THFN. Moreover, the adequacy of pavement design methods used should be reviewed to ensure that they accurately represent the deterioration caused by trucks of different configurations, capturing the higher frequency of overweight trucks, the changes in truck technology, and the strength characteristics of current pavements. Some peer states have made specific adaptations to their pavement design process for roads with high truck volumes. While most peer states rely on Equivalent Single-Axle Load calculations in pavement design, Michigan relies on the Mechanistic-Empirical method for designing pavement, which addresses some of the limitations of Equivalent Single-Axle Load designs and has the potential to better account for the impacts of truck loadings. TxDOT should consider how these and other approaches could be used to improve pavement designs throughout the THFN.

TRAFFIC OPERATIONS

Texas, like its peer states, does not design differently for intersections that have high truck volumes. Opportunities exist for improving this, while balancing driver expectancy and maintaining fluid operations for all traffic. The design of traffic-signal phasing could coordinate with the storage length provided in the intersection based on truck volumes during congested times of the day. The storage length at the intersection should accommodate the peak-hour truck traffic, and the clearance time of the traffic signal should accommodate queue length during peak hours. Also, trucks frequently block the visibility of overhead displays for drivers behind the truck. Placing supplemental far-side displays would maintain signal visibility when trucks are present. No change is recommended to RDM guidance on vertical clearance of signs, overhead sign bridges, and signals. TxDOT should explore making greater use of Intelligent Transportation Systems applications for managing truck traffic, like in some peer states. This includes warnings for trucks entering crossings, warnings for oversized vehicles, and warnings of potentially dangerous conditions, such as strong winds.

BRIDGES AND STRUCTURES

TxDOT recently increased guidance on bridge vertical clearance from 16.5 feet to 18.5 feet on the THFN for new and reconstruction projects. Although none of its peer states or national guidance have recommended such a change, this change has the long-term potential to improve safety, reduce the probability of bridges being struck and damaged by truck collisions, and facilitate the movement of oversize cargo. No change is recommended to this guidance.

The THFN presently has a moderate deficiency with regard to bridge clearances. Of the 3,175 bridges on the THFN, 251 bridges (7.9 percent) have clearances lower than 15 feet, which might represent a bottleneck for truck operations (conventional trucks have a height limit of less than 14 feet), and 1,263 have clearances lower than 16.5 feet, the previous standard. Only 379 bridges on the THFN clear the recent 18.5 feet standard.

KEY FREIGHT ATTRIBUTES WHERE NO MAJOR CHANGES ARE RECOMMENDED

- **PAVEMENT**
  - Rough in Beaumont
  - Patched in Amarillo
  - Intersection in Brady
  - Low Bridge Clearance: N I-35 East in Dallas

- **TRAFFIC OPERATIONS**
  - Texas, like its peer states, does not design differently for intersections that have high truck volumes.

- **BRIDGES AND STRUCTURES**
  - TxDOT recently increased guidance on bridge vertical clearance from 16.5 feet to 18.5 feet on the THFN for new and reconstruction projects. Although none of its peer states or national guidance have recommended such a change, this change has the long-term potential to improve safety, reduce the probability of bridges being struck and damaged by truck collisions, and facilitate the movement of oversize cargo. No change is recommended to this guidance.

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Executive Summary

The considerations presented by this study are likely to improve how the THFN accommodates freight movements; however, they are numerous and cannot be implemented simultaneously. A prioritization exercise was conducted to help identify the highest priority attributes for consideration. A key input into this exercise was a statistical analysis to assess whether deficiencies in any of the attributes would affect key mobility and safety measures. For some attributes, the results of this analysis were inconclusive, given the small data sample; however, for other attributes it was possible to find a meaningful correlation between a design deficiency and lower mobility or safety performance. The results of this analysis were then combined with other factors—such as how highly truck drivers rated the attribute in the survey—to establish a prioritization framework. Exhibit 2 summarizes this recommended prioritization framework.

Attributes categorized as “HIGH PRIORITY” tended to be significant to truck drivers, and also showed up in the statistical analysis as correlating with performance issues. For all these attributes, the FIDC recommends considerations that could improve how freight is accommodated, likely addressing the concerns of truck drivers and mitigating some of the performance issues.

Attributes categorized as “MEDIUM PRIORITY” were not found to correlate with performance issues; however, in many cases this was due to lack of data. Therefore, the analysis cannot rule out that these attributes are not important. In fact, these attributes fell in this category because engineering judgment suggested they are likely to also be beneficial.

Finally, attributes categorized as “LOW PRIORITY” could also prove to be beneficial; however, additional study is required to make specific recommendations. Several center around designing roads in mountainous areas, which is not a concern in most of Texas.

Exhibit 2: Prioritization Framework

“HIGH” PRIORITIZATION
Definition
- Attributes that demonstrate improvement in mobility, safety, or other Texas Freight Mobility Plan goals.
- Attributes that ranked the highest by truck drivers in survey.
Qualifying Attributes
- Lane width
- Outside shoulder width
- Bridge vertical clearance
- Railroad/highway bridge clearance
- Intersection turning radius
- Sight distances
- Acceleration lane

“MEDIUM” PRIORITIZATION
Definition
- Attributes that do not demonstrate improvement in the analysis, but are supported by engineering judgment as being worthwhile investments.
- Attributes that are relatively low-cost investments to implement.
Qualifying Attributes
- Ramp length
- Climbing lane
- Intersection channelization
- Railroad/highway grade crossing sight distance
- Work zone lane width
- Work zone shoulder width

“LOW” PRIORITIZATION
Definition
- Attributes that do not demonstrate improvement in the analysis of mobility or safety.
- Attributes for which no changes in design were recommended.
Qualifying Attributes
- Deceleration lane
- Passing/No-Passing Zones
- Vertical grade
- Critical length of grade