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16. Abstract

Adequate management of oversize/overweight (OS/OW) permit loads throughout the state of Texas is critical to maintaining a vibrant state economy. The growth in the number and size of permit loads in recent years is clear evidence that new tools and new techniques are needed to match this growth without causing undue delays to permit applicants. Problems such as increasing prevalence of reroutes due to maintenance and other district activities along with potential damage to the highway infrastructure from permit loads led to this research project. A related initiative was development of a new automated routing program—Texas Permit Routing Optimization System. Research objectives were to:

- Identify the most common OS/OW dimension and weight groups.
- Identify criteria for assigning these OS/OW groups to existing road networks.
- Identify criteria for assigning current and projected OS/OW groups to the future road network upgraded to meet future demand.

The research project resulted in a statewide map recommending primary and alternate OS/OW route networks for the most common origins and destinations based on historical Motor Carrier Division data. Keeping strategic routes open for OS/OW loads and minimizing the number of reroutes along the way will reduce the impedances and unknowns in this critical segment of the motor carrier industry.

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ACCOMMODATING OVERSIZE AND OVERWEIGHT LOADS: TECHNICAL REPORT

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- Mr. Justin Obinna.
- Mr. Andrew Wanees.
- Mr. Dean Wilkerson.
- Dr. Duncan Stewart.
- Mr. Frank Espinosa.

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CHAPTER 1: INTRODUCTION

BACKGROUND

Effective and sufficient support to domestic and international freight movements is a key to a vibrant economy. In 2007, the United States transportation system moved 51 million tons of commodities each day worth $45 billion (*1*). Although temporarily decreasing between 2008 and 2009, the total tonnage started to rebound in 2010, and annual tons per capita will likely increase 27 percent from 55 tons in 2010 to 70 tons in 2040. A significant proportion of this tonnage translates to oversize and/or overweight (OS/OW) truck loads that have to be routed to avoid permanent or temporary physical constraints of the transportation infrastructure.

Texas, along with many other states, has been making significant strides in developing the state transportation system to accommodate OS/OW loads. Available information based on research experience and interviews with the Texas Department of Transportation (TxDOT) indicate that many state permit offices experienced increased numbers of OS/OW permit requests and super-heavy load requests prior to the economic downturn. For example, TxDOT's Motor Carrier Division (MCD) experienced an increase in permit requests of 33 percent from 2003 to 2007 (*2*). Super-heavy requests increased 667 percent from 2004 to 2007, partly due to the statewide boom in wind energy and oil/gas development. Since 2007, TxDOT has issued more than 500,000 OS/OW permits every year. Although decreasing since 2008, there is little doubt that OS/OW activities will bounce back and continue to grow nationwide.

To prompt safe and efficient routing for OS/OW loads, improve safety, and minimize deterioration to state highways, Texas formed an OS/OW working group consisting of engineers from the north and east Texas (NETx) district and division representatives. In 2007, TxDOT further organized a Super-Heavy and Overweight Load/Seal Coat Damage Prevention Work Group consisting of staff from NETx districts, MCD, the Construction Division, and the Maintenance Division. In addition, TxDOT is currently in the process of developing geographic information system (GIS)-integrated software, called Texas Permit Routing Optimization System (TxPROS), to automatically route OS/OW loads online (*3*).

As part of Research Project 0-6404, the research team processed and mapped a massive dataset of OS/OW permit routes into a GIS format. This report presents the methodology and findings of the research, investigating the implications of improving current practice to more efficiently accommodate the movement of OS/OW loads.

OBJECTIVES

The primary objectives of this research included:

- Identify the most common OS/OW dimension and weight groups.
- Identify criteria for assigning these OS/OW groups to existing road networks.
- Identify criteria for assigning current and projected OS/OW groups to the future road network upgraded to meet future demand.

Tasks that addressed the objectives were as follows:

- Task 1: Conduct literature and Internet review.
- Task 2: Evaluate MCD Historical Data and Gather Stakeholder Input.
- Task 3: Review TxPROS.
- Task 4: Identify Criteria for Assigning OS/OW Groups to Existing Road Networks.
- Task 5: Identify Criteria for Assigning Current and Projected OS/OW Groups to Future Network.
- Task 6: Develop statewide map.
- Task 7: Develop deliverables.

ORGANIZATION OF THE REPORT

This research report consists of 10 chapters organized as follows. Chapter 2 provides the results of an extensive literature and Internet search.

Chapter 3 presents the results of stakeholder interviews pertaining to movements of OS/OW loads. Information came primarily from personal interviews, either face-to-face or over the phone, but some also came from participation in industry events such as professional conferences.

Chapter 4 summarizes some of the basic aspects of the TxPROS program. At the time the information was gathered, the program was not fully functional, but the information is still relevant. Since this research project developed components that need to interface with TxPROS, there was a need to be knowledgeable about the program.

Chapter 5 involves a preliminary analysis of MCD historical permit data. The remainder of the report builds upon this basic dataset covering six years of data and using data for which routes were assigned. Data for other permit types were not critical for this research since they did not have routes assigned.

Chapter 6 describes in detail the process of mapping the route descriptions in the original permit data into GIS route and origin-destination (OD) features. During this mapping effort, the research team standardized a large number of route descriptions that were originally in text format. Based on the standardized descriptions, the researchers developed computer scripts and programs to map the routes onto the current TxDOT on-system roadway network and converted the OD pairs into GIS linear features. The original load information was then analyzed and linked to the mapped GIS features for further spatial analysis.

Based on the mapped OS/OW route and OD features, Chapter 7 describes the findings of various route and OD analyses. The findings help provide a comprehensive picture depicting spatial and temporal distribution of the historical OS/OW routes. During this study, researchers analyzed the routes in a comprehensive manner, considering factors such as load characteristics, trip characteristics, highway type, and regional boundaries.

Chapter 8 contains research findings from a thorough examination of statewide permanent height and weight restrictions and the distribution of OS/OW routes. Such findings helped the research team to identify logical explanations on how the restrictions played a role in OS/OW routing as well as the implications to the industries if critical restrictions can be improved or removed. The chapter also includes findings of optimal route analyses that quantified the additional travels and associated costs due to restrictions on TxDOT highways.

Chapter 9 provides an overview of the workshop held in the Bryan District near the end of the research period. Input from district personnel is included.

Chapter 10 summarizes the key findings and provides recommendations. One key recommendation pertains to a future implementation project to further clarify needs of all districts pertaining to oversize/overweight permit routing.

CHAPTER 2: INTERNET AND LITERATURE SEARCH

INTRODUCTION

The significance of the topic of permitting for oversize/overweight loads in Texas had already prompted the formation of an oversize/overweight OS/OW working group, consisting of north and east Texas (NETx) district and division representatives. A meeting of maintenance and operations engineers in Tyler in November 2006 resulted in the formation of a Super Heavy and Overweight Load/Seal Coat Damage Prevention Work Group, consisting of staff from NETx districts, the Motor Carrier Division, the Construction Division (CST), and the Maintenance Division (MNT). The kickoff meeting of this working group occurred in April 2007, resulting in eight key issues to be addressed. These issues were subsequently reduced to three broad topic areas as follows (*4*):

- Reduce seal coat damage.
- Improve communications between districts and divisions regarding OS/OW routes.
- Improve route options for OS/OW loads by maintaining open corridors.

Based on these three issues, the working group identified problem areas and, in some cases, worked to identify and/or develop solutions. Table 1 is a summary of some of the major action items or concerns that needed to be addressed. Solutions for some of these items were already under way when this research began while others needed to be addressed in this research project or via other means.

Available information based on researcher experience, meetings with TxDOT, and literature and Internet findings indicates that many state permit offices are experiencing an increase in workload due to both the number of OS/OW permit requests and the number of super-heavy load requests. The Motor Carrier Division was no different, experiencing an increase in permit requests of 6 percent from 2006 to 2007 and 33 percent from 2003 to 2007. Super-heavy requests increased 337 percent from 2004 to 2007 (*5*).

Routing the loads to avoid obstructions, construction, maintenance, and new pavement surfaces was causing increased deterioration of the rural system as well as a concern for traffic safety with oversize loads and opposing traffic on narrow roadways. Additionally, there was concern for the safety of the load itself when narrow roads, lack of shoulders, and poor geometry often contributed to problems experienced by movers of OS/OW loads. The attitude in Texas then and currently is one of encouraging continued growth, so the number of permit requests will likely continue. One means that states have investigated and/or have implemented to counteract these increases in workload is an automated routing system. Reasons to automate the OS/OW permitting process include the following:

- Reduction in delay to the applicant to acquire the permit.
- Increased compliance with OS/OW permitting requirements.
- Enhanced safety through details not normally available through a manual process.
- Reduced bridge and pavement damage.
- Improved management to increase overall longevity of the infrastructure.
- Better tracking of carrier performance.

Table 1. Action Items or Concerns Expressed by NETx Engineers.

Description of Action Item or Concern	Potential Solution	Additional Needs
District route restrictions must be kept current	Better communications from MCD to districts	Review restrictions quarterly
MCD work load is increasing – number and size of permit loads increasing each year	Automated system being developed	Research 0-6404, H. B. 2093 added personnel for MCD
Districts not being notified by carrier as load is moved even though instructed to do so	Enforcement, carrier & MCD meetings	Technology to track permit load via satellite
MCD permit coordinators not always informing districts of permit issue and expiration dates	Establish Groupwise proxy account	TxPROS will allow districts to view routing information
Districts do not always tell MCD about carriers not complying with routes or other permit requirements	Groupwise account and enforcement	Better education of process to districts
Current limitations on pavement analysis	Problem is unclear	Clarify problem
Need for super-heavy corridors across the state from both seal coat and structural standpoint	Research Project 0-6404	Funding, review restrictions quarterly
Better communication from seal coat contractor since work is done on county basis and unpredictable	Better communication from contractor	Penalty for not complying
Districts must discuss with each other routes that are open and where construction planned	Groupwise proxy account	Each district have two N-S corridors w/one always open
Reduce damage to fresh seal coat applications	Avoid for 5 wks following treatment	Restrict if <1 yr old and Temp. >90°F
Need for legislative changes	MCD/DPS enforcement	Charge carrier for damage done, H.B. 2093 passed
Ensure that axle and gross vehicle weights of trucks loaded at ports are within specified limits	Install fixed scales	WIM along designated routes

Source: Reference (4).

Besides growing the Texas economy by encouraging commerce, there are other reasons the number of permit requests are likely to continue the increasing trend. One example in the renewable energy sector is increases in the number of wind farms, where wind turbines are being installed for generation of energy. The US wind industry grew by 45 percent in 2007, and over half of that growth was in Texas. Texas is the leading wind state in the United States, accounting for close to one-third of the nation's total installed wind capacity, which is the equivalent of the electricity needed to power more than one million Texas homes. In Texas, the Horse Hollow Wind Energy Center remains the largest wind farm in the world with a total capacity of 735 megawatts (MW) and spread across approximately 47,000 acres in Taylor and Nolan Counties near Abilene. The wind plant consists of 291 1.5 MW wind turbines from General Electric and 130 2.3 MW wind turbines from Siemens. Each of these wind turbines requires several OS/OW permits for movement of components to these destinations. Other TxDOT research projects planned for FY 2010 will investigate the effects on the transportation system of several renewable energy sources (*6*). This trend was happening elsewhere as well (*7*).

THE USE OF TECHNOLOGY TO ACCOMMODATE OS/OW LOADS

State departments of transportation are charged with regulating the movement of oversize and overweight commercial motor vehicles (CMVs) on the state highway system, to ensure the safety of the traveling public, and to preserve the transportation infrastructure though appropriate routing and mitigation measures. This responsibility is accomplished through the issuance of permits—on a single-trip, multiple-trip, consecutive month, or annual basis—for vehicles and loads whose size or gross weight exceeds the limits allowed by law and that cannot be reasonably dismantled.

Transportation agencies in the US are challenged to effectively and efficiently permit, route, and monitor OS/OW CMVs. The review, approval, and issuance process for OS/OW vehicle permits is labor-intensive, time-consuming, and prone to human error. The increasing demand for OS/OW permits and the incidence of unintentional reroutes due to roadway maintenance or other activities along primary routes suggest a need for new tools and techniques to adequately accommodate OS/OW loads in Texas. Adequate management of OS/OW permit loads throughout the state is critical to maintaining a vibrant economy.

The use of various technologies and associated technology-based policies and procedures has proven successful—both domestically and internationally—in enhancing the efficiency and effectiveness of OS/OW permitting, routing, and monitoring operations and in keeping pace with industry demand and expected levels of service.

This literature and state-of-the-practice review considers potential technology applications to enhance:

- Permit issuance and routing.
- Bridge safety assessments to support routing decisions.
- En route surveillance and coordination.

The following sections provide a general description of each, including selected domestic and international example applications.

Enhanced Permit Issuance and Routing

The I-95 Corridor Coalition, in partnership with the Federal Highway Administration (FHWA), recently conducted an investigation involving 20 permit agencies along the north-south I-95 corridor to identify best practices and lessons learned related to the OS/OW permitting process automation (*8*). The participating permitting agencies represented a myriad of organizational sizes, operating budgets, geographic and legislative influences, permit volumes and revenue generation, permit types and complexity, and sophistication of permitting processes and systems.

The observed level of automation ranged from the use of telephones, fax machines, scanners stand-alone databases, e-mail services, and the Internet to fully automated systems that perform both permit issuance and routing functions. The progression of automation across agencies was observed to be non-linear. Further, not all automation solutions were deemed applicable to each agency. Two factors influencing the observed levels of automation included: state regulations and agency priorities that conflict with automation methods and manual processes requiring re-engineering prior to automation.

Despite these challenges, participating permit agencies (8):

- Expressed no regrets regarding decisions to automate at any level.
- Recommended incremental development steps between fully manual and fully automated processes.
- Noted the importance of process analysis/re-engineering in conjunction with automation to achieve improved performance.
- Recognized favorable cost/benefit ratios associated with automation and improved investment decision making.

While the I-95 Corridor Coalition considered a broad range of automation levels, this literature and state-of-the-practice review limits consideration to fully automated systems leading to enhanced permit issuance and routing. Technology that automates both permit issuance and routing functions is currently commercially available and in use in several states in the United States.

Advanced routing and permitting systems (ARPS) generally enable CMVs to apply online for permits, pay for permits using secure Internet connections, and receive approved routes (based on road system constraints and the intended vehicle/load characteristics) by fax or email 24 hours a day, seven days a week. In addition, the issuing agency can automatically check permit applications against the carrier's account balances, insurance coverage, permitting violations, registration, and other background information. These automated systems use road, bridge, and map data to support determination of safe, consistent routes of travel appropriate for the specific vehicle dimensions and load. They also consider temporary restrictions that may be imposed because of construction, maintenance, weather, or related conditions. En route, the driver can access the permit via the Internet and view any changes or updates. Advanced permitting and routing systems reportedly offer significant efficiency, productivity, and cost-effectiveness gains in the permitting and routing process while improving service to the motor carrier industry.

In pursuit of these operational and service improvements, several US states have investigated and/or implemented ARPS. These states include but are not limited to:

- California.
- Colorado.
- Georgia.
- Indiana.
- Louisiana.
- Maryland.
- Michigan.
- Minnesota.
- Missouri.
- New York.
- North Carolina.
- Oklahoma.
- Rhode Island.
- South Carolina.
- South Dakota.
- Tennessee.
- Texas.
- Virginia.
- Wisconsin.

Certain Canadian provinces and European countries are also utilizing advanced routing and permitting systems. The following sections describe selected domestic and international example applications of ARPS.

Example Technology Applications

California. Between January 1996 and April 2000, 31 bridge hit crashes occurred in California as a result of overheight loads striking bridges with insufficient vertical clearance. Erroneous permits issued by the California Department of Transportation (Caltrans) Transportation Permit Branch were the suspected cause of these crashes. One of these crashes resulted in a fatality, raising public awareness and concerns about the effectiveness of Caltrans' permit procedures (*9*).

Caltrans personnel were also struggling to keep pace with demand for permits from industry. The Transportation Permit Branch processes approximately 180,000 permits annually. The permit branch reported delays for permit issuance of up to 24 hours.

In response to these concerns, Caltrans commissioned a contractor to develop the Single-Trip Application and Routing System (STARS), under the Transportation Permits Management

System (TPMS) information technology project, intended to automate the permit issuance process (*9*). As envisioned, STARS customers would submit a single-trip application with pre-cleared routes via the Internet to Caltrans for review and approval. Caltrans permit writers could accept or deny applications with a single mouse click, and immediately return the processed application. The STARS program would significantly improve turnaround time for industry and streamline Caltrans' application processing. The $7.56-million system was scheduled to go into operation by April, 2005 but to date has not been fully implemented (*10*, *11*). In 2007, Caltrans concluded the TPMS project, but did not implement the contractor's developed product, citing the system's perceived inadequacy to resolve the safety, business, and operational concerns intended from the project (*12*).

A feasibility study is currently under way to determine how Caltrans will move forward in implementing an automated system. As part of this study, Caltrans completed a market survey considering both states and vendors. The results of this market survey showed that automated permitting is achievable, but that existing commercial off-the-shelf solutions require high levels of modification. A custom software development approach is the preferred alternative based on the data from the states and vendors and validation of Caltrans' permitting needs (*12*).

Colorado. To keep pace with the more than 100,000 permit requests Colorado receives each year, the Colorado Department of Transportation (CDOT) developed an automated system for issuing single trip and annual permits. Beginning in 2003, CDOT has used the ARPS to:

- Document pertinent vehicle ownership and load information for a proposed transport.
- Check height, length, and weight restrictions (up to 200,000 lb).
- Determine an appropriate route.
- Identify special needs such as pilot cars.
- Issue a permit to the carrier electronically.

Geographic information systems (GIS) are used to monitor the current status of the state's highway network. The ARPS can identify appropriate routes automatically or can verify a particular route requested by an applicant. Applicants also have the option of selecting a "common route" or using a point-and-click feature to select a desired route on a map. The system logs all requests and creates an electronic database of applicants, which saves time and eliminates errors for future requests from the same company.

Permit requests for loads over 200,000 pounds are currently sent to and reviewed by engineers in CDOT's Bridge Branch Rating Unit. Planned enhancements to the ARPS include tools to aid in evaluation of loads greater than 200,000 pounds with the intent of reducing processing time for super loads (which can take five days or more) and improving bridge engineers' workload (*13*). These system enhancements are dependent upon full implementation of and integration with Virtis—the American Association of State Highway and Transportation Officials' (AASHTO) tool for rating bridge superstructures in accordance with the AASHTO Standard Specification—

tool for rating bridge superstructures in accordance with the AASHTO Standard Specification—and compliance with permitting standards established by the Western Association of State Highway and Transportation Officials (WASHTO) in its *Western Regional Agreement for the Issuance of Permits for Overweight and/or Oversize Vehicles and/or Loads Involved in Interstate Travel* (*13*).

Georgia. Using a similar system as that deployed in Colorado, the Georgia Department of Transportation (GDOT) recently developed an ARPS to streamline the issuance and administration of OS/OW vehicle permits for the state. The system was developed in phases with a progressive focus on data sharing, self-issuance of permits, and automated routing.

The ARPS shares permitting information with the Georgia Department of Revenue (DOR) and Department of Public Safety/Motor Carrier Compliance Division (DPS/MCCD). The system is integrated with DPS/MCCD's Oversized Truck Information System (OTIS) to enable permitting professionals to check for liability and citation information, and to collect delinquent revenue at the point of permit request. With complete data capture, the GDOT Permitting Office not only helps Georgia DOR and DPS/MCCD recover delinquent revenue, but also delivers up-to-the-minute accounting information to its customers. For example, the Permitting Office can quickly provide carriers that use third-party permit brokers with a complete list of carrier account charges. As a result of the deployment, Georgia reports extensive improvements in its ability to capture and share OS/OW information (*14*).

The next phase of ARPS implementation at GDOT included capabilities to allow some companies and load types to self-issue certain types of permits over the Internet. The ARPS allows the GDOT Permitting Office to maintain its standing goal to issue permits within a two-hour time frame 99 percent of the time. On average, GDOT's Permitting Office issues approximately 800 permits per day (*14*).

The third and final phase of implementation added automated routing capabilities to the ARPS. Using Traffic Interruption Reporting from the Georgia NaviGAtor System—GDOT's intelligent transportation system developed initially to ease traffic congestion during the 1996 Summer Olympic Games in Atlanta—appropriate routes are selected based on not only state and local laws, regulations, policies, and procedures, but also on current and dynamic road conditions including lane closures attributable to maintenance and construction activities. The ARPS also interoperates with Georgia's Bridge Information Management Systems to assess whether an OS/OW load can be adequately supported by a particular bridge structure (*14*).

Louisiana. The Louisiana Department of Transportation and Development (DOTD) Permit Office recently developed the Permits Electronic Routing and Bridge Analysis (PERBA) system to support OS/OW permit approval and issuance. The PERBA system relies upon a generally defined envelope vehicle of a defined maximum height, width, length, and gross vehicle weight and various pre-approved routes determined to adequately support these vehicles and loads.

Several of the noted shortcomings in the PERBA system since its development have either been or are being addressed. For example, some industry members were initially applying for inappropriate "oversize only" permits to support transport of OS/OW loads at a significantly reduced fee. The PERBA system has since been modified to distinguish oversize-only permits from other permit types. Personnel from the Louisiana DOTD Permit Office also indicated that the forthcoming ability of the PERBA system to process credit card transactions will further enhance efficiency and improve service to the industry. Currently, permit purchases by industry members using the PERBA system are charged against surety bonds covering each company's monthly bill. It should also be noted that although the system's name suggests a bridge analysis component, no *active* review of specific bridge structure safety takes place as part of the PERBA permit issuance process.

The development and use of the PERBA system is reported to substantially enhance DOTD Permit Office efficiency; supporting the processing of an estimated 40 percent of permit requests (*15*).

New York. The New York State Thruway Authority (NYSTA) issues approximately 80,000 permits for travel on the thruway system (8). To keep pace with this volume of permit requests, the NYSTA permit process is heavily automated, utilizing the Thruway Over-dimensional Permitting System (TOPS).

The system has been in operation for over seven years and is available to users on a near-24/7 basis, with only one-half hour per week reserved for system maintenance. A web-based application allows carriers to apply for and receive most permits online. All OS/OW and explosive permit applications may be submitted online and permits not requiring engineering or management review—which represent a sizable proportion of the total permits issued—are able to be issued automatically. The TOPS supports trip permits, but not annual permits.

Leveraging existing infrastructure and systems associated with the region's toll road network, electronic payments are accepted online via credit card or as a debit from an EZPass electronic toll collection system account.

NYSTA states that the most successful aspect of the automated system has been time savings for both internal staff and external customers. The primary motivation on the part of the agency for automating the system was improving turnaround time and overall efficiency in the permitting process. Before TOPS, "good" turnaround times were considered four to six hours, unacceptable to the agency from a customer service perspective, as well as in terms of addressing projected permit issuance volume. Since implementing the automated system, completion time of processing applications has decreased exponentially, although the average completion times vary by application complexity:

- Routine applications including those requiring limited bridge analysis requires less than three minutes, depending on the customer's typing proficiency.
- A non-superload application requiring manual review is generally returned in less than one business hour.
- A superload requiring manual review is generally returned in two to three business hours (8).

Since automation was implemented seven years ago, the NYSTA reported reducing its permitting staff by three positions through attrition (8). Two staff members currently process the portions of permit applications requiring manual intervention and manage the active set of temporary route restrictions.

Oklahoma. Modeled in part after the TOPS utilized by the New York State Thruway Authority, the Oklahoma Department of Transportation (DOT) and Department of Public Safety recently commissioned contractors to develop an ARPS intended to streamline the permit submission, review and issuance processes for the state and industry, improve the safety of OS/OW vehicle movements, and help preserve the state transportation infrastructure.

The system, which began development late in 2009, is intended to support the conduct of online permitting for oversize/overweight vehicles, automatically generate safe travel routes, share temporary changes in road conditions in real time, and log routes for simple tracking and improved infrastructure management through an easy-to-use, web-based application. Specific functions include:

- Online Permitting—Carriers operating oversize/overweight vehicles can access an online permitting application to create an account, request, pay for, and receive a permit to operate. A dashboard view provides quick access to pending permit requests (*16*).
- Online Automated Routing—Carriers can use an online routing application complete with mapping operations to request a route for travel. The application uses roadway and bridge data for comparison against the vehicle to ensure safe passage. Once a route is identified, the routing application provides a map and detailed driving directions for the permit document (*16*).
- Restriction Management—The application provides authorized staff with the ability to enter in real-time route notifications and temporary restrictions such as accidents and lane closures that reduce a road's capacity for handling oversize/overweight vehicles (*16*).
- Route Logging—The system logs the approved route for each permit, enabling staff to quickly recall all permits affected by a temporary restriction or route closure and notify the carriers. The route logging also enables DOT staff to track the volume and types of loads being moved across the state for infrastructure management purposes (*16*).

A series of related historic developments in their GIS and linear referencing systems (LRS), as well as their intranet and Web portal, will serve to support and enhance the development of Oklahoma DOT's ARPS.

Rhode Island. In 2007, the Rhode Island Department of Transportation (RIDOT) sponsored a study to investigate the potential for and feasibility of an ARPS. At the time of the study, 2.5 full-time equivalent engineers relied mostly on printed maps, bridge tables, basic structural analysis programs, and engineering judgment to determine appropriate routes for OS/OW transports. This existing process is labor-intensive, time-consuming, and prone to human error. The development of an ARPS was determined to offer several benefits including significant time and cost savings and improved customer service to industry.

To confidently establish the feasibility of introducing an automated system required more information regarding the current RIDOT OS/OW permitting process, including the interrelations between different RIDOT sections as well as the state-of-the-practice among other states (*17*). This investigation uncovered no further progress in developing an ARPS in Rhode Island.

South Dakota. Following a similar decision-making process, the South Dakota Department of Transportation (SDDOT) sponsored an initial study to evaluate the feasibility of an ARPS (*18*). The objectives of the project were to:

- Determine the need for automating South Dakota's vehicle permitting operation.
- Define functional and data requirements for automated routing and permitting.
- Evaluate existing software and hardware solutions meeting those requirements.

The study also considered organizational changes and procedures required to support the proposed system.

At the time of this study (in 1997), approximately 10 US states had already or were in the process of implementing ARPS. Building upon other states' experiences and their own internal operational needs, SDDOT identified select desirable features for a newly developed ARPS. In brief, the automated system should:

- Be centrally housed but accessible via the Internet and dial-up modems to other sites.
- Include or account for:
    - Spring thaw restrictions.
    - Construction zones.
    - Maintenance restraints.
    - Bridge and roadway restrictions.
    - Bridge capacity.
- Support "on the fly" bridge rating capacity.

SDDOT was already collecting the majority of data required to support an automated system.

Acting on the 1997 study's final recommendation for ARPS implementation, the SDDOT created the South Dakota Automated Permitting System (e-SDAPS) through a cooperative effort involving the SDDOT Office of Research and the South Dakota Highway Patrol. The e-SDAPS allows the user to:

- Store and recall information.
- Run route analysis.
- Check the status of permit requests.
- Create reports that summarize permit activity.

The e-SDAPS database maintains current route clearance and restriction information, enabling "one click" route analysis on permit applications. Customers can provide payment using the Internet via credit card or escrow account and, once issued, applicants can receive permits via fax or email (*19*).

Recently, SDDOT initiated an e-SDAPS enhancement effort intended to:

- Incorporate additional permit types for e-screening applications.
- Include interchange ramps and connections to local roadways.
- Expand reporting capabilities for e-SDAPS Internet users.

The inclusion of interchange ramps on the interstate and state highway networks followed a comprehensive inventory effort. The results allow redefining of all ramp bridges and network links to include access points with local roadways (*19*).

Tennessee. Between 1991 and 1997, the state of Tennessee experienced average annual increases of almost 9 percent in the number of permits issued. Permits for vehicles exceeding 150,000 pounds in total load grew at a disproportionate 14 percent rate. Despite the increases in both the number of permit requests and the proportions of anticipated loads, staffing resources at the Tennessee Department of Transportation (TDOT) were constrained to existing levels and challenged to keep pace with the demand for permits from industry.

In response to these challenges, TDOT implemented the Tennessee Computerized Permit Issuance System (TCPIS) to automate and speed the permit issuance process. Implemented in 1998, the TCPIS offered only limited automation capabilities, with the processing and issuance of each permit requiring some level of manual staff action—no permits were issued automatically. The system also required industry customers to have copies of TCPIS on their local computers (to enable them to enter applications and retrieve approved permits) and to periodically connect, via telephone line, to TDOT to synchronize the customer's local workstation with the TDOT server.

Despite the automation constraints of TCPIS, TDOT reported sufficient increased productivity supporting adequate regulation of permit vehicles with limited staff resources (*20*). A reduced agency turnaround time for both regular trip and superload permits has been achieved through automation. Additionally, the automated process encourages industry to utilize a defined subset of the state highway network (other routes may be requested, but the turnaround time for permits along these routes may be longer).

Nearly a decade after the initial development of the TCPIS, TDOT recently upgraded this system to offer web-based access. The upgraded system—renamed the Tennessee Oversize/Overweight Permit System (TOOPS)—incorporates a standard routing network, accounts for route restrictions, and supports screening parameters to enable the automatic issuance of permits. Although not formally evaluated, TDOT believes that TOOPS will further improve cycle time, efficiency, and level of customer service in Tennessee (8).

Texas. Over the last two decades, the Texas Department of Transportation has sponsored a series of research activities focused on various aspects of OS/OW activity, with a particular focus on developing an ARPS for the state.

An initial study conducted in 1988 (*21*) investigated TxDOT's permit policy, focusing on the fee structure and safety aspects of OS/OW movement. The study recommended increasing the overall fee for permits, including both weight and distance factors in the fee assessment for single-trip permits (as opposed to a fixed fee) and improving the current escort vehicle policy to include a complete description of the escort vehicle and duties of escort drivers.

Subsequent projects conducted in the 1990s focused on developing software for routing OS/OW permit vehicles. In 1993, researchers at the University of Texas El Paso and Texas Transportation Institute demonstrated initial software applications intended to evaluate a proposed Bridge Formula using a road network model in TxDOT's Houston District. One of the weaknesses identified in this early demonstration was insufficient span length information available in TxDOT's Bridge Inspection and Inventory System (BRINSAP) (*22*).

In a series of follow-on projects conducted in 1997 and 1998, researchers undertook further efforts to implement an automatic procedure for routing OS/OW vehicles in the Houston District. The applied methodology again used a road network model and corresponding software to identify bridges on a vehicle's route and evaluate their adequacy for the specified vehicle. Route optimization procedures were also included (*23*, *24*).

Beginning in 1999, researchers shifted focus to incorporate the use of GIS to support the automatic routing of OS/OW vehicles. Using this methodology, the enhanced system automatically identified all bridges on a specified route using bridge load formulas, evaluated the adequacy of bridge structures to support a specific vehicle, and evaluated vertical and horizontal clearances along the proposed route (*25*). An additional enhancement to the initial GIS-based software came the following year to enable the evaluation of bridges and clearances along superload routes (*26*).

In recognition of significant and ongoing advances in private industry software development, TxDOT (August 2007) commissioned a contractor to develop a web-based software application—the Texas Permit Routing Optimization System (TxPROS)—to automatically generate and evaluate alternate routes for transporting OS/OW loads on Texas roadways. The automated system would take full advantage of TxDOT's existing technical architecture and available roadway data. Estimated completion for TxPROS was December 2009.

The development of TxPROS was anticipated to:

- Substantially reduce the time it takes to process OS/OW permits.
- Allow TxDOT to meet increasing demand for services.
- Improve TxDOT's tracking of structures that affect OS/OW routing.
- Provide the ability to track the transport of OS/OW loads on Texas roadways.
- Increase the safety of the traveling public (*27*).

Wisconsin. In 2002, the Wisconsin Department of Transportation (WisDOT) sponsored research to design and develop an automated OS/OW permit processing system to overcome existing labor-intensive, paper-based processes. The resulting ARPS is capable of seamlessly generating route and escort instructions, trip conditions, restricted bridge notifications, and maps that are appended to the permit information and made available for the motor carrier during the trip.

Reported benefits of the automated system include increased public safety through the accurate identification of optimal routes and reduced turnaround times on permit applications. The system design accommodates multiple data sources, multiple location-referencing methods, and state-to-state interoperability (*28*, *29*).

Manitoba, Canada. The Manitoba Transportation and Government Services (MTGS) recently developed an ARPS to enhance the Permit Services program responsible for the regulation of the Province-wide movement of OS/OW vehicles.

At the time of its development (beginning in 2005), MTGS's Permit Services personnel were anticipating the following benefits from the ARPS:

- Streamlined issuance and administration of permits.
- Provision of even more accurate and current routing information.
- More accessible services to the transport industry.
- Support of on-road motor carrier compliance activities.
- Enhanced road safety.
- Protected investments in infrastructure (*30*).

No additional information came out of this investigation to confirm that these benefits were, in fact, realized following automation.

Switzerland. Motivated by a need to gain industry cooperation for safety measures implemented at tunnel approaches, limit the impacts of temporary closures resulting from incidents or adverse weather, and promote the national policy of shifting goods traffic from road to rail, Swiss transportation officials developed a comprehensive website that provided:

- A description of tunnel traffic management measures.
- Real-time road and rail traffic information.
- Weather forecasts and related road conditions.
- An interactive self-routing function that includes transalpine piggyback rail services as an alternative to roadway transport (*31*).

The four main mountain pass roads and tunnels along the transalpine routes constitute a critical capacity constraint for CMV traffic, especially when weather or incidents force temporary closures. Hence, the web-based information system targets medium- and long-range CMV goods transport through Switzerland. Commercial motor vehicle drivers can self-route based on origin, destination, and route restrictions (*31*).

Enhanced Bridge Safety Assessments to Support Routing Decisions

A number of factors support determination of appropriate routing for OS/OW vehicles such as:

- Vertical clearances.
- Horizontal clearances.
- Bridge structure strength.
- Pavement structure strength.
- Seasonal restrictions.
- Roadway geometry.

While each of these factors is important in determining appropriate routes for OS/OW loads, the ability of bridge structures to adequately support the intended load is often viewed as a critical consideration. As such, Swiss authorities have expended significant recent effort toward improving the bridge safety assessment process. This literature and state-of-the-practice review considers the role of technology in improving bridge safety assessments and subsequent decision making regarding appropriate routes for OS/OW vehicles.

Issuance of an OS/OW permit could require an evaluation of the bridges along the permitted vehicle's intended route. Because longer spans might have to support the full vehicle weight, the bridge's load carrying capacity often becomes the limiting factor in issuing a permit.

For existing bridges, important factors to consider include:

- The condition and extent of damage to the structure.
- The dead (i.e., bridge superstructure) and live (i.e., traffic) loads to which an existing structure is subjected.

- The resistance to loading that an existing structure provides (i.e., load carrying capacity).
- The structure's continued serviceability and potential obsolescence.

The greatest uncertainties exist in determining the live loads to which an existing structure is subjected and the structure's response to those loads. Traditional methods for calculating bridge load carrying capacity tend to be conservative to account for uncertainty levels in the live loads applied to a structure and the structure's response to those loads. In many cases, these methods also neglect potential sources of reserve capacity (i.e., additional strength resulting from the composite action between slab and girders).

Bridge safety assessments use the intended OS/OW permit vehicle as the live load reference, effectively eliminating any uncertainty related to loading. However, uncertainties related to the structure's response to the load still exist. Higher uncertainty in bridge response estimates leads to higher safety factors and more stringent design and/or performance requirements for bridges.

As observed during the 2006 Commercial Motor Vehicle Size and Weight Enforcement Scanning Study (*32*), a cornerstone technology supporting European bridge safety assessments is bridge weigh-in-motion. Bridge WIM systems utilize strain transducers or gauges attached to the bridge soffit or embedded in the bridge deck and on-road axle detectors or Nothing-On-the-Road/Free-of-Axle Detector (NORFAD) systems to provide information on axle and gross weights, axle spacing, speed, and position for CMVs and other vehicles traveling at highway speeds. Bridge WIM systems also provide strain measurements and information to support accurate determination of influence lines, load distributions, and impact factors for additional bridge analysis. Because the measurements are performed while the entire vehicle is passing over the structure, the system is less influenced by dynamic effects than in-road WIM systems. By design, an operating agency can remove and install bridge WIM systems at different sites in less than a day and with little or no disruption to traffic flow.

Improving upon theoretical assumptions about the structural behaviour of a bridge (i.e., moving from theoretical to measured influence lines) can dramatically change the input parameters used in bridge safety assessment models. The result is different conclusions regarding the safety of an existing bridge under the intended vehicle loading.

A dozen countries on four continents deploy bridge WIM systems, including but not limited to:

- Austria.
- Brazil.
- Canada.
- Croatia.
- Finland.
- France.
- Hungary.
- India.

- Slovenia.
- Sweden.
- The Netherlands.
- United States.

More than 60 bridge WIM sites are fully operational in Croatia, France, India, Slovenia, Sweden, and The Netherlands. The US investigated and deployed the first bridge WIM systems nearly 30 years ago—leading up to and following development of an FHWA bridge WIM system. However, the US presently lags behind other countries in deployment of the current generation bridge WIM systems, which possess enhanced functionality and offer superior performance over early bridge WIM systems that FHWA developed.

Descriptions of select domestic and international example applications of bridge WIM systems follow. Although not included in this information, the cost and insufficient software sophistication driving early bridge WIM systems likely contributed to their lack of success.

Example Technology Applications

Alabama. In the US, Alabama was the first state to deploy a current generation commercially available bridge WIM system for testing. The 2006 Commercial Motor Vehicle Size and Weight Enforcement Scanning Study observed this WIM system, which was developed in Slovenia (*32*). A multi-campus team of researchers from the University of Alabama (UA), UA Birmingham, and UA Huntsville evaluated the potential use of B-WIM technology on selected bridges in Alabama.

The research team selected two interstate highway bridges for instrumentation installation, calibration, and in-service testing. The first bridge proved to be a poor test site, posing a series of challenges related to flexibility of the bridge girders, a rough bridge surface, an inoperable solar panel/battery power supply system, and weak cellular signals in the vicinity of the bridge to support wireless communications.

The second bridge was a four-lane highway south of Birmingham. Researchers applied lessons learned from the first installation, resulting in greater success in the calibration and in-service data collection efforts. While the bridge WIM system gathered useable data for many of the CMVs crossing the bridge, it either did not detect a large number of CMVs or had associated unusable measurements. The cause of these errors stemmed from difficulties in identifying a single vehicle when multiple high-speed vehicles crossed the bridge simultaneously.

Conclusions of the Alabama tests indicated a successful demonstration of this current generation commercially available bridge WIM system. The project report (*33*) fully documents:

- Installation.
- Calibration.

- In-service experiences.
- Recommendations for bridge selection criteria for bridge WIM instrumentation.
- Conclusions about the accuracy of the system.

Connecticut. Similarly, researchers at the University of Connecticut investigated the use of an alternative long-term bridge WIM system for use in determining live loads (i.e., gross vehicle weights) and structural response behavior for various steel girder bridge structures throughout the State (*34*, *35*). Researchers cite the advantage of not using any axle detectors in the roadway providing for a long-term monitoring system with minimal maintenance.

The bridge WIM system uses strain gauges attached directly to the steel girders and associated strain data to determine truck weights on various interstate highway bridges. Strain data for determining live load stresses comes from normal truck traffic, load distribution factors, peak strains, and the location of the neutral axis in each girder. The analysis uses known weight trucks along with a finite element analysis for verification of bridge component behavior.

The goal was to use existing, readily available technology for long-term use on selected bridges. Conditions raising concern included corrosion found during routine visual inspections, overloading, or fatigue indicators. The proposed bridge WIM system could be used on a continuous basis to identify significant changes in the structural behavior that could indicate major damage to either the girders or the concrete deck.

France. In France, calibrated influence lines derived from the same bridge WIM systems tested in Alabama were routinely used to calculate the safety of a particular bridge under OS/OW loading using the vehicle's exact axle loading and axle spacing (*36*). France was also testing bridge WIM systems on alternative concrete and steel bridge structures. Previous tests determined that the bridge WIM system could achieve adequate levels of accuracy for a short-span integral concrete bridge and improved accuracy for another short-span integral concrete bridge with better road smoothness. French officials encountered early challenges when installing the bridge WIM systems on orthotropic steel bridge structures. The strain transducers used in the bridge WIM system did not adequately adhere to steel. Instead, installers secured the transducers to metal plates using screws connecting these plates to the steel structure (*32*).

Slovenia. Slovenia has emerged as a leader in the development of bridge WIM system technology. In the early 1990s and into 2000, Slovenia developed an early prototype of a bridge WIM system that provided:

- Increased accuracy.
- Extended applicability to a wide range of bridge types (e.g., short concrete slabs, box culverts, integral construction, and long-span bridges).
- Integration with the concurrently developed NOR/FAD systems (*32*).

Slovenian developers were continually looking for ways to enhance the existing bridge WIM system to support a wider array of functions and enhance performance on various bridge types.

Even then, they were using existing deployments within Slovenia to enhance bridge safety assessments and routing for OS/OW loads (*31*).

Enhanced En Route Surveillance and Coordination

En route, the movement of special transports through constrained roadway environments or the transport of unusual loads may require additional traffic control or assistance from transportation or law enforcement personnel. An unexpected delay of a permitted vehicle can adversely affect agency personnel as well as the motoring public if the movement requires a temporary route or lane closure to accommodate the permitted vehicle. Various vehicle- and/or road-based technologies, allowing for the real-time surveillance of the permitted load, could enhance coordination of these supporting activities. Transportation or law enforcement personnel could mobilize based on an accurate estimation of the vehicle's arrival, improving their operational efficiency.

A variety of surveillance technologies are available to support a broad range of traffic monitoring functions. For commercial motor vehicles, these technologies generally include the following:

- Global Positioning Systems (GPS) to track the speed and location of GPS-equipped vehicles and display their location on a map.
- Vehicle-mounted transponders combined with roadside readers to uniquely identify a vehicle, determine its speed and location along an instrumented roadway, and/or link to additional credential-based information regarding a driver, vehicle, or carrier.
- In-road WIM systems to estimate axle and gross vehicle weight (bridge WIM systems offer similar capabilities).
- Height or size detection systems that commonly rely upon laser technology to detect overheight and/or oversize vehicles based on predefined dimensional thresholds.
- Closed-circuit television (CCTV) cameras that provide still images of a vehicle with particular interest in overall vehicle silhouette and/or unique vehicle identifiers (e.g., license plate number, USDOT number, or container information) that can be converted to numeric data using optical character recognition (OCR) software.
- Wireless (e.g., cellular, satellite) or wired (e.g., fiber optics, T-1 line) communications technologies that support the exchange of data and information between the various technologies in the roadway environment and on-site or remote personnel who must act on the information.

In recent years, both Federal and state DOTs have bundled these technologies (with the exception of GPS) and promoted the system as a Virtual Weigh Station (VWS). The intent of a VWS is to use automated tools at the roadside to monitor CMVs in conjunction or in addition to fixed weigh stations. Virtual weigh stations do not require staffing on-site but communicate data in real time to nearby enforcement sites or to roving officers. The industry uses GPS primarily to monitor the location of its vehicle fleet and improve its overall logistical productivity.

The FHWA recently published a *Concept of Operations for Virtual Weigh Stations* (*37*) that identifies basic and supplemental technologies to support VWS functionality. Basic components include:

- A WIM system for capturing vehicle weight.
- Cameras to provide real-time vehicle images.
- Software that integrates the WIM and camera image data.
- A supporting communications infrastructure that supports remote access of these data.

Supplemental components and capabilities include:

- Augmented WIM systems to enhance the accuracy of weight measurements.
- License plate or USDOT number readers.
- Driver identification systems.
- Remote access to credential and performance databases (i.e., registration and tax payments, OS/OW permits, out-of-service violations, etc.).
- Two-way communications that support access to traveler information, parking information, etc.

Still a relatively new concept, FHWA has supported or is currently supporting a variety of additional initiatives intended to advance deployment of VWSs:

- In partnership with FMCSA, the *Smart Roadside Initiative* (*38*) supports integration of advanced technologies into CMV enforcement, inspection, and transport industry information needs delivered at the roadside with information exchanges integrated into highway facilities and key nodes on the freight system (ports and terminals, international border crossings, toll plazas, weigh stations, and other check points).
- The FHWA recently published the *Truck Size and Weight Enforcement Technologies State of the Practice* and *Implementation Plan* (*39*, *40*), which recommend strategies to encourage the deployment of VWSs (and other roadside enforcement operations) and identifies the necessary support from FHWA. Important information contained in these reports relates to state and Federal funding eligibility for VWSs. VWSs may be eligible for funding through the Federal-Aid Highway Program (FAHP), State Planning and Research (SP&R) Program, Federal Commercial Vehicle Information Systems and Networks (CVISN) Deployment Grant funds, and others.
- A systems architecture for *e-Permitting/Virtual Weigh Stations* is currently under development to identify and document data production, storage, and interrelationships associated with the array of potential automated systems operating at the roadside. Data flows enabling United States Code Title 23 and Title 49 vehicle inspections and measurements coupled with State permit verifications, revenue agency oversight interests, and carrier and driver services will be mapped in a comprehensive roadside architecture model (*37*).
- Existing vehicle identifiers including license plates, vehicle identification numbers, and USDOT numbers challenge the performance of optically based detection technologies (e.g., CCTV, license plate readers, etc.) at highway speeds. The FHWA-sponsored *Universal Truck Identification Project*, currently under way, will consider an expanded set of vehicle identification technologies (i.e., 900 MHz transponders, passive

transponders, 5.9 GHz radios, cellular, and satellite technologies) in an effort to improve vehicle identification performance. Project outcomes will identify which technologies offer the greatest potential over a three- to five-year time horizon to accurately identify all CMVs at the roadside. The benefits/costs associated with mandating a technology will also be evaluated (*37*).

Virtual weigh stations have also been identified as a focus technology by the American Association of State Highway and Transportation Official's (AASHTO) Technology Implementation Group (TIG). Lead states in this effort include North Dakota, California, Florida, Indiana, and Nevada (*41*).

As deployment of VWSs proliferates, extended uses of the associated technologies may be realized. For example, one study recently considered opportunities to utilize VWSs along toll facilities to facilitate a fee structure that incorporates weight into the determination of an appropriate toll amount (*42*).

Interest in deploying VWSs appears to be increasing. During Fiscal Years 2006 to 2008, 14 states applied for and received Federal CVISN Deployment Grants to deploy VWSs. Several other states are currently operating VWSs or planning to deploy VWSs using non-CVISN funds. States currently known to be investigating, deploying, or operating VWSs include, but are not limited to:

- Arkansas.
- California.
- Colorado.
- Connecticut.
- Florida.
- Indiana.
- Kentucky.
- Mississippi.
- Minnesota.
- Montana.
- Nevada.
- North Dakota.
- Pennsylvania.
- Washington.
- Wisconsin.

Certain Canadian provinces and European countries are also applying the VWS concept. The following narrative describes select domestic and international example applications of VWSs.

With few exceptions, consideration and/or deployment of VWSs by these jurisdictions were motivated by a desire to improve CMV weight enforcement efforts (e.g., pre-screening vehicles, verifying permits, targeting enforcement resources, etc.) under constrained personnel/resource conditions. The search did not uncover a single example where agencies used the real-time surveillance capabilities provided by VWSs to *facilitate* rather than enforce movement of a permitted load. Despite the current limited motivation for deployment, VWSs nonetheless provide the potential to enhance coordination between industry and transportation/law enforcement agencies en route.

Example Technology Applications

Arkansas. The Arkansas State Highway and Transportation Department (ASHTD) is currently sponsoring a multi-year project to support development of a VWS. Serving as an exception, the project is primarily motivated by a desire to improve current traffic data collection. ASHTD will evaluate system usability, cost, and maintenance along with the accuracy of the WIM system. Additionally, this project will identify strategies to support the Arkansas Highway Patrol in curbing bypass activities of potentially non-compliant CMVs. The project was completed in 2011 (*43*).

California. In response to increasing CMV travel and constrained enforcement resources, Caltrans looked to VWSs to cost-effectively improve enforcement of commercial vehicle regulations. Prior to deploying an initial VWS, Caltrans comprehensively investigated this strategy. In 2005, researchers conducted a preliminary cost-effectiveness evaluation for VWSs in California and later developed this early work into a comprehensive business case for VWSs that provided an in-depth understanding of CMV enforcement challenges in California and possible technology-based solutions, including their cost-effectiveness and associated rate of return (*44*) (*45*).

During that same year, another research team considered potential legal and institutional issues associated with VWS deployment in California (*46*). The study emphasized the need to involve public agency and industry stakeholders early in the deployment process to remediate any institutional issues. Enabling legislation might also be required to specify liability, defense procedures, infraction type, penalty and fine provisions, admissibility of evidence, and confidentiality.

A year later, researchers followed a systems approach to identify potential challenges and solutions associated with VWS deployment and operation (*47*). During the same year, Regan et al. (*48*) conducted a synthesis study to identify the current state-of-the-practice regarding VWS technologies and operating procedures.

Feeling confident in the extent of preliminary investigation, Caltrans deployed a prototype VWS at Cordelia—halfway between Sacramento and San Francisco along eastbound Interstate 80. This site represented a location that was not easily or cost-effectively bypassed by CMVs. The VWS prototype was co-located with a PrePass transponder reader in advance of the Cordelia vehicle inspection station.

The Cordelia VWS included a bending plate WIM scale and cameras (side fire for vehicle silhouettes and license plate readers with associated OCR capabilities). Processing CMVs includes the following steps:

- Matching vehicle images with weight measurements.
- Determining weight compliance.
- Formatting data for transmission and remote viewing.
- Transmitting weight data only to the PrePass system.

The PrePass system integrates vehicle identification information obtained from the vehicle's transponder with the WIM data and sends the results to the Cordelia inspection station. The system then verifies safety and credentials status and subsequently notifies the driver to bypass the inspection station or pull in for inspection (*39*).

Connecticut. Connecticut does not currently operate a VWS, but recommends this strategy following a recent investigation into various weigh station technologies and practices. Findings indicate that "virtual weigh and inspection stations should be used to supplement enforcement and data collection at permanent weigh and inspection stations" (*49*).

Based on observed practices, researchers recommended locating VWSs at the same locations where portable weigh scales are currently being used to ensure that enforcement personnel can safely stop and inspect vehicles, and also stress the need for real-time data in a user-friendly format that readily supports use by enforcement personnel.

Florida. Florida has deployed several VWSs that support a variety of functions, including sites at:

- Punta Gorda.
- The Jacksonville Port Authority (JAXPORT).
- Sneads.

All of Florida's weigh stations and some of the state's agricultural inspection stations also deploy license plate readers to support limited VWS functionality.

Florida initially deployed the VWS at Punta Gorda to evaluate bypassing for the nearby weigh station. This installation installed two WIM systems and four cameras north and south of the weigh station to monitor trucks leaving Interstate 75 using parallel route U. S. Highway 41 then reentering the interstate. The time between the observed exit and entrance to Interstate 75 is a consideration. An elapsed time between observations of at least one hour indicates to enforcement personnel that the driver had a legitimate reason to exit the Interstate (e.g., fuel or food stop) and was not bypassing the weigh station. Another use of the Punta Gorda VWS beyond its original objective of assessing scale bypassing was to support real-time pre-selection of overweight trucks (*39*).

Florida designed the VWS at JAXPORT to display real-time vehicle weights to drivers as they exit the container port, alerting them to the possible need for a permit if they exceed their designated weight limit. Industry was supportive of this deployment, recognizing its intent for compliance through information rather than citations (*39*).

Technology components at JAXPORT VWS include the following:

- WIM systems with quartz piezoelectric sensors.
- A vehicle profiler system that captures vehicle height, width, and length.
- Various imaging cameras including:
  - Low resolution camera for vehicle images.
  - USDOT number camera.
  - Container number camera.
  - Pan, tilt, and zoom camera to remotely view the area.
- Dynamic message sign that displays the vehicle's weight.
- Weather station (*39*).

Accessing the data through a wireless Internet system is available for real-time enforcement screening, but enforcement is not currently using the system for that purpose.

The Sneads VWS (or Remotely Operated Compliance Station [ROCS]) initially served as a test bed to demonstrate technologies and collect and analyze related data. Florida DOT sponsored the ROCS development in partnership with the University of Central Florida. During the first year of operation, the Sneads ROCS captured almost 700,000 operational records that included speed, overall weight, axle weights, and three photographs of each vehicle. These data were valuable for designing roadway systems, planning for infrastructure developments, and enhancing safety and security (*50*).

Although not consistently deployed across each of the 23 sites operated by the Florida Department of Agriculture and Consumer Services (DACS), Florida's agricultural inspection stations support a unique suite of advanced technologies at select sites:

- License plate readers: Readers capture plate numbers and transmit this information to the Florida and National Crime Information Centers to check for stolen equipment, Amber Alerts, warrants, etc.
- Container readers utilizing OCR software: Readers capture container identification numbers and transmits this information to DACS's Tag Recognition System—an alert will be displayed if the container is problematic.
- A vehicle and cargo inspection system (VACIS): This system utilizes gamma ray imaging technology and radiographic images to help inspectors examine closed contents of vehicles, containers, and cargo for hidden compartments containing contraband (*39*).

Select agricultural inspection stations also support participation in "AgPass" or "PrePass Ag" that allows eligible enrolled carriers to bypass the inspection stations in the same way they bypass PrePass-equipped weigh stations (i.e., through the use of a transponder). Florida DOT weigh stations and DACS agricultural inspection stations are closely located along certain interstates, requiring vehicles without transponders (i.e., not participating in PrePass and AgPass) to pull into both stations (*39*).

Indiana. Similar to the VWS deployed at Punta Gorda, Florida, Indiana initially installed VWSs to control bypassing at fixed weigh facilities. Early deployments at three sites included WIM systems with a wireless transmitter and camera that sent real-time data to a mobile enforcement officer. An overweight vehicle alerted an enforcement officer to escort the truck to a location with a portable scale. Green et al. (*51*) documented the observed benefits of these early VWS deployments, describing several cases where VWSs identified significantly overweight vehicles and enforcement personnel subsequently impounded the vehicles.

Indiana continues to operate three VWSs, but has expressed interest in utilizing the entirety of its 50 traffic monitoring WIM sites to support enforcement. The state estimates the cost of retrofitting a single existing WIM site to provide VWS functionality (using existing WIM system components) at approximately $30,000. The state's long-range plan specifies that new WIM installations will:

- Be located along "troublesome" routes.
- Utilize piezoelectric WIM sensors.
- Be designed as VWSs (*39*).

Indiana/Illinois/Wisconsin. A project designed for the unique challenges for the Gary-Chicago-Milwaukee (GCM) corridor, one of the busiest commercial vehicle corridors in the US, involved the deployment of VWSs at three sites: one each in Indiana, Illinois, and Wisconsin. The project called for the development of a central operating system that would monitor and control multiple sites across the three states. Since the three states had limited permanent weight enforcement facilities within the GCM corridor, decision makers saw this initiative as a cost-effective solution with a reasonably short time horizon (*52*).

Kentucky. In response to weigh station bypass concerns and constrained enforcement resources, Kentucky installed a VWS in 2003, utilizing quartz piezo WIM sensors and a digital camera system. Personnel at a nearby weigh station used digital images to manually determine the USDOT number. This initial VWS site no longer operates (*53*).

Kentucky has since deployed VWS technologies such as license plate and USDOT number readers at operational weigh stations as part of ongoing research, testing, and development efforts. Kentucky was concurrently installing additional technologies, including radiation portal monitors and infrared cameras for detection of brake deficiencies, at select sites as part of the state's Integrated Security and Safety Enforcement System (ISSES). At these fully equipped sites and as currently configured, the VWS and ISSES technologies were too close to the scale building to practically support automated screening. This limitation required human monitoring and data entry (i.e., keying in of the license plate and USDOT numbers) (*39*).

As part of the next generation VWSs, Kentucky plans to link license plate and USDOT number readers with the state's CVIEW to support automated screening of potentially non-compliant CMVs (*39*).

Mississippi. Consistent with the approach planned in Indiana, Mississippi is planning to retrofit existing traffic monitoring WIM sites to provide VWS functionality. Mississippi is currently evaluating its existing sites throughout the state for suitability to dually support data collection and fixed enforcement activities. One promising location is a heavily traveled route that does not support a data collection and fixed weigh station facility. The state might deploy an additional pilot VWS at a location where trucks routinely bypass a weigh station (*39*).

Minnesota. Minnesota created the *Virtual Weigh Station Demonstration Project* to advance the weight compliance objectives developed in the *Minnesota Statewide Commercial Vehicle Weight Compliance Strategic Plan.* This effort focuses heavily on enhancements to existing WIM systems to introduce VWS functionality (*54*). Key outcomes from the project included the following:

- WIM Site Maps: Details of the existing WIM sites were collected and mapped to produce handy reference materials for enforcement personnel.
- Equipment Comparisons: Several brands of WIM systems were installed and tested to assess the state-of-the art features and establish a listing of acceptable products for VWS applications (all were found acceptable in terms of accuracy and data produced).
- Weigh in Motion Compliance Assessment Tool (WIMCAT): This data processing tool analyzes raw WIM data and produces useful output related to the:
  - Hour of the week violation rates.
  - Hour of the day violation rates.
  - Excessive Equivalent Single Axle Load (ESAL) results.
  - An excessive load ratio performance measure.
  - Odds of capturing a violator.
  - Other.
- Performance Measures Plan: This plan refines performance measures established in Minnesota Statewide Commercial Vehicle Weight Compliance Strategic Plan to produce working level measures including:
  - Damage estimates (i.e., potential pavement life extensions).
  - Violation rates by day of week and hour of the day.
  - Potential ESAL benefit if all overweight trucks were made legal.
- Communications Plan: The recommended standard mode of communication is a wireless application based upon a cellular air card or wireless high-speed Internet service. Remote areas that did not have wireless service available required development of a decision tree to determine cost-effective alternatives for new sites.

Pennsylvania. Pennsylvania recently let a contract to procure and install 17 VWSs, in addition to the eight VWSs currently operating in the state. The contract also included a three-year maintenance and service agreement for all 25 stations (*55*).

Pennsylvania will deploy VWSs statewide to be used by the Pennsylvania State Police Motor Carrier Enforcement Division to screen for overweight trucks. Multiple users can connect simultaneously through their laptops via a local wireless network using a web-based browser. All systems will include bending plate WIM sensors in a double threshold configuration providing more accurate weight measurements (*55*).

Washington/British Columbia, Canada. Rapid growth in trade and commercial truck traffic across the Washington State-British Columbia border has strained border crossing facilities and enforcement agencies. Public and private stakeholders in Washington State and British Columbia established the International Mobility and Trade Center (IMTC) partnership in 1997 to identify and pursue improvements to cross-border mobility.

As one of several strategies, the IMTC supported development of a *Bi-National Virtual Weigh Station* system. This CVISN-based system will monitor both northbound and southbound trucks operating in the IMTC for safe and legal compliance, allowing eligible carriers to bypass IMTC corridor weigh stations on both sides of the border. The system initially screens drivers, vehicles, and/or shipments via electronic means or through physical inspection, then clears them from further inspections along the corridor, subject to verification using WIM systems and vehicle-based transponder technologies.

Decision makers conducted a benefit-cost analysis based on statistical weigh station usage data and focusing on five weigh stations along the IMTC corridor to quantify the potential benefits and costs associated with the binational VWSs (*56*). The analysis estimated travel time savings for industry associated with bypassing weigh stations to be between $25.6 and $61.7 million over the next 10 years.

The analysis also estimated resource savings and safety benefits for enforcement agencies attributable to the elimination of double weighing of compliant trucks along the IMTC corridor and increased focus on vehicles/carriers considered to be high risk. The safety benefits associated with this operational concept were estimated to be between $21.1 and $50.9 million over the next 10 years (*56*).

Overall, the VWS deployment at the border crossing facilities showed significantly positive benefit-cost ratios ranging from 4.0:1 to 8.5:1, with associated cost savings ranging from approximately $35 to $102 million, depending upon the level/sophistication of technology deployment (*56*).

Wisconsin. Interest in preserving roads and keeping motorists safe motivated the installation of a VWS on Interstate 43 in Wisconsin. In an effort to minimize traffic disruption, WisDOT coordinated installation of the VWS technologies with the resurfacing of Interstate 43 (*57*). WisDOT planned to install three additional VWSs, combined with Bridge Monitoring Systems, on select ramps of the Milwaukee Zoo Interchange. The bridges immediately following these ramps have restricted vehicle weight limitations that are actively enforced (*58*). As a truck passes the VWS, the system will automatically determine whether the truck is weight compliant. This information is accessible remotely by officers using laptops in state patrol cars or by state personnel from a central office computer.

Saskatoon, Saskatchewan. Motivated by a desire to modernize while saving money, Canada is also investigating and deploying VWSs. Unmanned facilities can save not only on labor but also on necessary facility upgrades. Virtual weigh stations are also more cost-effective for controlling seasonal overweight activity.

One of the earliest VWS deployments in Canada occurred within the city limits of Saskatoon, Saskatchewan. Technology components included a WIM system, frontal license plate reader, a side capture camera, and a transponder reader. Since its initial deployment in 2001, the automated system has expanded beyond real-time pre-selection of potentially non-compliant vehicles to include enhanced dispatch and scheduling of enforcement resources and identification of habitually non-compliant carriers. A noted benefit to this VWS deployment is the ability to effectively enforce CMVs within an urban environment that cannot support a traditional fixed weigh facility (*59*).

Slovenia. With a unique focus on OS/OW permit vehicles, ensuring that intended legally permitted OS/OW vehicles are in fact legal poses a challenge in Slovenia. During a special investigation, enforcement officials in Slovenia observed violation rates of more than 50 percent pre-trip and 70 percent en route for permitted OS/OW vehicles. Of the OS/OW vehicles intercepted pre-trip, 47 percent were overweight.

Prompted by the results of these studies, transportation and enforcement officials in Slovenia are now utilizing VWSs to remotely verify and subsequently enforce non-compliant OS/OW movements. Slovenia captures CMV weight and configuration characteristics and unique vehicle identifiers (i.e., vehicle silhouette and license plate image) in the field and compares them in near real time to details contained in the approved permit application. Field measurements that differ substantially from the details in the approved permit application or no permit application on file could alert mobile enforcement units to intercept the vehicle and assess appropriate penalties.

The Netherlands. Enforcement officials in The Netherlands are similarly challenged to control permitted OS/OW vehicles confirming, as part of a special investigation, that 40 percent of OS/OW vehicles were operating without proper credentials. As in Slovenia, The Netherlands is now using VWSs to remotely verify and subsequently enforce non-compliant OS/OW movements.

IMPLICATIONS FOR THIS INVESTIGATION

This literature and state-of-the-practice review has demonstrated the successful use of various technologies and associated technology-based policies and procedures for enhancing the efficiency and effectiveness of OS/OW permitting, routing, and monitoring operations and in keeping pace with industry demand and expected levels of service. In particular, technology applications have demonstrated the potential to enhance permit issuance and routing, bridge safety assessments to support routing decisions, and en route surveillance and coordination.

This review has also demonstrated support for technology deployments at both state and Federal levels in the form of standardized deployment guidance and monetary funds. As a result, technology deployments capable of supporting OS/OW permitting, routing, and monitoring are proliferating.

CHAPTER 3: STAKEHOLDER INPUT

INTRODUCTION

The stakeholder input task will ultimately lead to development of a set of oversize/overweight dimension and weight groups (Task 4) and origin-destination routing needs. The task involved the following three subtasks:

- Subtask 2a—Analyze MCD permitting data.
- Subtask 2b—Solicit stakeholder estimates of future likely loads and ODs.
- Subtask 2c—Gather information from other stakeholders.

ANALYZE MCD HISTORICAL PERMITTING DATA

The MCD provided the research team a six-year database of historical data on permit loads (2004 through 2009). Making this database fully usable required significant data cleaning by the research team to ensure the full utility of the data for this and subsequent tasks. Load routings in the database were those that were assigned specific routes, representing about 65 percent of all permit loads. Information pertaining to permit loads not assigned to routes had to come from other sources through an interview process. Examples of loads that required permits but were not assigned routes included 2060 permits, hubometer permits, and oversize permits issued for 30, 60, or 90 days. The result of this analysis formed the beginnings of the OS/OW origin-destination corridors for routing vehicles up to selected thresholds of height, width, length, and weight.

The underlying assumption behind investigating historical permit data was that future loads would have similar origins and destinations and size/weight patterns. To complement this historical data, researchers solicited stakeholder input to help in terms of future trends that might not necessarily follow historical trends.

It was apparent from the outset that utilizing the MCD database would require substantial cleaning to remove superfluous characters and, in some cases, replace them with useful characters. Besides the unnecessary characters, there were records with multiple lines and some with blank record fields. Table 2 summarizes the extent of these problems for the fiscal year (FY) 2009 (the most recent) dataset. The problem with multiline records was that the computer program that would be developed to read the route information would be interrupted at the line breaks. The same was true of blank record fields.

Table 2. Central Permitting System (CPS) Permit Data Summary for FY 2009.

Number of Records	529,899
Number of Multiline Records	317,114
Number of Blank Record Fields	96,135

Table 3 summarizes the most prevalent anomalous characters in the FY 2009 dataset. The reason these characters were used to begin with was not usually apparent, so the cleaning process began with removal of these characters and, in some cases, replacement of them with useful known characters.

Table 3. Incidence of Anomalous Characters in FY 2009 CPS Dataset.

Character	Count	Character	Count	Character	Count
SPACE	9,007,245	'	42,491	TAB	632
,	3,464,335	\	30,093	>	614
.	2,812,381	[	26,486	$	390
Carriage Return	1,168,926	(	21,775	<	304
LF (new line)	1,166,586	]	21,516	+	222
/	873,528	)	20,869	?	68
:	482,342	"	14,151	%	22
*	206,711	;	11,258	_	13
-	197,465	=	9404	`	13
@	106,682	{	3027	^	10
#	54,968	}	2897	~	9
&	53,210	!	1138	|	5

Table 4 shows route description details for two permits—one from Big Spring to Houston and one from the Louisiana state line to Killeen. The first of these routes has a note pertaining to Bexar County below the route description, but it appears to be incomplete. The second permit also has a note below the route description field with an incomplete word, “Certifica.” Such comments required special treatment since a computer program might confuse the comments as part of the route description. For both permits, the route descriptions begin and end with “….”

Table 4. Examples of Raw Data before Processing.

Permit Number	Route Start	Route End	Route Description
080903011543	Big Spring	Houston	…JCT FM33/US87s, SH163s, US190e, US277s, IH10e, N.LP1604w, LA CANTERA (WEST OF IH10) CROSSUNDER, N.LP1604e/s, IH10e, W.IH610n/e/s, JCT CLINTON DR… **BEXAR COUNTY/8PM TO 6AM: CAUTION MUST BE USED ON ALL STATE MAINTAINED HIGHWAYS WHEN TRAVELING ON OR
080904015295	LA Line	Killeen	…IH20w, W.LP281n, SH31sw, IH20w, US69s, N.LP323w/s, W.SH31w, E.LP7n/w/s, W.SH31sw, US84w, N.LP340w, N.IH35s, DETOUR LOW STRUCTURE @ FM935 IH TROY, IH35s, N.LP363w/s, FM2305w, SH317s, US190w, FM3470sw, SH201n, JCT US190… WT DOC ON FILE Certifica

Upon determining which characters were already being used, computer programmers determined the best characters to replace the ones that were no longer needed. It became clear that route descriptions needed characters to consistently indicate the beginning and end of a description or landmark. There were many instances of questionable information, so programmers chose characters to note the beginning and end of such information. Directional information was also crucial to being able to plot a route, so they chose the underscore character to precede each cardinal direction. Finally, there were characters that simply needed to be removed and replaced with a known character.

Table 5 shows examples of changes in the "before" and "after" route descriptions, to include route segments that use frontage roads (e.g., IH0010_NFR_w). In summary, the key route description cleaning logic was as follows:

- Use "[" and "]" to mark the beginning and end of landmark or description.
- Use "?" and "$" to mark the beginning and end of questionable information.
- Use "_" for direction information.
- Replace all "┐" with space.

Table 5. Example of Route Before and After Processing.

Before Processing	After Processing
...JCT IH0010/E.IH0610s/w/n, IH0010w, COLUMBUS: BS0071 EXIT TO IH0010.NFRw, 1ST ONRAMP WEST OF BS71:IH0010w, WAELDER:SH0304 EXIT TO IH0010.NFRw, 1ST ONRAMP WEST OF SH304: IH0010w, E.LP1604n/w, IH0010w...	[JCT IH0010/E.IH0610s/w/n] E.IH0610_s_w_n, IH0010_w, [COLUMBUS: BS0071 EXIT TO] IH0010_NFR_w, [1ST ONRAMP WEST OF BS71:]IH0010_w, [WAELDER:SH0304 EXIT TO] IH0010_NFR_w, [1ST ONRAMP WEST OF SH304:] IH0010_w, ?E.LP1604_n_w$, IH0010_w

STAKEHOLDER ESTIMATES OF FUTURE LIKELY LOADS AND OD

The Texas Transportation Institute (TTI) developed a list of stakeholders for approval by the Project Monitoring Committee. These stakeholders, which were intended to represent shippers and movers of OS/OW loads, included:

- Specialized Carriers and Riggers Association (SC&RA).
- Texas Association of Structural Movers.
- Texas Motor Transport Association (TMTA).
- The American Transportation Research Institute (ATRI).

Despite repeated calls to two key representatives of ATRI, the effort to gather information was unsuccessful. However, researchers did gather information from the other three associations on this list.

Specialized Carriers and Riggers Association

The Project 0-4664 research supervisor participated in the SC&RA conference held in the Dallas area March 3–5, 2010, by making a presentation during a formal session entitled “Challenges in Over-Dimensional Moves.” One reason for involvement in this session and conference was to learn from stakeholders related to OS/OW movement in Texas (and elsewhere). Other organizations represented in this session were:

- Bennett International.
- Agility Project Logistics.
- TxDOT’s Motor Carrier Division.

The Bennett International representative spoke primarily about challenges faced by motor carriers operating across the US due to the lack of uniformity among states pertaining to size and weight laws. Most of his comments were for non-permit loads, although he also discussed maximum limits of weight and dimensions (permit loads). His company requires about 15 permit persons per region to oversee and maintain the permits for Bennett. He showed a number of multicolored maps of the US with state limits shown by different colors. Some of the categories he covered were statutory load limits (non-permit) for one-, two-, three-, and four-axle groups, and maximum load limits for one-, two-, three-, and four-axle groups for each state. Then he discussed maximum widths, heights, and lengths allowed by each state. He mentioned that some states do not allow OS/OW loads to move on weekends, while others do. Given the current economic situation, he stressed that his drivers have to operate on weekends to make a living.

The Bennett representative also discussed non-uniformity in escort requirements. There might be two out of 10 states that the load has to pass through that do not require escorts for a particular load. The carrier will probably not be reimbursed for the two states that do not require escorts, but hiring multiple escorts for one trip is not practical. It is much better for the carrier to keep the same escort(s) for the entire route. He also commented that the requirement for escorts for over-height loads needs to be reconsidered.

He also mentioned that some states limit or restrict the use of trunnion axles. Some states serve as barrier states by their current restrictions and adjacent state restrictions. The typical trunnion axle configuration uses eight tires in a row instead of the more common four tires (duals on each side of the vehicle).

The Agility Project Logistics representative stated that his firm is a member of the Exporters Competitive Maritime Council (ECMC). In this role, he represents the "high, wide, and heavy" transport community. There has been an ongoing initiative called "high, wide, and heavy" but a more recent initiative (perhaps similar) is the "specialized freight initiative." One answer to some of the challenges to this industry is a nationalized freight network. He just returned from the Middle East, and his experience there refocused his attention on how important safety is to everyone involved in moving large loads. Like the Bennett speaker, he emphasized that having to acquire single state permits continues to be inefficient and should not continue. A better option is region-based or perhaps even national permits. One of the problems that carriers experience is moving a load in one state on a certain route and arriving at a state line to discover that the route in the next state is a different route. He believes there should be OS/OW corridors throughout the US. Such challenges to OS/OW moves cause the US to be less competitive on a global scale.

He mentioned several items to make the US more competitive globally and to improve the efficiency of OS/OW moves. Again, one need is that there should be a single permit that would be legal in multiple or all states. There should be a designated "envelope vehicle" that would meet selected high-wide-heavy requirements and that could operate on a system of known routes across the country. Establishing these minimums would require legislative action. He went on to say that we must restore shipper confidence as much as possible.

The TxDOT Motor Carrier Division representative provided some information on trends in permit requests in Texas. There was a consistent upward trend in permit issuance from 2005 through 2008, but the 2009 requests were down, probably due to the sluggish economy. He talked about trends in total permits, over-height permits alone, over-width permits alone, and overweight permits alone. All the trends were similar—all grew from 2005 through 2008 and declined in 2009. He commented that not only are permit requests increasing but the number of route restrictions is increasing as well. There is a saying that goes, “Request a permit in Texas and see the countryside.” In other words, it is likely that all the restrictions will cause the allowable route to be circuitous and indirect.

The MCD spokesman offered some ideas that the industry could do to help make the movement of permit loads a smoother process. The first thing was to engage the Permit Office sooner. For super-heavy loads in particular, someone must spend considerable time evaluating every bridge and other features along candidate routes to make sure they will be safe and that the infrastructure will be protected. This process might require weeks or months to come up with a good route.

The second thing he suggested was that the industry must police itself. TxDOT often finds damage to signs or poles or traffic signal mast arms where oversize loads have caused damage but nothing was reported. Carriers that cause such damage must be willing to report this damage to TxDOT. He said the carriers that do the damage are probably in the minority, but they need to work to maintain a good image. TxDOT has now changed its design standards for traffic signals to raise them enough to reduce some of the damage that might be done by oversize loads.

The third thing he suggested was for carriers and shippers to work with organizations such as Specialized Carriers and Riggers Association to work in harmony both with industry partners and with state departments of transportation (DOTs). Working in this environment allows everyone to understand both sides of the issues and to work toward similar goals. He mentioned that the MCD is beta testing a new automated routing software called TxPROS. It will be an effective tool to allow certain envelope vehicles to get a permit on a 24/7 basis 365 days a year.

An SC&RA representative followed with some comments that basically summarized what was presented by panelists. On the issue of uniformity, the federal government might have to get involved to achieve a more uniform operating environment. Audience comments and questions at the end of the session indicated that the shipper and motor carrier communities appreciate the efforts of Texas government agencies to improve efficiency and productivity.

Subsequent Input from another Shipper Affiliated with SC&RA

Following the conference, the research team contacted a shipper who was affiliated with SC&RA and movement of large loads. He was working at that time with the shipper Panalpina Inc. (located in the Houston area), but he retired just after the interview in October 2010. He initially suggested an alternate approach to researchers for getting input from motor carriers on favored routes that should remain open year-round. That method would have involved contacting the major shippers of OS/OW loads and asking them to provide their preferred routes for specific origins and destinations and for a particular set of weights and dimensions. While the suggestion had merit, the research team did not believe that the carriers would make the necessary resources available for the idea to be successful. He commented that the Motor Carrier Division might assign different routes for the same load (although there might be legitimate reasons to doing so that are not apparent to the carrier). He stressed that consistency is important in this business (but he did not elaborate).

This representative had spoken with carriers that same day regarding 10 ft wide, 12 ft wide, and 14 ft wide loads. He commented that people are more complacent about these smaller loads than with the super-heavy loads, perhaps because there is not as much planning required for these smaller loads. However, he emphasized that there is still concern for safety of other motorists with all OS/OW loads.

Over the past 10 years or so of his career, he took the opportunity to review not only the execution of transport functions but also the risk factors associated with each. In his business, he looks at barge lines, riggers, airlines, railroads, and, of course, motor carriers. One of the most obvious things he ran across almost from the start of this tracking exercise was the issue of defining risk. For motor carrier operations, he classified operations into the three following general areas:

- Legal loads.
- Anything over legal up to 15 ft wide, 16 ft tall, and under 254,300 lb gross weight.
- Anything over 254,300 lb gross vehicle weight.

His conclusion regarding legal loads was that they involve medium risk. He explained that they are medium because the industry cannot guarantee all risks. Technically, he said, the industry can determine and verify pricing, carrier billing accuracy, supply of sufficient backup data/documents, and so forth. Outside sources can determine safety ratings to determine things like insurance rates, and these ratings give us a good idea about the risk involved.

He went on to say that vehicles that exceed 254,300 lb gross vehicle weight are low risk. These are super-heavy loads, and the routes are heavily scrutinized mile by mile. This process usually investigates comprehensively any challenges that might occur and has a reasonable action plan to mitigate any perceived delays and problems. These loads are usually moving under direct traffic control of private as well as governmental escorts. The loads are so high profile and so expensive that the carrier and shipper cannot afford to overlook anything.

Finally, he maintained that the loads that fall between the first and second categories above are the high-risk loads. These loads seem to be treated as business as usual by everyone. States tend to route these loads on all types of roads and oftentimes allow carriers to tell the states which routes they would like. There are probably safer routes that probably offer greater clearance or have less traffic.

He emphasized that there has to be a clearer picture of the method in which these loads are actually routed, and the states must become more proactive in managing the risk. His comments indicated that he is emphatically against allowing carriers in this middle category to route themselves, stating that the real issue for states is to control traffic flow and the only way that can be done is by controlling the routing. He reaffirmed his beliefs by saying that accidents and claims usually show up on these middle-of-the-road size/weight loads, and usually not on the legal loads and hardly or almost never on the super loads. There must be a better procedure for routing and permitting available to motor carriers for this type of high-risk load.

Texas Association of Structural Movers

A structural moving contractor and a member of the Texas Association of Structural Movers provided the following information. This carrier usually moves structures that are 24 to 28 ft wide. He is required to drive the route he requests from the Motor Carrier Division to make sure there will be minimal problems during the move. This mover could not think of any specific trends in origins or destinations or in the size of structures he has moved over the past several years. He has not experienced any highly unusual situations during recent moves that would indicate that the permitting process needs to be changed.

Beyond acquiring the permit, this mover recommended changes that could improve the efficiency of future moves of large structures. The two issues he noted involved enforcement personnel and the standard positioning of traffic signs along the roadways.

On the enforcement issue, he stated that enforcement personnel should not stop a large load en route and tie up traffic while the officer checks the permit and/or the load. He said officers usually have a citizen's band (CB) radio and can contact the mover via radio to request the permit number without interfering with the load movement. Movers are required to have radio communication front-to-back of the load so the officer can communicate with someone to request the permit number. Once the officer has the permit number from the driver using the CB radio, he can check on the permit to make sure it is valid. Even if there is a discrepancy detected, the mover emphasized that the officer should wait until the load arrives at an off-road location to minimize traffic disruption. He added that enforcement rarely checks the weight of these loads, although they do sometimes stop the truck to check the permit.

On the issue of standard highway signs such as speed limit signs or route markers, movers of oversize loads (specifically over-width loads) often have problems negotiating between signs that are placed directly across the road from each other. This mover stated that even a longitudinal separation of 30 ft would help get the load through. There are also problems with concrete mailboxes in rural areas not mounted on a breakaway support. He acknowledged that

TxDOT tries to keep such roadside obstacles breakaway but is not always successful. He has not experienced problems with traffic signal mast arms as suggested elsewhere in this document.

Texas Motor Transport Association

The director of policy and governmental affairs at the Texas Motor Transport Association in Austin provided the following information. TMTA membership includes carriers who are involved in the movement of oversize/overweight loads. He noted the trend in larger and heavier OS/OW loads (i.e., super-heavy loads) and commented that loads will probably continue along this trend unless the government steps in and somehow limits or discourages the maximum sizes and/or weights that can be shipped on highways. The manufacturers decide how big or how heavy a particular load will be, apparently in the absence of much discussions with the transportation community. Then, the manufacturer ships the load by whatever means is most appropriate at the time.

In a recent situation, apparently an exception to normal practice, the shipper contacted the motor carrier *prior to* manufacturing the load to inquire about shipment. The carrier told the manufacturer that if he could reduce the load width by 2 inches, it would reduce the transportation cost significantly and would not require a permit. Another example that illustrated a lack of understanding on the part of a manufacturer was when the manufacturer began building components for generating wind energy that would require super-heavy permits for shipment. The manufacturer apparently thought the Motor Carrier Division could issue permits immediately, but that was a false assumption.

During the summer of 2010, Mammoet USA moved a 1.8 million lb super-heavy load, a huge generator, 226 mi from the Port of Houston to the small community of Riesel, Texas. This shipment required a very expensive and specially designed truck. The generator was built overseas and moved by ship to the port where it was off-loaded onto the truck. The future will likely see other large loads or even larger loads built overseas and transported to the US. The only limit to the size might be the capacity of the vessel transporting the load to the port. The alternative is to build a generator on site, but in the current economy, that option is unlikely.

Motor carriers do not simply assume that trucks are the best option at the outset. When the initial request goes out to a carrier to move an extremely large load, the carrier will investigate every option and determine which one is the most appropriate. Some carriers might investigate rail as an option, even abandoned but still usable rail lines, to help move the load for at least part of the distance. They might also investigate the feasibility of barge movement as far as possible and then use highways for the remainder.

One of the physical impediments to the movement of the taller loads is the existence of traffic signal mast arms. These mast arms are cantilevered supports that extend out over the roadway to support traffic signal heads and, in some cases, they also support vehicle detection cameras pointed at each intersection approach. The TMTA representative had heard comments from carriers about this impediment more than anything else. Since the mast arms are fairly rigid, the load might have to pass to one side or the other to clear the arm. In other cases where the load is extremely large, mobile cranes might be used to lift the mast arms upward just enough to let the load pass, or field personnel might have to unbolt the mast arm to provide the required clearance. There is a risk of damage to the traffic signal equipment or vehicle detection equipment when this happens.

One remedy might be more widespread use of span wire to support the signal heads instead of the more rigid mast arms. The vertical clearance would be about the same, but the supporting cable would be easier to displace while causing little or no damage in allowing the load to pass. Mast arms are perhaps more aesthetically desirable than cables, but the design should consider all the factors that might restrict load movement, especially along designated truck routes. Also, the requirement for carriers to provide TxDOT a 24- or 48-hour notice prior to modifying a traffic signal for large load passage is often unrealistic, given the demands placed on the carrier by the shipper or others. The carrier might be given short notice to deliver a load on a Monday morning and have no way of notifying TxDOT over the intervening weekend. (An MCD representative later commented that a mechanism exists for carriers to contact them on weekends.)

The motor carrier community is anxious to see the new automated routing program, TxPROS, released into full service. For some reason, the program has experienced multiple delays and is now about a year behind schedule. The carriers believe that TxPROS will make routing more efficient with fewer unanticipated problems en route, so they are obviously anxious for its release.

An issue that motor carriers would like addressed is when multiple loads moving from the same origins and general destinations require a separate route inspection before each permit will be issued. Carriers would prefer to have a few predetermined routes so that the permits of all of the same cargo loads moving to the same general area would not require separate route inspections. One recent example involved the shipment of 6000 loads of poles for wind farms, where the poles were all over the legal length. According to a TMTA spokesman, the Motor Carrier Division required separate route inspections for each load.

INFORMATION FROM OTHER STAKEHOLDERS

The TTI team solicited information from a comprehensive and broad-based list of agencies to gather information and data. TTI conducted phone and/or office interviews with knowledgeable personnel from each of the identified agencies. The "other stakeholders" included:

- Enforcement agencies.
- Escort companies.

- Metropolitan planning organizations.
- TxDOT:
  - Bridge Division.
  - District Permit Coordinators.
  - Maintenance Division.
  - Traffic Operations Division.
  - Transportation Planning and Programming.

Enforcement Agencies

Texas Department of Public Safety Motor Carrier Enforcement

A sergeant in the Austin office of the Texas Department of Public Safety (DPS) office of Motor Carrier Enforcement provided the following information. He spent several years in the Abilene area in truck enforcement, so some of the examples he used come from there. One trend that this sergeant is aware of is that the super-heavy loads are getting bigger. A few years ago, loads of 300,000 to 400,000 lb were spectacular and relatively rare. However, today, the heaviest loads are as much as a million pounds or more. Another Texas trend that is well-known is the growth in wind energy, which adds to the number of permit loads being transported in West Texas. One of the enforcement issues with the very long loads (e.g., turbine blades) is whether the person remotely steering the rear (steerable axles) of these loads is required to have a commercial driver's license (CDL). The sergeant affirmed that the person is required to have a CDL.

During the officer's time in West Texas, there was not much enforcement of OS/OW loads to verify that the weights were the same as claimed on the permit. The problem with checking the weights of the bigger loads (especially super-heavy loads) is that it requires using scales from several roving troopers to be able to accurately weigh the load. Each motor carrier trooper carries four-wheel load scales, so weighing an axle with 12 tires (e.g., trunnion axles) would require portable scales from three troopers. Bringing in several troopers is disruptive to normal schedules and might take a few hours for all the troopers to arrive at the enforcement site and then conduct the weight check.

The second challenge to weighing these OS/OW loads is in getting the portable scales in position to accurately check the weight. The scales that DPS uses today for such weight checks are Haenni wheel load scales that use hydraulics and are better than the scales they replaced, according to this sergeant. However, this process still takes time. The earlier electronic scales used by DPS had a time-out feature that would inconveniently disrupt a weighing operation due to the scale going into a sleep mode. First, it would take DPS troopers a while to get the electronic scales in position for simultaneous weighing of several tires across a given axle. The setup required someone to crawl underneath the loaded truck to position the scales in front of loaded axles, followed by the truck driver carefully moving forward until the axles were directly over the scales. If one or more electronic scales timed out, it required a trooper to manually reset the scale and restart the process. Part of the challenge was due to the (lowboy) trailers being so low to the ground that crawling underneath to position the scales was difficult, even with a smaller person. Finally, the old scales required building a ramp out of wooden timbers to bring each axle directly over the scales.

Given the challenges associated with weighing these large loads, DPS usually relies on visual observation for the weight check. In some cases, troopers also use weigh-in-motion scales but only as an initial estimate of the load since WIM is not sufficiently accurate for direct enforcement by itself. If tire bulge or other visual indicators suggest that the load is illegal, the supervisor might call in the required number of troopers to check the weight. However, it is the supervisor's prerogative, given the constraints already noted. DPS is receiving more requests from TxDOT to check the weights on the heaviest vehicles than it did a few years ago. One example of moving a 450,000 lb propane tank up a significant grade at the Caprock Escarpment in the Texas panhandle required two power units. It drew the attention of TxDOT engineers because the two trucks were severely damaging the pavement due to insufficient traction. The result was the carrier had to transport the tank to be loaded onto a railcar to be delivered to its destination.

When asked whether technology might be helpful in alerting enforcement personnel about the movement of OS/OW loads, the sergeant responded that that would be very helpful. For example, there might be information about the load stored on a transponder that would transmit parameters of the load or information that could be accessed over the Internet.

A lieutenant with the DPS Motor Carrier Enforcement group provided additional information beyond that provided by the sergeant. When asked for input regarding routes that might be better or worse for enforcement purposes, the lieutenant stated that DPS does not store information on routes. However, a citation being issued results in information recorded on the nature of the offense, the number of axles, and whether it is a permit load. He also stated that he would check on information pertaining to the permit being insufficient for the actual conditions or whether it should have had a permit but did not. He was not sure that DPS stores this information, but if it does, he promised to provide one or two months of data. Research personnel did not receive any further information from DPS.

City of Houston

The Houston Police Department (HPD) motorcycle (solo) officers who escort OS/OW loads receive a request indirectly from the carrier who provides the details of the load. The carrier first contacts an independent agency who actually makes contact with HPD. The department is not required to do all OS/OW loads, but some carriers simply prefer to have motorcycle escorts, maybe due to the size of the load or other factors. These HPD escorts are in addition to the escorts who might escort the load using a full-size vehicle from the load's origin to its destination. Due to the demands of escorting these loads, only the more experienced officers are allowed to provide this escort service.

Another officer (a sergeant with the HPD truck enforcement unit) provided additional limited information on loads that had or should have permits. One of the noticeable trends in Houston has been an increase over the past several years of wind energy turbine blades being transported along city streets. The length of these blades makes them particularly problematic, but the sergeant could not name specific intersections that were worse than others. The City of Houston does not currently have a permitting requirement, although this HPD officer stated that it would be desirable and has been considered by the Houston City Council.

Harris County, Texas

Harris County is a member of the Houston-Galveston Area Council (HGAC) metropolitan planning organization for the greater Houston area. The Harris County Sheriff's Office Commercial Vehicle Enforcement Unit is responsible for enforcing state and federal laws pertaining to commercial motor vehicles operating within Harris County. This unit conducts roadside safety inspections and safety seminars for motor carriers and does weight enforcement. Also, pertaining to safety of commercial vehicles, the unit conducts post-crash inspections of commercial motor vehicles to determine pre-crash conditions that may have contributed to the crash.

A spokesman with the Harris County office that issues OS/OW permits provided the following information. Harris County requires permits for trucks exceeding 80,000 lb on five axles operating on Harris County roadways. The county issues very few permits—maybe an average of two to three permits per month. A significant number of these loads originate at the Port of Houston and use county roads for part of their trip. OS/OW loads that also travel on state routes must have a separate permit issued by TxDOT to make them legal on the state portions of the trip. Harris County issues mostly single-trip permits, but they also issue permits for activities like oilfield development to a carrier for some stipulated time, such as 30 days. These latter permit requests have not been as prevalent recently. Harris County requires the carrier to obtain a bond in the amount of $100,000 per mile (county portion of the route). Harris County does not require OS/OW carriers to pay any other fees besides the cost of the bond.

The Harris County Permit Office does not operate with the Harris County Motorcycle Enforcement Unit. The Permit Office is part of the Harris County Engineers Office and is responsible for reviewing and issuing the OS/OW permits and inspecting the routes for any damages caused by the move. The Permit Office might require escorts, but this requirement is based on the conditions of each individual load, to include the size, weight, and/or routes proposed.

In the past, Texas DPS troopers have stopped trucks to check permits. However, the carrier is not required to possess a permit issued by TxDOT unless it uses TxDOT roadways. The county-issued permit is sufficient for county roads. There have been rumors that Harris County might discontinue issuance of permits for these loads on county roads since the TxDOT Motor Carrier Division could probably issue permits for both on-system and off-system roadways. In that case, the carrier would only need one permit.

The Economic Alliance, Houston Port Region investigated and promoted the idea of OS/OW corridors. This alliance is a non-profit group located in the La Porte area that provides professional economic development services on behalf of 16 communities surrounding the 25-mile Houston Ship Channel (*60*). Some of the routes being promoted by this alliance include State Route 146 and State Route 225. The use of these routes by heavy loads would likely involve county roads as well, possibly at the beginning or end of a route, or both. Examples of non-TxDOT roadways are Port Road, Barbour's Cut, and Bay Area Boulevard. The alliance wants to get one or more of the corridors in this area designated as super-heavy haul routes. Many of the loads being transported from the Port of Houston require a staging area nearby to reconfigure the load for the remainder of the trip.

Given the current enlargement of the Panama Canal, the shipment of OS/OW loads from the Houston-area ports will probably increase. The size of these loads is also likely to increase since the capacity of the marine vessels will increase.

Metropolitan Planning Organization (MPO)

The Houston-Galveston Area Council is currently sponsoring a regional goods movement study, which will include permit loads, but the report will not be available until the end of calendar year 2011. The only reason this HGAC study includes permit loads is that Harris County requested it. If roadways within the HGAC area serve a significant number of trucks as well as permit loads, then this study would have a greater emphasis on those routes.

Escort Companies

The information provided in this section comes from the Trailblazer Pilot Car Escort Service, with headquarters in the San Antonio area. The company consists of a husband and wife team, but several contacts in the industry affirmed that they represent a well-respected company and they provide quality service. At the time of the interview, they were en route to a destination in Nevada escorting a load that was 25 ft wide, 15 ft high, 110 ft long, and weighed 160,000 lb. The states they are routed through will only allow them to move at night in some areas, such as Albuquerque, New Mexico. Due to the restrictions imposed on the load, they only traveled 56 mi the day before the interview and 70 mi the day before that. They were escorting a large piece of Caterpillar equipment (a rear off-road dump bed) to a gold mine near Reno, Nevada. For some reason, the MCD had sent this load on a new route to this escort. They started at the international border in Laredo and traveled north (route not specified) to I-40 and then west across New Mexico toward Reno.

At one time, this escort service was allowed to contact a district directly regarding reroutes and would be able to handle the reroute that way. However, today, the carrier has to request a new permit if something changes along the route. Current rules say the load can deviate off route by as much as about 2 mi without having to request a new permit. If a new route is required, the escort (or likely the carrier) has to contact the Motor Carrier Division in Austin again to get a new permit. If he escorts a super-heavy load, he will probably have to deal with the district anyway. If this escort goes into Houston with an oversize load, HPD provides an additional escort to the destination. The escort representative commented that the additional escort is beneficial.

The escort representative said the real challenge in moving the oversize loads is height. On bigger loads, he drives the route first to make sure that the load can clear all the height obstructions. Some of the super-heavy loads he escorts are over 20 ft wide and up to 300 ft long. He has poled loads up to 26 ft high and loads weighing up to 800,000 lb. He generally works with only one individual who does the bridge analysis for the super loads because he trusts the person. He commented that there are some companies that bootleg and are not trustworthy.

This escort service has been lobbying to get a certification law passed to make it a requirement for all escorts to be certified. Mobile home escorts have this requirement already, but mobile homes operate under different rules. Trailblazer Pilot Car does not escort mobile homes. He is pushing for escorts to have the authority to keep a load from moving if it is actually bigger than the permit says it is. Some carriers will get a permit for a smaller load that does not require an escort so they can save money. According to this escort service, enforcement personnel rarely stop oversize loads. He commented that in his 16 years of operating the escort service, enforcement has only stopped two or three oversize/overweight loads. Even then, officers gave the permit a cursory glance and sent the driver on his way.

The escort company wants to bring Texas in line with the surrounding states with respect to requirements for escorts. Some states require escorts for loads that are 12 ft or 12.5 ft wide. Length is also a consideration in the need for one versus two escorts. He has been able to get this item on the agenda for the Texas House of Representatives (for the upcoming session). One load trend he noted was that loads are getting larger and heavier.

This escort service is involved in four big upcoming loads that might take five years to get ready to move. One of them is 22 ft wide and 34 ft tall, but the escort representative did not give further details. He is in favor of developing designated routes for OS/OW loads getting moved across Texas. He said this is a step in the right direction. He emphasized that there should be high routes where loads could be as much as 25 ft tall. On one trip into Canada, he noticed that along some routes there are no overhead lines to restrict the movement of tall loads.

Texas Department of Transportation

Bridge Division

The Bridge Division was responsible for a contract to measure the structural (overhead) clearances by lane across the entire state. A need for Research Project 0-6404 was to request access to a recently acquired database of overhead clearances from the Bridge Division for structures using Light Detection And Ranging (LIDAR). Not only was this dataset more recent, it was also viewed as more accurate than other datasets. In past measurements, there was one measurement per structure for each direction of travel, whereas this most recent project included measurements for each lane. In the final analysis, the LIDAR project did not finish its data collection early enough for use by Research Project 0-6404, but another source of restriction data became available.

District Permit Coordinators

The research team prepared an Internet survey and sent it to TxDOT district permit coordinators. The first step was to get approval of the survey from the Texas A&M University Institutional Review Board (IRB). The requirement to get IRB approval for the use of human subjects in research is a federal requirement. Upon approval by the IRB, the research supervisor sent the approved list of questions to the project director for dissemination to the permit coordinators. Following are results from that survey.

Survey Question #1: Do you have data on routes actually used?

Figure 1 indicates the percentage of responding permit coordinators that did or did not have information on routes actually used. The question addresses the issue of routes assigned by the MCD versus actual routes used. In some cases, reroutes were required, due possibly to unanticipated construction activity. Comments were as follows:

- I know some of the routes they normally take.
- Only information copies of permits issued from MCD.
- I save all the permits sent—sorted into one mail file with super-heavy loads noted.

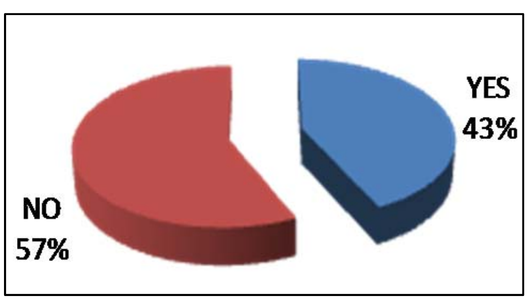


Figure 1. Data on Routes Actually Used by Permit Loads.

Survey Question #2: Do you have origin and destination information that would be available?

Figure 2 indicates that only 14 percent of responders had OD information that could be made available.

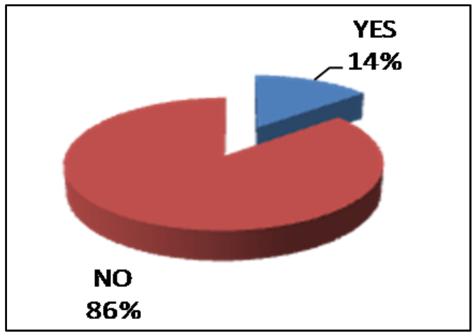
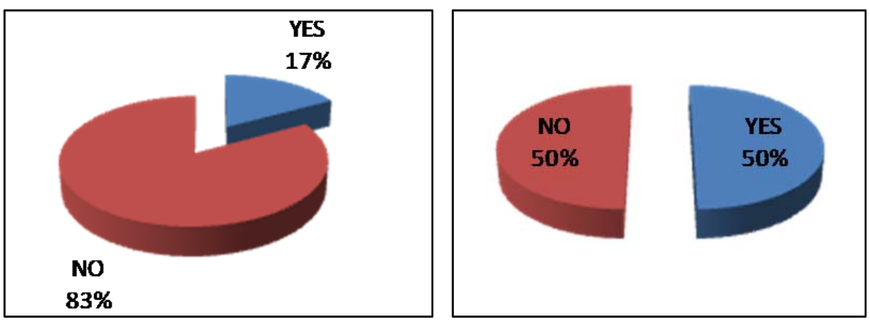


Figure 2. Available Data on Origins and Destinations.

Survey Question #3: Have locations of origins and/or destinations significantly changed within the last 10–15 years?

Figure 3 a) Origins b) Destinations

Figure 3 indicates that 50 percent of responders thought destinations had changed, whereas only 17 percent thought origins had changed.

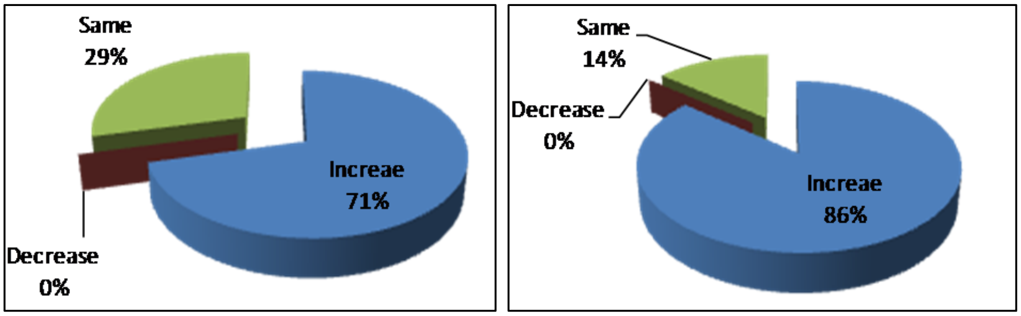


a) Origins b) Destinations

Figure 3. Changes in Origins and Destinations.

Survey Question #4: Is the trend in OS/OW loads increasing or decreasing in size, weight, or frequency?

Figure 4 shows that more than 70 percent of responders indicated that the overall dimension and weight of OS/OW loads had increased. In addition, 86 percent of the permit coordinators suggested that the frequency of OS/OW permit applications had increased.



a) Size and Weight b) Frequency

Figure 4. Changes in Size, Weight, and Frequency.

Survey Question #5: Are there trends in highway freight that you anticipate in the next 5 to 10 years?

Figure 5 shows the results graphically.

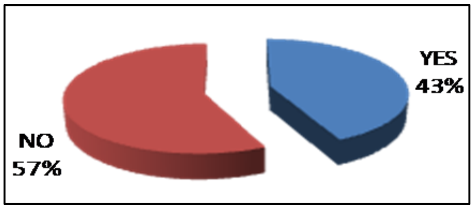


Figure 5. Anticipated Changes in Other Trends.

Supplementing Figure 5 were responses indicating the following other trends:

- More loads that are bigger than in the past.
- Increased number of loads coming from Mexico and shipped to Mexico.
- Based on history in our district, they have steadily increased.
- I believe the loads are only going to increase.

Survey Question #6a: What are the current impediments to movement of these OS/OW loads on trucks in your area?

Responses to this question were as follows:

- Traffic signals and bridges.
- Construction, fixed traffic signal mast arms instead of cables.
- Lower bridges and underpasses, low-hanging lines.
- Structure heights, particularly near downtown Dallas.
- Low structures, one-way frontage roads (contra flow) confined turning radius.
- Low railroad overpass on US 82, load-zoned roads, narrow roadbeds.

Survey Question #6b: Do intermodal facilities need to be made larger or otherwise changed due to the predicted trends?

Figure 6 indicates that only about one-third (29 percent) of responders thought changes were needed.

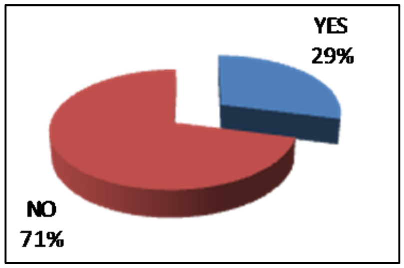


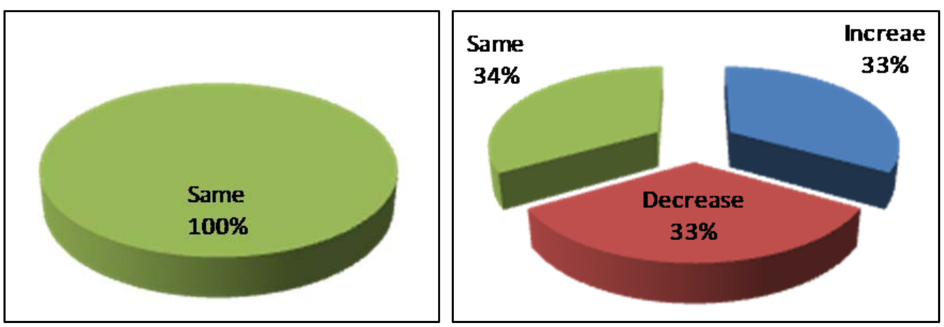
Figure 6. Responses to Need for Changes in Intermodal Facilities.

If responders answered yes, their specific responses were as follows:

- More OS/OW loads could be transported by rail.
- Roads need to be built to higher standard to withstand the weight and turning (radius) of these loads. Roadways need to be made wider.

Survey Question #7: What are the trends in other modes of transport besides trucks regarding these OS/OW loads?

Figure 7 shows the results graphically.



a) Rail b) Marine

Figure 7. Trends in Other Modes.

Specific responses were as follows:

- Rail: Limited in moving OS/OW due to their size restrictions.
- Marine: Ships are bringing in larger cargo more often.

Survey Question #8: Are there other changes in OS/OW loads that you are aware of?

Figure 8 shows the results.

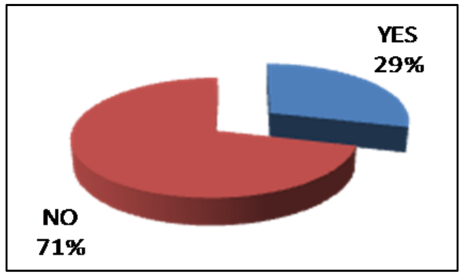


Figure 8. Other Changes in OS/OW Loads.

Specific responses were:

- More companies are hauling them than in the past.
- Carriers seem unaware of the damage, fewer routes available.

TxDOT Maintenance Division

A Maintenance Division representative in the Austin office acknowledged that OS/OW trucks are a significant burden on the TxDOT infrastructure, but he suggested that illegal overweight trucks are also a problem. There are probably more of these overweight trucks than anyone realizes. There are also other types of legally permitted vehicles that the department does not know enough about. They include permits with hubometers that track the number of miles traveled but not the routes. The Maintenance Division receives data on 1547 permits, which involve a cost based on the number of counties the carrier operates in. He indicated that the permit involves three categories for costs:

- Operation in a single county.
- Operation in up to seven counties.
- Operation throughout the entire state.

In the month of November 2009, the revenue generated by trucks with 1547 permits was $330,000. The Maintenance Division spokesman did not know whether the MCD had more details on these permits than what he receives. Examples of the number of permits issued by county were as follows: Harris County—350 permits; Dallas County—360 permits. The Maintenance Division does not get data on the number of axles per vehicle.

Based on his discussions with district maintenance personnel, the districts that are experiencing more challenges due to OS/OW loads are those where oilfield activities and wind farm activities have caused the most movement of their respective loads. The Fort Worth District and districts in southwest Texas are experiencing more windmill activity plus oilfield activity.

A Fort Worth District spokesman provided additional information on the movement of OS/OW loads in that district. He stated that the most noticeable increase in these activities recently has been related to two industries—wind energy production and oilfields. A few super-heavy loads have passed through the district, but they have not caused unexpected damage to the roadways. One of these super-heavy loads moved on a recent seal coat that was only four days old. District maintenance personnel inspected the pavement surface immediately after the load passed. Surprisingly, the passage of the heavy load did not do noticeable damage to the new seal coat. In fact, maintenance personnel believe that the load's passage had a positive effect in helping to seat the aggregate into the surface.

A San Antonio District maintenance spokesman stated that both oilfields and wind energy activities have been on the increase. However, he did not believe that the movement of wind energy components had been a significant problem for pavements. That was not the case for oilfield activities, although he was not sure the oilfield vehicles causing the damage were permit vehicles. Repetitive loads hauled by trucks weighing 70,000 to 80,000 lb are more likely to be the culprits. He said damage has occurred from over-height loads hitting bridges with insufficient clearance for the load height. Bridges with less than 16 ft clearance (some in the 14 ft range) are struck often—perhaps due to drivers getting off their assigned route or simply not paying attention.

On the subject of keeping haul routes open, one way to understand what routes might be available (or, conversely, which ones to avoid) for any one-year time period would be to investigate the One-Year Plan of each district. This plan provides information on routes that are planned for construction for that one-year period. It still would not provide a starting month due to a number of factors that affect construction-letting dates, but it should still be helpful.

TxDOT Traffic Operations Division (TRF)

Traffic Operations Division personnel were aware of traffic signal equipment damage due to the movement of OS/OW loads and the need for district crews to oversee the removal of traffic signal mast arms to allow the passage of these loads. They suggested contacting one of the districts such as the Corpus Christi District to find out its experience. A Corpus Christi District traffic operations spokesman stated that the district's typical procedure when a very large load passes through signalized intersections is to have its signal crew or a contractor who is familiar with TxDOT procedures on site as the load passes. The larger loads sometimes require unbolting mast arms and rotating them away from the roadway. District traffic operations personnel find out about the load being moved if the carrier applies for a permit.

As of January 2011, it had been a while since the district had had to make such modifications due to a large load, and the spokesman did not think it was a significant problem overall. The biggest industry segment that the district has problems with is with "house movers." He stated that some districts use span wire mounts for traffic signals, but that decision is usually more of a cost consideration than due to large loads. The Corpus Christi District does not like span wire due to high winds, even though the newer light-emitting diode (LED) signals have a wider cone of vision than the older incandescent bulbs, reducing the wind effects. One change in TxDOT practice that resulted from large loads was raising the mounting height of mast arms and signal heads. The district spokesman thought that the 2003 version of the *Texas Manual on Uniform Traffic Control Devices* was the one that changed this height.

The Beaumont District has apparently experienced more problems with oversize loads than the Corpus Christi District. The district has experienced significant problems with loads mostly originating in the Houston District and routed through the Beaumont District. There are two routes through the district that are the most prominently used routes for oversize loads—SH 321 and US 90 through Dayton and Liberty. The district had a problem intersection on SH 321 in Cleveland, which was a two-pole diagonal span wire signal, that was often a limitation to the movement of these loads. The motor carriers often request these routes. In fact, a carrier recently requested SH 321 but was denied unless he would pay for modifying the signal at this Cleveland intersection for passage of the load. The carrier was willing to pay for it. The district finally had to rebuild the intersection and install mast arms instead of span wire. With mast arms, the signal heads are oriented horizontally, providing additional clearance. The Beaumont District is tracking these repairs caused by oversize loads better than it did a few years ago, and the problem seems to have gotten worse, although district personnel admitted it might be only because of better tracking.

TxDOT Transportation Planning and Programming Division (TPP)

TPP has an ongoing count, classification, and weighing program for on-system roadways throughout the state of Texas. TPP uses the Federal Highway Administration Scheme F for classifying vehicles in its classification and weight data collection systems. This classification scheme goes up through seven-axle vehicles, but if a permit vehicle is not a standard vehicle according to Scheme F, then the classifier or WIM system could place the vehicle into an unclassified bin. Of course, one could not assume that all vehicles stored as unclassified would be permit vehicles. If a classifier or WIM system missed or double-counted an axle on a truck, it could place the vehicle in the unclassified bin. In conclusion, TPP data would not be helpful in determining the number of permit loads or their trends.

Equipment used by TPP cannot accurately classify many of the current permit vehicles, so many of the heavy loads end up as unclassified by current monitoring systems. Some of the unclassified vehicles likely cause more damage to the TxDOT infrastructure than more typical combination trucks cause. An accurate analysis of the number of vehicles using the TxDOT roadways via the permitting system depends on accurate detection. The Motor Carrier Division only knows the information provided by the permit applicant, and there are likely cases where the information is inaccurate, incomplete, or missing altogether. The challenges involved with enforcing OS/OW loads (see TxDPS section) suggest that there is an urgent need to monitor these loads to determine how big the problem is. This monitoring will require equipment that TxDOT does not currently possess.

Truck Drivers

Research staff discussed moving OS/OW loads with a commercial vehicle operator who worked for Holt Cat in San Antonio. The driver was concerned with some of the routes he was assigned by the Motor Carrier Division. All of the loads he talked about were heavy equipment, so they were both oversize and overweight. Most of the loads were 14 ft wide but not necessarily over the legal height.

This driver's assigned route was not always consistent with how he had been routed before with the same or similar load, nor was it always consistent with the route he would have chosen. He was sometimes routed through construction zones that had restricted width available, though he knew of better routes for the load he was hauling. The driver is anxious for TxPROS to become available because he believes it will reduce the number of suboptimal routes assigned.

CHAPTER 4: TEXAS PERMIT ROUTING OPTIMIZATION SYSTEM

INTRODUCTION

TxDOT has been gradually implementing TxPROS, a permitting system that allows TxDOT and its customers to automatically generate and evaluate alternate routes for OS/OW loads. TxPROS will eventually replace an older information system called the Central Permitting System. This chapter provides necessary background information about the permitting system, given the close relationship between the system and this study.

During this study, researchers conducted several meetings with TxDOT representatives from the MCD to gain an understanding of:

- TxDOT's permit application process.
- MCD's routing process.
- The information systems that manage overweight load permitting process activities.

TXDOT MOTOR CARRIER DIVISION OS/OW PERMIT SECTION

The role of the TxDOT Motor Carrier Division Permit Section is to route OS/OW loads to their destinations following state and federal regulations without undue damage to the TxDOT infrastructure. MCD handles approximately 500,000 permit applications per year for 25 different types of oversize/overweight permits and generates annual revenue of over $100 million. In 2008, the division issued about 580,000 annual and routed permits; however, recently this number has decreased by about 20 percent due to reduced demand. Transportation Code Chapter 623 (*61*) defines permits for oversize or overweight vehicles. Table 6 provides a listing of permit types and descriptions for overweight loads that are issued by MCD (*61, 62, 63, 64*).

Permits for super-heavy loads following section 623.078 (*64*) require that TxDOT provide a specific route for the movement that the permit holder must follow. This type of permit, which is only valid for a single movement, is the most frequently issued permit at MCD and accounts for about 65 to 70 percent of the total permits issued by the office. Figure 9 is a sample single-trip, routed overweight permit for a movement with a gross weight of 92,000 lb. As illustrated by the information entered, the starting city and/or ending city can be vague (e.g., ending city of NM line), and route descriptions can contain multiple comments.

Table 6. Types and Authorization for Overweight Load Permits.

Permit Name	Permit Description	Permit Applicability	Section
Permit for Excess Axle or Gross Weight	Annual permits for loads that cannot be reasonably dismantled (over-axle/over gross weight tolerances permit).	• valid for vehicles registered for a maximum gross weight of 80,000 lb • allows axle weights up to 110% of the allowable axle weight and a gross weight of up to 105% of the allowable gross weight • excludes movements on interstate highways and load-posted bridges when exceeding posted limits unless the bridge is the only public vehicular access to the permit holder's origin or destination • can be issued for one or more counties	Subchapter B (623.011–623.019)
Contract for Crossing Roads	Permit to cross a highway from private property to other private property.	• grain, sand, or another commodity or product transporters with a gross weight up to 110,000 lb • unlicensed vehicles transporting sand, gravel, stones, rock, caliche, or similar commodity	Subchapter C (623.051–623.052)
Permit to Move Certain Heavy Equipment	Single-trip, 30-, 60-, and 90-day permit for overweight (and oversize) loads (general oversize/ overweight permit).	• oilfield drill pipe or drill collars stored in a pipe box using farm-to-market or ranch-to-market roads	Subchapter D (623.071–623.082)
	Single-trip, 30-, 60-, and 90-day permit for the transportation of cylindrically shaped bales of hay.	• cylindrical shaped bales of hay	623.071
	Annual permit for super-heavy equipment (annual envelope permit).	• loads that cannot be reasonably dismantled up to 120,000 lb • up to 12 ft wide, 110 ft long, 14 ft high • may be issued to a truck or a company	623.071
	Annual permit for water-well drilling machinery and implements of husbandry.	• water-well drilling machinery • farm/harvesting equipment • movement of an implement of husbandry by a dealer	623.071
	Single-trip permit for a super-heavy load. Requires analysis and routing by a TxDOT engineer.	• vehicle exceeding 200,000 lb with axle spacing less than 95 ft • vehicle exceeding 254,000 lb regardless of axle spacing	623.078

Table 6. Types and Authorization for Overweight Load Permits (continued).

Permit Name	Permit Description	Permit Applicability	Section
Oil-Well Servicing Units and Drilling Machinery Permit	Single-trip, quarterly, and annual permit for oil-well machinery.	• movement of oil-well servicing and drilling permits	Subchapter G (623.141–623.150)
Unladen Lift Equipment Motor Vehicle Permit	Single-trip, quarterly, and annual permit for the movement of unladen lift equipment motor vehicles (mobile crane permit).	• motor vehicles designed for use as lift equipment	Subchapter I (623.181–623.182) and Subchapter J (623.191–623.200)
Multi-State Permit	Single-trip permit under reciprocal agreement with a state participating in the WASHTO Western Regional Permitting program.	• single axle weight up to 21,500 lb • tandem axle weight up to 43,000 lb • tridem axle weight up to 53,000 lb • gross weight up to 160,000 lb • valid on highways of the regional network only	621.003
Temporary Registration Permit	Single-trip, 72-hour, or 144-hour permit.	• for commercial vehicles and buses owned by residents of the US, Canada, or Mexico • allows the operator of vehicle to temporarily increase the maximum allowable weight for which a vehicle has been registered, up to the state axle and gross weight limits	502.352

TXDOT OS/OW PERMITTING PROCESS

The permitting process at MCD generally includes the following four steps:

- **Application Submission.** To apply for an overweight permit, a customer submits an application either online; by phone, fax, mail; or in person at district offices. Staff at the Permit Applications & TPM Program branch inputs data from the application into a permitting system. Currently, MCD receives about 75 percent of its applications online, with most of the rest submitted through phone, fax, or mail.
- **Application Processing**. After a permit application is entered into the permitting system, a permit specialist extracts loads, origins, and destinations; determines the correct permit type; and identifies a route that does not have restrictions or other barriers. For customer-preferred routes, the permit specialist verifies the preferred route against permanent and temporary restrictions and either approves the route or identifies an alternative route.
- **Permit Delivery.** Upon approval of an application, MCD issues a permit and mails it to the customer.
- **Post-Processing.** When a customer requests an alternate route, MCD reviews the request, and if the movement is feasible on the requested route, MCD may issue a permit amendment or a new permit, as necessary. The Special Services Permits branch handles permit amendments in addition to special permits.

Texas Department of Transportation

Texas Oversize/Overweight Single Trip Permit and/or Temporary Registration

Name: [redacted]
Address: [redacted]
Account: [redacted] Phone: [redacted]
Applicant: [redacted]

Permit Number: [redacted]4825
Issued On : 11/30/2009 Time: 15:49:01
Effective : 11/30/2009
Expiration : 12/04/2009
Permit Officer : Richards, Deborah

Load Description: JOHN DEERE 624J FORKLIFT Gross Weight: 92,000
Max. Width: 10' 0" Max Height: 13' 6" Max. Length: Legal ROH: Legal FOH: Legal

Axle:	1	2	3	4	5
Distances:	19	4	36	4	
Weights:	12,000	20,000	20,000	20,000	20,000
# of Tires:	2	4	4	4	4
Tire Sizes:	11	11	11	11	11

Truck:
2001 / Peterbilt
18443
P589523 / IL

Trailer:

Temporary Registration
Truck Start: End:
Trailer Start: End:

Route Description: Starting City: TOMBALL Ending City: NM LINE

...JCT TIMBERTECH LN/SH249n, X-OVER @ NORTHPOINT BLVD TO SH249s, N.BW8.FRw/s, IH10w, SAN ANTONIO E.LP1604n/w, IH10w...

BEXAR COUNTY/8PM TO 6AM: CAUTION MUST BE USED ON ALL STATE MAINTAINED HIGHWAYS WHEN TRAVELING ON OR INSIDE LP1604 DUE TO NIGHTLY LANE OR HIGHWAY CLOSURES; LOADS MAY BE DIVERTED TO FRONTAGE ROADS OR CITY STREETS.

THIS IS A LOWBOY TRAILER
LOAD #2777042

Special Conditions:

Use caution at all railroad crossings. Railroad crossing hotline: 1-888-877-7267.
Permit is valid for one trip only. Not valid without movement conditions sheet attached.
Escorts: Over 14' wide, or 110' long = one escort. Over 16' wide, or 125' long = two escorts.
Over 17' high = front escort with height pole. Over 18' high = front escort with height pole and rear escort.
If the load is over two dimensions that require escorts, then front and rear escorts are required.
A rear escort is required when the front or rear overhang exceeds 20'. When one escort is required, escort should be in front on a two lane hwy and in rear on a multi-lane highway. Only overweight/overlength loads may travel IH35 inside travel lane in Austin.
Self-propelled oil well servicing units that do not exceed 9' wide, 14' high, or 65' long are allowed night movement.
All loads exceeding 8'6" wide and/or 13'6"high may not travel on the main lanes of IH35 between US183/SH71 in Austin.
El Paso District: Over 17'6" high= front escort with height pole.
Odessa, San Angelo & Abilene Districts: Over 16' wide= one escort. Over 18' wide= front & rear escorts.
Odessa, San Angelo & Abilene Districts: 16' wide & 95' long combination = front & rear escorts. Over 18' high =front escort with height pole.
Lubbock District-Gaines & Dawson Counties only: Over 16' wide= one escort. Over 18' wide= front & rear escorts.
Lubbock District-Gaines & Dawson Counties only: 16' wide & 95' long combination = front & rear escorts. Over 18' high =front escort with height pole.

Amadeo Saenz Jr., P.E., Executive Director
Texas Department of Transportation

Payment Method : PAC
Trace # : 1991632
Wire Co. Name:
Permit Destination: McDonough, GA.
Amendments :

Permit Fee:	$30.00
Registration Fee:	$0.00
Overweight Fee:	$150.00
Other Fee:	$30.00
Total Fee:	$210.00

State law requires permit to be carried in vehicle until one day after expiration.
For more information, call the Texas "One Stop Shop" toll free number at 1-800-299-1700 or visit our website at www.txdot.gov .

Figure 9. Sample Single-Trip Permit.

Identification of appropriate routes, especially for super-heavy loads, is the most challenging activity in the permitting process. The main difficulty of identifying an appropriate route for overweight loads is to ensure that the route complies with current permanent and temporary highway restrictions. These restrictions include geometric restrictions (e.g., height, weight, length, width, and turning radii limitations) and temporal restrictions (e.g., temporary and permanent road closures).

Additionally, OS/OW routing is constrained by numerous local, state, and federal regulations (which often vary), special permits, and exceptions. These regulations can cause additional delay in permit delivery. For example, TxDOT issues permits only for routes on the state highway system. Using county roads for a permitted route requires a special permit from the county. Frequently, MCD has to develop innovative solutions to facilitate the delivery of heavy loads.

TXDOT OS/OW PERMITTING INFORMATION SYSTEMS

At the time of this research, the TxDOT Motor Carrier Division was in transition between two information systems (i.e., CPS and TxPROS) that manage overweight load permitting process activities. MCD anticipates phasing out CPS and replacing it with TxPROS. The following sections describe CPS and TxPROS.

Central Permitting System

The Central Permitting System provides a centralized, automated process for issuing oversize/overweight and over-axle weight tolerance permits. In addition to providing MCD accounting reports related to permit issuance, CPS provides access to permit data for law enforcement through the Department of Public Safety (*65*).

The MCD has used CPS for over a decade and has reworked it with modifications, patches, and enhancements during this time period (*66*). Changes have included the CPS database system, the development language, and the user interface. CPS was stored on an Adaptable Data Base System (ADABAS) using the Natural development language. A read-only copy of CPS resided in Virtual Storage Access Method (VSAM) format. Part of CPS resided on personal computers (PCs), using Clipper DBF, which uploaded data to the mainframe. TxDOT programmers reconfigured the PC portion of CPS in PowerBuilder and used a Sybase database. Alongside CPS, MCD provided the Texas One-Stop-Shop toll-free automated telephone line to assist motor carriers with applications, forms, permits, licensing, registration, regulations, and other items (*67*).

The latest version of CPS (called CPS III) is an Internet-based permit program that allows motor carriers to log into the CPS III system, submit permit information, and receive a permit by e-mail or fax (*68*). CPS III allows motor carriers to apply for the following permits (*69*):

- General oversize/overweight (excluding house moves and super-heavy moves).
- Manufactured homes.
- Portable buildings.
- Well servicing units—mileage.
- Cranes—mileage.
- Concrete beam girders.
- 30/60/90-day width/length.
- Annual cylindrical hay.
- Annual truck-specific envelope.
- Annual implements of husbandry permits.
- Annual utility pole permits.
- Temporary registration.

Since CPS does not provide automated routing capabilities, approximately 80 percent of all OS/OW permits are routed manually using customized paper maps. MCD routing specialists produce these customized paper maps by systematically and meticulously transcribing all restrictions from numerous folders that contain memos and descriptions of highway restrictions in each district to a current set of district highway maps. The resulting district highway maps show roadway attributes such as structure heights, lane widths, roadway curvatures, weight limits, current highway restrictions, and so forth (*66*).

To determine an appropriate route, the MCD routing specialist reviews his/her restriction map set and develops a route by selecting the shortest possible route between requested origin and destination that does not violate a restriction. The restriction map set must be carefully updated every morning when MCD receives updates on current and new restrictions from district officials. TxPROS will replace these manual processes with an automated mapping and routing system, which is described in the following section.

Texas Permit Routing Optimization System

TxPROS is a web-based "integrated GIS-based mapping system with real time restriction management that provides 'true' automated routing for transporting OS/OW permitted loads on Texas maintained roadways" (*70*). The MCD anticipates that full implementation and integration of TxPROS will (*71*):

- Reduce the time required to issue OS/OW permits.
- Allow MCD to meet increasing demand for services.
- Improve safety of the traveling public.
- Improve TxDOT's tracking of structures and restrictions that affect OS/OW routing.
- Allow tracking and reporting the movement of OS/OW loads on Texas roadways.
- Provide the most customer-focused solution for meeting the needs of OS/OW carriers.
- Optimize use of current TxDOT technical architecture and available roadway data.
- Improve management of the transportation infrastructure.

TxPROS Functional Requirements

The TxDOT General Services Division specification for development of TxPROS (*71*) intended that TxPROS accomplish the following:

- Real-time restriction management: "Provide a single, electronic, oversize/overweight mapping source that includes required parameters for OS/OW routing (i.e., vertical clearance, structure height, lane width, load ratings, one-way attributes, access roads, turn restrictions, at-grade railroad crossings, etc.) for use by internal and external customers and allows for web-based updates, due to construction and other restrictions, from designated location(s) in real time and on a daily basis."
- Automated multiple optimal path routing of OS/OW loads: "Provide an automated routing system for OS/OW permits that is web-based; self-service; compatible with TxDOT's base GIS architecture; offers alternative routing solutions based on origin and destination points; evaluates routes based on obstructions, load parameters and other weighted data including Texas traffic laws and rules."
- Interfaces with supporting TxDOT and non-TxDOT information systems: "Be compatible with bridge/construction/pavement data, systems, and processes in TxDOT's Bridge (BRG) and Construction (CST) Divisions for locating and tracking structures and roadway data as well as provide for additional data to be imported from non-TxDOT resources as needed for effective mapping and routing."
- Single source electronic base map for permitting: "Provide a single source for the official permit map to eliminate the numerous changes each permit officer or customer must make to their individual paper maps each day. All permits will be issued using one electronic base map, eliminating the current paper maps (except for manual backup processing capability)."
- Automated web-based permitting: "Enable automatic processing and delivery of qualified Internet permits (based on pre-determined vehicle envelope size) to replace the current process, which requires a permit officer to analyze or develop a route for each single-trip permit application."
- Reporting, tracking, and statistical analysis capabilities: "Provide reporting capabilities for TxDOT divisions and districts to identify routes used to transport OS/OW loads, how often these routes are being used, sizes and weights of permitted vehicles traveling these routes, the effect of permit restrictions on other roadways, types of loads transported over which routes, and other reporting capabilities."
- Scalable system design and service-level screening: "Provide growth ability that will allow MCD to provide quality customer service while experiencing increased permit demand without incurring significant backlog."

Major Features of the TxPROS Application

MCD and its development contractor integrated the functional requirements expressed in the previous section into the TxPROS application. The following sections describe the major features of the TxPROS application.

Mapping

TxPROS includes a GIS-based map viewer that illustrates the best route selected by the system given a set of current restrictions and impedances. Each route includes roadway restrictions and segment information along with any structure (e.g., bridges) that the segment crosses. The map viewer application is proprietary; functions are provided by the vendor, though TxDOT can create, update, or delete attribute values (e.g., retire a road).

The core element of the TxPROS mapping component is a TeleAtlas transportation network conflated with TxDOT roadway inventory data from the Bridge, Construction, and Transportation Planning and Programming Divisions. Segments in this network are link/node-based for routing purposes.

In addition to the modified TeleAtlas network, the map viewer contains other GIS layers, including TxDOT on-system and off-system transportation networks and attributes. The map viewer includes a geocoding component and has map printing capabilities (*72*). In the near future, the map viewer will also show routes assigned for super-heavy loads. This map will allow TxDOT to identify routes that are more heavily impacted by super-heavy loads.

Restriction Management

A core function of TxPROS is the ability to automatically generate and evaluate optimum and alternate routes for transporting OS/OW loads on Texas roadways, given a dynamically changing set of physical and temporal restrictions. TxPROS allows customers to go online and answer questions such as "I want to go from A to B during a specific time period; what route can I take?" The system will also issue a routed permit if desired by the customer.

This core function, to generate and evaluate optimum and alternative routes, requires management of restrictions and a reliable yet adaptable routing algorithm. Restrictions disallow the movement of an OS/OW load over a segment and effectively block the segment for inclusion in the routing determination.

TxPROS manages restrictions by an application called Restriction Manager; it stores the location and data for geometric restrictions, temporal restrictions, maneuvering restrictions, and special instructions (e.g., flagmen needed to traverse a certain bridge). There are over 1500 restrictions in place across the state of Texas at any given time. Restriction Manager is updated in real time with information provided by districts. In rare cases, districts forget to update MCD with new restriction information, such as a temporary restriction. Examples of temporary restrictions include construction, road and bridge maintenance, special events, closures due to traffic incidents, and curfews. As a result, MCD personnel talk quarterly to the district permit coordinators to verify that bridge restrictions are still valid.

Compared to the CPS-based permitting process that heavily involves manual processing of routes, TxPROS has several advantages. For example, TxPROS can apply restrictions automatically to all permits as soon as they are entered into the system. When a new restriction comes into effect, the system can also identify all affected ongoing permits and send out notifications to customers automatically.

In addition to restrictions, TxPROS uses impedances on network segments to limit travel on specific network routes. Selection of a path involves applying a routing metric (i.e., impedance) to a network to select the best route. Impedances help generate the actual or proposed time to traverse a road segment in the routing algorithm. Segment impedances can be length, volume, or speed; these impedances can change depending on day of week (e.g., weekend vs. weekday) and/or time (7:00 a.m. to 9:00 a.m. vs. 11:00 a.m. to 2:00 p.m.). TxPROS uses impedances to identify the optimum route when multiple options are available. An example of a TxPROS impedance is roadway length. TxPROS permitting specialists can manually adjust the length values of certain road sections so that road selections for routes are more balanced over the road network, or to encourage the system to use more preferred routes.

Routing

In addition to management of restrictions, generation of optimum and alternative routes requires a reliable, high-performing yet adaptable routing algorithm to find the shortest path from an origin to a destination. The TxPROS routing algorithm generates a route with input by the user, constrained by the Restriction Manager.

The TxPROS routing algorithm provides a variety of user input options with high performance and error-correcting features. The routing component uses route points to specify origins, destinations, and intermediate points (*72*). Route points can be specified by address, intersection, border crossing, or road and mile marker, or by clicking on the map viewer. Intermediate points can be cities or highways. The routing algorithm also provides options such as allowing off-system roads to be included in the route or splitting a route. The routing algorithm checks the requested route and intermediate points. If there is an error in the request, the algorithm corrects the route and generates a new route with an explanation of why the route changed. The map viewer displays the route along with restrictions so that users can understand the route choice, along with turn-by-turn driving directions. Users can save or further edit the route.

According to a meeting with a representative from MCD, the TxPROS routing algorithm uses a modified dual Dykstra routing algorithm on directed and reverse graphs. For transportation planning and operations, graphs composed of vertices and edges have represented abstractions of transportation networks composed of roads and intersections. The TxPROS directed and reverse graphs each have about 4.3 million edges and 3.4 million vertices.

Dykstra's algorithm (*73*, *74*) is popular for transportation-based shortest-path routing between two locations. The algorithm functions by constructing a shortest-path tree from an initial vertex to every other vertex in the graph. The steps involved in this algorithm are as follows (*75*):

1. Create the following lists with vertex identifiers: an impedance list, a previous vertex list, a visited list, and a current vertex.
2. Set all the values in the impedance list to infinity except the starting vertex, which is set to zero.
3. Set all values in the visited list to false.
4. Set all values in the previous list to a special value signifying that they are undefined, such as null.
5. Set the current vertex as the starting vertex.
6. Mark the current vertex as visited.
7. Update impedance and previous lists based on those vertices that can be immediately reached from the current vertex.
8. Update the current vertex to the unvisited vertex that can be reached by the shortest path from the starting vertex.
9. Repeat (from Step 6) until all vertices are visited.

One of the challenges with using Dykstra's algorithm for statewide OS/OW routing is performance. For each permitted route, the search space of the traditional Dykstra's algorithm would visit a large portion of nodes on the modified TeleAtlas network for the state of Texas. For performance reasons, TxPROS uses a modified version of Dykstra's algorithm that uses dual graphs and partitioning of search spaces. Research has shown that partitioning of search spaces can reduce the time of a single shortest-path search up to a factor of 500 (*20*). For TxPROS, the modified Dykstra's algorithm routing begins from the origin and destination locations simultaneously using partitioned directed and reverse graphs. A solution for a route is where the origin and destination search spaces meet.

Once a route is identified, TxPROS creates a list of road segments comprising the route. TxPROS uses this list to produce a route description, detailed driving directions, a GIS route, and a list of notices for the customer to be aware of, such as curfews or escort requirements.

Based upon information from the MCD, there are several challenges for the TxPROS routing algorithms. These challenges include:

- Increasing performance by pre-processing routes: Pre-processing routes is not possible since the selection of routes is based on vehicle configurations, which often vary.
- Merging origin and destination search spaces for a route: TxPROS has to check overlapping search spaces for restrictions, such as a maneuver restriction. If a restriction exists, TxPROS continues searching for a better solution for a route.
- Routing using customer-preferred roads with non-standard notation or missing information: For permit routing, TxPROS accepts preferred roads from customers. However, these roads might not be contiguous or might not intersect, or the origin and

destination might not be provided. For these situations, TxPROS creates a route from intersection to intersection.

Reporting

In addition to mapping, managing restrictions, and routing, a major TxPROS feature is reporting. With available road segment and bridge data and detailed routes associated with a specific time period, TxPROS can generate a variety of reports for various uses. TxPROS reporting tools allow periodic and ad-hoc reporting. The report tools include the following parameters (*72*):

- Active or historic permits.
- Start date to end dates.
- Permit type(s).
- Vehicle dimensions.
- Road segments (by map, by road name and marker, in a restriction, over a bridge, by county, city, or district).
- Restrictions (for a bridge, by text, by map).

These tools also facilitate the following:

- Identifying the impact of a restriction or type of a restriction in a region or location.
- Identifying bridges and roadways most impacted by current and historical permitted loads (e.g., how many X ton loads have traversed this segment, what is the history of permits on this particular structure).
- Identifying emerging freight corridors.
- Researching impacts of OS/OW loads on congestion and pollution.
- Alerting customers with active permits affected by a new restriction to contact MCD for rerouting.
- Letting customers self-issue most permit types 24 hours a day, seven days a week.
- Allowing customers to manage their own accounts including vehicle inventory and account users.
- Allowing customers to generate online bid routes for planning and proposal purposes. A bid route is not a permit but a quote to determine how much it would cost to get an OS/OW permit.

In addition to reporting, TxPROS facilitates multi-jurisdictional permitting for routing of OS/OW loads. According to a representative from MCD, TxDOT issues permits only for routes on the state highway system. Travel on off-system roadways requires coordination and permits from affected counties and/or cities. TxPROS has the ability for multi-jurisdictional routings, although TxDOT currently does not have the authority to route OS/OW loads on off-system roadways. Some counties and cities (e.g., Harris County) have started efforts to modify relevant regulations and laws so that MCD can route loads on their roadways as well. It is MCD's intention that TxPROS operate on a roadway network combining all on- and off-system roadways with restrictions directly entered by TxDOT as well as by counties and cities.

Another feature in TxPROS is service-level screening permit requests. A customer can obtain a permit online if the vehicle dimensions and load are within a set envelope size. If the vehicle dimensions and load are outside the envelope size or if the customer needs vehicle routing, TxPROS directs the customer to a permit officer. By screening permit requests, MCD is able to reassign resources to complex, time-consuming tasks that meet MCD's need to "provide growth ability that will allow MCD to provide quality customer service while experiencing increased permit demand without incurring significant backlog" (*71*).

Development of TxPROS

As of 2010, TxPROS was under development by ProMiles Software Development Corporation. TxPROS is a customized version of the ProMilesOnline application rewritten using TxDOT's architectures (e.g., core technology, data, and GIS technical architectures), standards (e.g., graphic data and configuration management standards), and available roadway data. According to specifications, development of TxPROS followed a multi-phase approach with a set of anticipated deliverables for each phase. TxPROS project management uses a project methodology plan, which includes the following items (*72*):

- Project documentation management processes.
- Software version control.
- Requirements management.
- Business process reviews.
- Naming conventions.
- Change control.
- Timekeeping procedures.
- Deliverable submission and approval.
- Phase submission and approval.
- Meeting procedures.

MCD and customers used the beta version of TxPROS for testing prior to its full release. Some users were allowed to use the system in 2010 for further testing and feedback. MCD planned to migrate the last four years of permits stored in CPS to TxPROS.

Originally, TxPROS was to interface with CPS to manage requests and issue permits for OS/OW loads (i.e., CPS would initiate a session with TxPROS and pull the results back into CPS). However, TxDOT subsequently received approval to expand the TxPROS project to include permitting functionality within TxPROS, replacing MCD's legacy permitting system (i.e., CPS) (*70*).

CHAPTER 5: PRELIMINARY ANALYSIS OF OS/OW DATA

INTRODUCTION

For the purpose of this project, the research team requested OS/OW permit data from TxDOT MCD between FY 2004 and 2009. MCD exported the data directly from CPS into six DBF files, each of which contained OS/OW permit data for one fiscal year. The original CPS database consisted of 128 fields in a flat file format. Table 7 provides a list of these fields along with field type, field size, and field description.

Table 7. Structure of CPS Database.

Field Name	Field Description	Type	Size
PERMIT_NBR	**TxDOT-Assigned Permit Number**	**Text**	**12**
TRUCK_YR	Year of Semi Truck's Manufacture	Text	4
TRUCK_MAKE	Manufacturer of Semi Truck	Text	30
LOAD_DESC	Permit Load Description	Text	50
WIDTH_FT	Semi Truck Width in Feet	Double	8
WIDTH_IN	Semi Truck Width in Inches	Double	8
LEGAL_WIDT	Semi Truck Legal Width	Text	1
HEIGHT_FT	Semi Truck Height in Feet	Double	8
HEIGHT_IN	Semi Truck Height in Inches	Double	8
LEGAL_HEIG	Semi Truck Legal Height	Text	1
LENGTH_FT	Semi Truck Length in Feet	Double	8
LENGTH_IN	Semi Truck Length in Inches	Double	8
LEGAL_LENG	Semi Truck Legal Length	Text	1
FOH_FT	Semi Truck FOH Length in Feet	Double	8
FOH_IN	Semi Truck FOH Length in Inches	Double	8
LEGAL_FOH_	Semi Truck FOH Legal Length	Text	1
ROH_FT	Semi Truck ROH Length in Feet	Double	8
ROH_IN	Semi Truck ROH Length in Inches	Double	8
LEGAL_ROH_	Semi Truck ROH Legal Length	Text	1
WEIGHT	Semi Truck Weight	Double	8
WEIGHT_OVE	Semi Truck Weight Over	Text	1
WEIGHT_RED	Semi Truck Weight Red	Text	1
LEGAL_WEIG	Semi Truck Legal Weight	Text	1
ROUTE_START	TxDOT Permit Route Start City Name	Text	30
ROUTE_END	TxDOT Permit Route End City Name	Text	30
ROUTE_DESC	TxDOT Permit Route Description	Text	255
PERMIT_STA	TxDOT Permit Start Date	Date/Time	8
PERMIT_END	TxDOT Permit End Date	Date/Time	8
SPACING1 - 24	These were 24 fields showing semi truck spacing 1st increment to 24th increment	Double	8 each
WEIGHT1 - 25	These were 25 fields showing semi truck weight 1st increment to 25th increment	Double	8 each
TIRES1 - 25	These are 25 fields showing semi truck 1st to 25th tire	Double	8 each
SIZE1 - 25	These were 25 fields showing semi truck 1st to 25th size	Double	8

The PERMIT_NBR field provided a unique number for each permit in the table. However, records might have the same permit number, especially if a commercial vehicle exited and later reentered Texas during the same trips. Therefore, although providing a primary identification mechanism, PERMIT_NBR was not a unique identifier of a record in the database. The PERMIT_TYP field identified the type of permit associated with a given record.

PRELIMINARY ANALYSIS OF OS/OW PERMIT DATA

OS/OW Permit Overview

The original OS/OW permit data contained more than 3 million permits for the six study years (Table 8). A limited number of permit numbers (less than a half percent of the total records) were associated with multiple records, each of which included identical information for most fields except for vehicle configuration. This observation suggested that some permits could be updated after being issued or a single permit could be issued to multiple loads on the same routes from the same applicants.

Table 8. Number of OS/OW Permits by Year.

Fiscal Year	Total Records	Unique Permit Numbers	Permits with Routes	Percent of Total
2004	445,081	444,326	386,510	87%
2005	482,230	478,764	383,316	80%
2006	523,474	522,696	445,202	85%
2007	556,337	554,198	461,494	83%
2008	582,582	580,410	480,969	83%
2009	529,899	527,447	431,335	82%
Total	3,119,603	3,107,841	2,588,826	83%

The TxDOT permit databases included information about two general types of permits: route-specific permits (i.e., permits with route descriptions) that represented about 83 percent (Table 8) of the total permits, and non-route-specific permits. The latter included primarily the following permit types, as shown in the PERMIT_TYP field (from most frequent to least frequent):

- 30/60/90-day length.
- 30/60/90-day width.
- Crane (annual).
- Cylindrical bales of hay (annual).
- Envelope (annual non-specific).
- Fracing trailer (annual).
- General.
- Hub (hubometer permit).
- Implement of husbandry (annual).
- Manufactured housing (annual).
- Over-axle (1547).

- Rig-up truck/unladen lift (annual).
- Temporary registration.
- Utility pole (annual).
- Water-well drilling machinery and related equipment.
- Well service unit (annual).

OS/OW Permit Vehicle and Load Information

Table 9 shows the 75th, 85th, and 95th percentiles of the OS/OW permits for overall vehicle/load height, width, length, and weight. The statistics suggest that the overall vehicle/load length increase for the permitted OS/OW vehicles during the six-year study period coincided with an increase in gross vehicle weight.

Table 9. Major Percentiles for Vehicle/Load Height, Width, Length, and Gross Weight.

Year	Vehicle Height			Vehicle Width			Vehicle Length			Gross Weight (lb)		
	75th	85th	95th	75th	85th	95th	75th	85th	95th	75th	85th	95th
2004	14′8″	15′2″	16′	14′	14′6″	16′	95′	100′	110′	96,000	120,000	160,000
2005	14′8″	15′3″	16′	14′	14′6″	16′	95′	100′	110′	100,000	120,000	160,000
2006	14′8″	15′3″	16′	14′	14′5″	16′	95′	103′	110′	98,000	120,000	160,000
2007	14′10″	15′6″	16′	14′	14′2″	16′	95′	105′	112′	105,000	128,000	164,000
2008	14′10″	15′6″	16′	14′	14′5″	16′	97′	110′	120′	106,000	130,000	169,175
2009	14′8″	15′5″	16′	14′	14′	16′	95′	110′	120′	107,000	130,300	168,000

Figure 10, Figure 11, and Figure 12 illustrate the percentages of OS/OW permits by overall vehicle height, width, and weight, respectively. In terms of load height, a majority of the permits involved vehicles less than 14 ft high (legal vehicle height in Texas). In addition, most of the permitted over-height vehicles were between 14 ft and 16 ft. In terms of vehicle width, as illustrated in Figure 11, more than 75 percent of the permitted loads exceeded the legal vehicle width (i.e., 8.5 ft). As to vehicle gross weight, Figure 12 illustrates that about a third of the permits involved gross weights greater than 80,000 lb, roughly half of which were less than 120,000 lb.

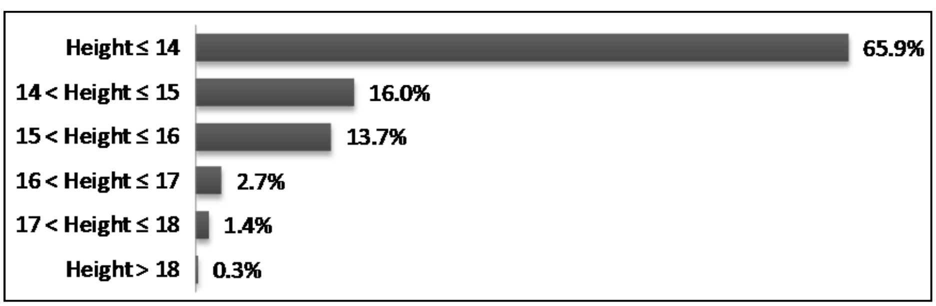


Figure 10. OS/OW Permits by Vehicle/Load Height (ft).

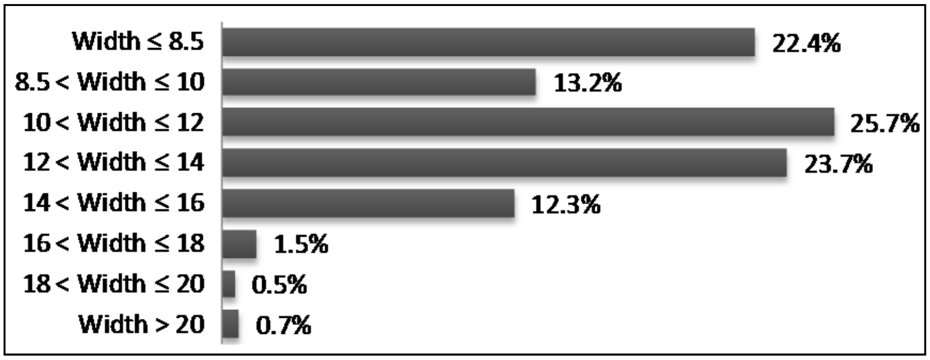


Figure 11. OS/OW Permits by Vehicle/Load Width (ft).

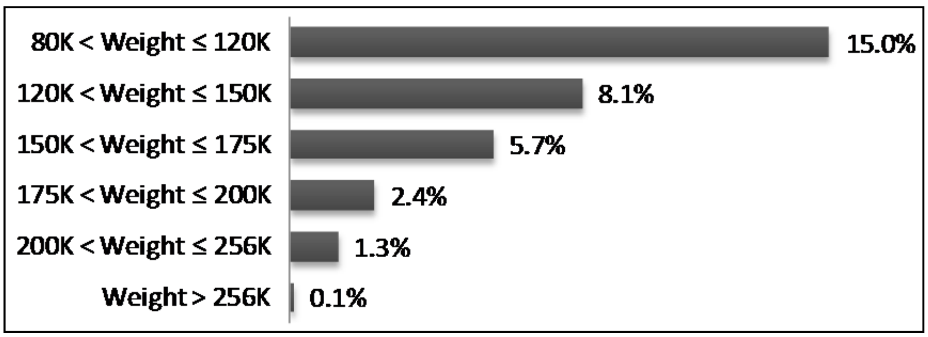


Figure 12. OS/OW Permits by Vehicle/Load Weight (lb).

In addition to vehicle/load information, the researchers developed a general categorization of the types of the loads involved in the OS/OW permits based on load descriptions by searching through a set of keywords (Table 10). Figure 13 shows that many permits were issued for trucks hauling heavy equipment (16.8 percent) and equipment related to oil/gas field operations (14.0 percent). In addition, a non-trivial percent of the permits involved loads that could be associated with wind energy development.

Table 10. Keywords Used for Load Categorization.

Heavy Equipment			
cat	crusher	compressor	track hoe
caterpillar	excavator	trailer	trackhoe
dump	track assembly	lowboy	paver
dump bed	rotor	transformer	grinder
oversize	rotary	generator	loader
chassis	trimmer	boiler	sideboom
clam shell	crawler	vessel	side boom
dozer	drill	cherrypicker	forklift
crane	compressor	cherry picker	skidder
trencher	scraper	grader	pipelayer
tractor	loader	mine	end dump
dipper			
Oil/Gas Field			
oil	frac pump	derrick	ballast
gas	pump house	substructure	bunkhouse
drill	pump truck	drawworks	bunk house
drilling unit	rig	draw works	dog house
well	drilling rig	draworks	riser
frac	skid	crew house	mud
Oversize			
boat	portable	empty tank	unladen trailer
building	mobile home		
Millitary			
military	Abrahms M1A2	Army tank	battle tank
Bradley tank	Abrams		
Wind Energy			
wind	windmill	tower	lower mid-section
mill	nacelle		
Miscellaneous			
electric motor	concrete	wood chipper	spool
transformer	beam	shelter	railroad regulator
steel	wrecker	motor	heat exchanger
cooler	dump truck	reel	cotton picker
motor	house		

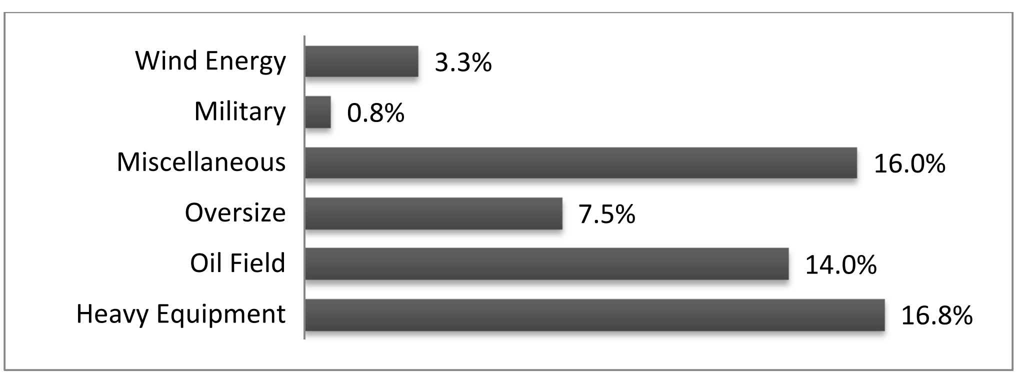


Figure 13. OS/OW Permits by Commodity Type.

CHAPTER 6: GIS PROCESSING OF OS/OW PERMIT ROUTES

INTRODUCTION

To enable detailed OS/OW route analysis, the research team needed to map the permitted routes of the OS/OW permits into a GIS format suitable for analysis. This chapter describes the process the research team used for GIS mapping of the text descriptions of TxDOT OS/OW permit routes, route origins, and route destinations. The route mapping process involved the following major steps:

- Clean and standardize original route descriptions.
- Prepare a navigable route network based on a TxDOT on-system roadway layer.
- Create a route intersection layer (referred to as the junction layer hereafter) that contained all intersections, origins, and destinations involved in the original route descriptions.
- Map route descriptions into ESRI Shapefiles based on the route layer and junction layer.
- Further process the resulting Shapefiles for future GIS route analysis.

The OD mapping process involved the following major steps:

- Clean and standardize original route OD descriptions.
- Prepare an OD table that contained all origins or destinations of the unique OD pairs for GIS mapping.
- Map unique OD pairs into ESRI line features.
- Further process the resulting OD features for future OD analysis.

INITIAL ROUTE DESCRIPTION EXAMINATION

For the permit route and OD mapping purposes, the research team focused on three data elements in the original permit data: ROUTE_START, ROUTE_END, and ROUTE_DESC. For the majority of records, the field ROUTE_START provided the starting city of the route, and the field ROUTE_END contained the destination city. The field ROUTE_DESC provided a description of the specific route between the ROUTE_START and ROUTE_END. Among the records that contained valid ROUTE_START and ROUTE_END entries, there are generally the following three types of origins or destinations:

- Cities: A majority of the permits had Texas cities as their origins and/or destinations. Those cities were standardized according to the names as specified in the 2011 US Geographic Names Information System (GNIS) Populated Place dataset (*76*).
- Landmarks: A very limited number of permits used major landmarks as their origins and/or destinations, such as Red River Army Depot (RRAD). The research team manually standardized the most frequent entries and left those less frequent or unrecognizable entries due to time limit.

- Intersections between state line and highways: For the routed OS/OW permits that passed the state border, TxDOT only specified the route portions within the state. Therefore, a number of permit routes contained intersections between the Texas state line and crossing highways as origins and/or destinations. The research team used an understandable syntax to standardize those intersections. Based on this syntax, for example, the intersection between the Louisiana state line and IH 10 was standardized as IH0010 @ LA STATE LINE, and the intersection between the Mexican border and US 57 would become MEX STATE LINE @ US0057.

The ROUTE_DESC field generally contained one of the following:

- A route description with JCT or related variation (JCT could appear at the beginning of the record or somewhere within the route description).
- A route description starting with a descriptor other than JCT (e.g., IH30w; JCT or a related variation did not appear in this route description).
- A city name.
- An unprintable character (e.g., carriage return/line feed, which was sometimes followed by additional content on the following lines).
- The abbreviation TX.
- Null, which means the field was empty or, more specifically, the content of the field was equal to the ASCII code "null" (i.e., a hexadecimal code of 00).
- The field started with an uncommon delimiter (e.g., "&").

The route information in these three fields was not immediately ready for mapping in a GIS platform because of several reasons:

- The syntax used for route starts, route ends, and route descriptions was not standardized and contained spelling errors, blank entries, and unknown entries.
- Abbreviations used for route starts, route ends, and route descriptions were not consistent.
- The route description field contained multiline records in which only one line corresponded to the route information.
- Some records contained special characters such as " ┌" that further increased the mapping difficulty.

Table 11 includes some examples of the entries in the ROUTE_START and ROUTE_END fields of the original permit data. The examples illustrate some of the major challenges that the research team had to face when cleaning and standardizing the OD information.

The route descriptions of approximately 70 percent of the permits contained JCT or related variation that indicated intersections of adjacent highway pairs. A review of these records found several variations of JCT, such as "…JCT," "..JCT," ".JCT," "..**JCT," and "**JCT." Figure 14 provides a sample of permit route descriptions stored in the route description field.

Table 11. Sample Spellings of Cities in the Start Route and Route End Fields.

Sample Values in ROUTE_START and ROUTE_END	
* SAN ANTONIO *	AMARILL0
\SAN ANTONIO	AMARILLLO
MSAN ANTONIO	6 MILES SOUTH OF LEH
HOUSTON	A;VARADO
0HOUSTON	ASDF
HOUST6ON	CIT
☺CORPUS CHRIST	DESSA
CORPUS	R.R.A.D
CORPUS CHRI	SSS
1DALLAS	T.S.L.
DALLLAS	UFKIN
DA;;AS	UNCERTAIN
AAMARILLO	VARIES

ROUTE AND OD DESCRIPTION STANDARDIZATION

The result of the initial data analysis was a need for extensive data cleansing in order to map the permitted routes and ODs into a GIS format. The research team found that data entered in the route description field were not selected from a set of valid values and did not follow a defined data standard. This lack of data integrity and standards in the data input process was the primary reason for the extensive data cleansing.

Route Description Standardization

The route description standardization efforts focused on those that contained valid route descriptions (Table 8). The research team developed a five-step string parse data cleansing process using Microsoft Excel and Visual Basic for Applications (VBA) to clean the 2.6 million records with route information. The data cleansing process included the following five steps:

- **Step 1: Standardize Route.** Route names are standardized to follow a two-character, four-digit convention and validated against a TxDOT route lookup table containing all standardized TxDOT on-system route names. For example, IH10 becomes IH0010 and Loop 1604 becomes LP1604. For spurs (SPs), the researchers searched the lookup table to identify whether it was FS, RS, SS, UP, RU, or RP.
- **Step 2: Separate Multiline Records.** There were a large number of records with route descriptions that spanned multiple lines. To enable the use of the route standardization scripts, the research team separated each line into individual fields.
- **Step 3: Identify Valid Route Information**. This step identified the lines of the multiline records that contained the intended route descriptions.

┐JCT 2 MILES EAST OF SH 326 ON US 90w,SH 326n,US 69s,SH 327e,US 96n,e,FM 2246e,SH 62s,SH 12n,e,SH 87s, to JCT IH 10┐   UNIT # 4034
..JCT US287/US380e, IH35n, DENTON: NW.LP288e,s, US380e, IH30e...   US380: 20K SINGLE AXLE; 34K TANDEM AXLE ICC#259050
...JCT RALPH FAIR RD/ IH10e, FM3351n, FM473w, FM473e, JCT FM1376,... SEVEN SISTERS DRROUTING IS THE SOLE RESPONSIBILITY OF THE APPLICATE ON CITY STREETS & COUNTY RDS
JCT.SP50/IH35Wn, IH20e, FT WORTH/EXIT BU287, IH20SFRe, US287WFRs, TO 1ST XOVER, US287n, IH20e, US175se, JCT.FM2860...
....JCT SHADY GROVE/ W.LP12s, SP408s, IH20e, US67sw, SH174s, SH171se, HILLSBORO- SH81s, IH35.W.FRs PAST FM310, IH35s, @TEMPLE: EXIT @ AVE H, IH35.W.FRs PAST S.LP363, IH35s, (PALMER)FM734se, JCT YAGER,...
αα JCT FEDERAL/IH10w, E.IH610n/w, IH45n, HUNTSVILLE***S.SH75n (PRISON EXIT), DROP @ SOUTHWOOD RD (HUNTSVILLE)αP/UP @ IH45 EFRn*** 1st ON-RAMP: IH45n, DETOUR LOW STRUCTURE @ANGUS RD IN ANGUS, IH45N, IH20E, IH635N,W, SH78N, **SH190 NFRw, US75n, US380w, SH
**jct Holmes Rd/SH288WFRs, SH288s,* S.BW8FRe, x-under @ fm865 to BW8FRw, us90Aw, sp762s/w, fm762s, fm2218sw, us59sw, sh36n, fm1640w, sp529sw, us59sw, sp10n, us90Aw, fm3013s, fm102nw, fm950w, sh71nw, us90Aw, sh97n, us90w, sh304n, sh71w, fm969n, fm1704ne, e
"αJCT JUDSON RD/LP1604e/s, IH35n, IH35En, IH20e, IH45n, IH345n, US75n, JCT IH635α" ROUTE APPROVED BY SUSAN/DALLAS DISTRICT**LOAD MAY TRAVEL AT NIGHT TO DESTINATION DURING DALLAS CURFEW HOURS. MUST TRAVEL INSIDE LANE & LOWER LEVEL OF IH35 IN AUSTIN FR
*****jct sh329/sh349/s, to jct of south sh290****
RQ ROUTE JCT IH20.SFR/SH149s, SH322s, US259s, US79sw, PALESTINE: NE.LP256s&w, US79sw, JCT FM542...
. . . . JCT N. FM 2943 / US60sw, US385n, US87e, US287n, JCT FM 297 . . . . .
... IH10w, SH62s, SH87s, JCT FM3322...
┐JCT FEDERAL/IH10w, E.IH610n/w/s, IH10w, E.LP1604n/w, IH10w, JCT NM LINE┐File Code: T\LOUISIANA TRAN\HOU-NM10

Figure 14. Sample Route Descriptions Starting with a Variation of JCT.

- **Step 4: Remove Unwanted Characters.** This step included the following sub-steps:
  - Replace all occurrences of "┐ " with a space.
  - Search for "[" and "]" and replace with "(" and ")", respectively, so that brackets could be used to indicate segments (see Step 5).

Search for "$" and "?" and replace them with a space so they could be dedicated to mark the beginning and end of questionable information (see Step 5). During this process, however, engineering judgment was needed in many cases to ensure original route descriptions were not altered. For example, a portion of an actual route was described as follows: IH0035n,W.SL1604s/e?n,IH0010e. As described, the route most likely originated from IH 35, continued on Loop 1604 going south, then east, then north, and finally east on IH 10. Therefore, the "?" in this example should be replaced with "_" rather than a space.

- **Step 5: Route Data Cleaning.** This step involved the implementation of the following route data cleaning rules:
    - Use "[" and "]" to mark the beginning and end of landmark description, respectively. If the landmark is a junction of two roadways, the second roadway is duplicated and added after the closing bracket. This allowed the separation of the information within the bracket from the route without changing the actual route.
    - Use "?" and "$" to mark the beginning and end of questionable information, respectively.
    - Use "_" before and between travel direction information (e.g., n, s, e, w, ne, se, nw, and sw) to mark the direction of travel along a route segment.
    - Use "," to mark the end of a route segment (e.g., "SH0036_NW, us0059_sw,").
    - Use CAPITAL LETTER PERIOD (N., S., E., or W.) to indicate the portion of a loop highway. These roadways are often called beltways, loop routes, or ring roads and are often found around or within cities.

The following is an example of an actual route description and how the data were cleaned and processed using the five-step process. Modifications of the data from one process step to the next are highlighted in yellow. The example begins with the unedited text that the record provided in the route description field:

```
…JCT Everman Parkway/IH35Wn, IH20e, IH45s, N.IH610e?s, IH10e, JCT
Sheldon Rd…


Not lowboy


AFFIDAVIT STATUS: PWG
```

In Step 1, the text was edited by the process and the route names were standardized as follows:

```
…JCT Everman Parkway/IH0035Wn, IH0020e, IH0045s, N.IH0610e?s,
IH0010e, JCT Sheldon Rd…


Not lowboy
```

```
AFFIDAVIT STATUS: PWG
```

In Step 2, the process separated the multi lines into three separate fields:

```
…JCT Everman Parkway/IH0035Wn, IH0020e, IH0045s, N.IH0610e?s,
IH0010e, JCT Sheldon Rd…
```

```
Not lowboy
```

```
AFFIDAVIT STATUS: PWG
```

In Step 3, the process identified valid route information in field 1, retained that field, and discarded fields two and three:

```
…JCT Everman Parkway/IH0035Wn, IH0020e, IH0045s, N.IH0610e?s,
IH0010e, JCT Sheldon Rd…
```

~~Not lowboy~~

~~AFFIDAVIT STATUS: PWG~~

In Step 4, the researchers manually removed and cleaned up special characters in the descriptions:

```
…JCT Everman Parkway/IH0035Wn, IH0020e, IH0045s, N.IH0610e/s,
IH0010e, JCT Sheldon Rd…
```

In Step 5, the process standardized the route information and grouped data elements into route segments using the "[" and "]" symbols. This data cleaning process produced the following cleaned route description:

```
[JCT Everman Parkway/IH0035Wn]IH0035W_n,IH0020_e, IH0045_s,
N.IH0610_e_s,IH0010_e,[JCT Sheldon Rd]
```

After the automatic cleaning process, the research team screened the descriptions that the cleaning program flagged as problematic and manually standardized many of them. At the end, however, there were still a number of records with valid route descriptions that were not usable due to a variety of issues and had to be abandoned. The most common issues included:

- **Unknown route.** A number of permits could not be processed because they had entries in the route description that could not be programmatically identified as a valid route. The following are two examples of route descriptions that were flagged as "no route":

  Example 1:

```
?Jct FM3167/FM0649n- SH0016n- Jct US0059$
```

  In this case, the operator used " - " to separate route information instead of ",". Since no comma is found, the program could not positively determine whether this was a valid route description.

  Example 2:

```
?*SEE ATTACHED SHEETS FOR ROUTE AND RESTRICTION INFORMATION*$
```

  In this case, the entry is not empty, but it is clearly not a route description.

  Example 3:

```
[JCT FM0480/SH0027e]SH0027_e, [COMFORT]?BU0087_s$,
IH0010_e,N.SL1604_w,?LA CANTERA (WEST OF IH10)
CROSSUNDER$,SL1604_e,US0281_n,US0190_e,US0183_n,US0281_n,FM1690_n
e,FM0183_ne,US0084_e,S.SL0340_e_n,US0084_e,W.SL0256_n_e_s,US0079_
n,US0259_n,IH0020_e,US0059_n,IH0030_e
```

  In this case, BU0087 is not shown in the route database; thus, the record was flagged as "unknown route." In addition, there is no route information for LA CANTERA (WEST OF IH10) CROSSUNDER.

- **Unknown information.** Some permits were not processed because the entry in the route description field provided unknown information before the term JCT in the route description. The following route description, for example, contained TO THE, which was not recognizable by the cleaning scripts:

```
[VICTORIA.....3 MILES NORTH OF BU0059ON]
US0087_n,US0077_s,US0059_n,W.IH0610_s_e,SH0225_e,SH0146_n,?TO THE
$[JCT. SP0330..........BAYTOWN]
```

- **Multi-spur route.** A number of permits were not automatically processed because the entry in the route contained a highway designated as a spur with multiple matches in the route description. The following is an example of such a route description:

```
[JCT. IH0035/S.SL0013E]S.SL0013_e,?SP0122_s$, IH0410_e_n,
US0087_s ,[SAN ANTONIO]E.SL1604_e_n, IH0035_n,[BUDA]S. FM1626 _n
_e,FM2304_n,[JCT SLAUGHTER LN...P/U S.SL0001ne]S.SL0001_ne
,FM0734_se,IH0035_n,
FM0093_e,SH0095_n,[TEMPLE]S.SL0363_n_w,IH0035_s,[JCT SH0053]
```

In the route lookup table, there were records of FS0122 and SS0122. As a result, the research team was unable to determine which roadway this record referred to.

The route description standardization process resulted in about half of the original records that could be used for GIS route generation (Table 12). The processed records were then imported into six Oracle® database tables separated by permit year.

Table 12. Permit Route Description Processing Results.

Fiscal Year	Total Permits	Permits with Valid Route Description	Permits with Processed Routes	Percent of Processed Routes
2004	444,326	385,912	225,083	51%
2005	447,876	417,263	238,772	53%
2006	522,696	445,976	240,399	46%
2007	554,198	463,621	233,653	42%
2008	580,410	483,136	268,240	46%
2009	527,447	428,920	255,490	48%
Total	3,076,953	2,624,828	1,461,637	48%

OD Description Standardization

The standardization of OD descriptions was necessary for any meaningful OD analysis using GIS. This data cleansing process focused on the text descriptions in the fields ROUTE_START and ROUTE_END of the original permit data. Because OD analysis would require the association between OD pairs and the actual mapped routes and because clean and standardized route origins and destinations were also needed for route mapping as the start and end of each route, the OD description cleansing primarily focused on records that contained valid route descriptions. However, researchers also addressed origins and destinations of additional permit records.

The research team first identified unique OD descriptions and stored them in a separate table. The cleansing efforts were then based on those unique OD records to minimize redundancy. Following a similar approach as used for route description cleansing, the research team analyzed the OD description patterns and developed several scripts within Microsoft Access to clean the data. In addition to the automated scripts, the research team manually checked through a large number of the results to ensure reasonable accuracy. The entire data cleansing process involved the following steps:

- Remove duplicate permits: As mentioned earlier, a limited number of records contained the same permit numbers and OD information but different vehicle configurations. During the standardization process, the researchers only kept one record for each permit number for simplicity.
- Identify unique origins and destinations: The research team identified unique origin or destination entries and stored them in a separate database table for further processing. This step helped the research team to reduce data processing redundancy and improve processing speed.
- Clean and standardize OD descriptions: The goal was to process and standardize the information in a way that would enable an automated GIS process to use the information. As provided, the route start and end information was not immediately useable. During the data cleansing process, the research team first examined the OD records to identify major patterns and rules that could be utilized for automated processing. They then developed several scripts within Microsoft Access to automatically standardize those that followed the patterns or rules. After the automatic process, the researchers manually checked and standardized a large number of origins or destinations that could not be processed automatically.
- Combine processed results with original permits: After the cleaning process, the researchers matched the processed OD descriptions back to their original permit numbers along with the cleaned permit route descriptions.

At the end of the process, the research team standardized a total of 147,728 unique OD pairs that represented more than 1.2 million (i.e., 1,228,405) permits over the six-year study period (Table 13).

Table 13. Counts of the Processed OD Pairs.

Fiscal Year	Total Original Permits	Number of Permits Represented	Percent of Total
2004	444,326	224,886	51%
2005	447,876	170,196	38%
2006	522,696	181,198	35%
2007	554,198	185,646	33%
2008	580,410	210,993	36%
2009	527,447	255,486	48%
Total	3,076,953	1,228,405	40%

GIS MAPPING OF PERMIT ROUTES

To generate a GIS route based on a standardized route description table, a straightforward method would be to use the Network Analyst tool available in ArcGIS Desktop. However, due to the overwhelmingly large number of routes to be mapped, simply using the tool manually would be extremely time-consuming. In addition, an automated route creation process purely based on ArcGIS Network Analyst (e.g., through ModelBuilder or VBA/VB.NET scripts) would require significant computing resources and time and therefore was not practical considering the timeframe of the research.

To enable timely completion of the route reconstruction, the research team developed a modified shortest-path algorithm in ArcGIS Desktop to reconstruct the previous processed OW/OS permit routes. The algorithm directly read and wrote data from/to an Oracle database and therefore dramatically increased the processing speed. In addition, it allowed the researchers to execute the process in batches of controllable sizes defined by researchers in numbers of data rows. The overall GIS route processing included the following major steps:

- Further cleaning of route descriptions.
- Route network preparation.
- Junction layer generation.
- Route Shapefile generation and attribution.
- Post-processing of route Shapefiles.

Preparation of Route Network

One of the basic components for mapping the standardized route descriptions into Shapefiles was a navigable route network. For this research, the OW/OS permit routes at TxDOT only involved on-system routes. Local routes between the origin points or final destinations and the nearest access points on a state route were not described. Therefore, the research team decided to construct a route network using a TxDOT roadway network. For the purpose of this and other separate projects, the research team received two roadway networks from TxDOT: the official 2008 on-system network from TPP and the 2009 on-system network used by TxDOT's Maintenance Division (MNT) for its Pavement Management Information System (PMIS)-related mapping purposes. Both highway networks were centerline layers that contained only single-line features representing the centerlines of state highway roadbeds.

During a previous evaluation, the researchers noticed inconsistencies associated with some linear features on the two centerline layers. The 2008 TPP centerline layer was an updated version of the 2007 layer, but a result of a significant modification and verification from the previous TPP centerline datasets. Although some features on the official 2008 TPP dataset represented the ground condition better, it reflected the roadways as of August 2008. In contrast, the 2009 PMIS centerline layer was maintained and continuously updated by MNT based on the 2006 version of the TPP centerline layer, and therefore many features were more current.

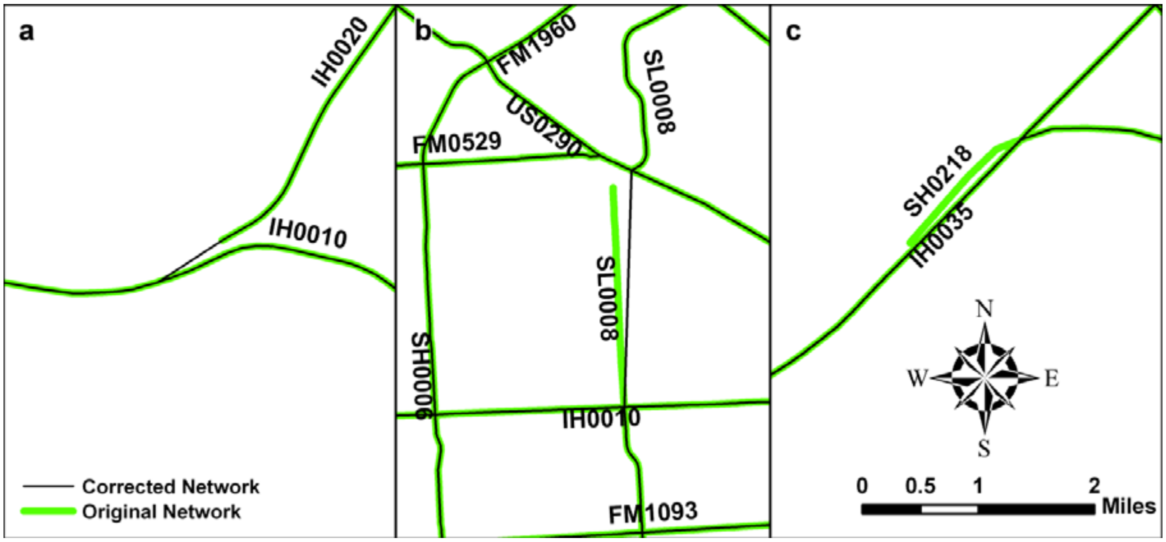
Since this research involved FY09 permit data and due to the reasons described above, the research team used the 2009 PMIS roadway network as the basis for the route network. During the development of the route network, the research team checked through all roadway intersections manually and programmatically (e.g., testing by connectivity by generating a sample of complex routes) to ensure the network was fully navigable and correctly reflected the ground condition. The following are some of the major considerations and challenges the research team faced when preparing the route network.

Network connectivity. Connectivity is a key requirement for a navigable route network. Several factors need to be considered during route network construction to ensure connectivity, including at least:

- Grade separations: Grade separations refer to the cases where a highway overpasses another roadway without physically intersecting with it. These cases would appear as intersections on a PolyLine (as opposed to PolyLineZ) layer but should not be considered as intersections. The scope of this research focused strictly on the on-system highways (i.e., major state routes). Most, if not all, intersections between those highways are physically connected either at grade or by frontage roads or interchanges. Therefore, grade separation was not an issue of concern for this research.
- Turn restrictions: Certain intersections may have turn restrictions that partly limit the connectivity at those locations. Such cases typically occur on local roadways, and a close examination of the on-system roadway network indicated that this was not an issue of concern for the research.
- Frontage roads, ramps, and turnarounds: Most Texas freeways are constructed with frontage roads and use ramps and turnaround lanes for connection and U-turns. In reality, when a vehicle navigates from a freeway to a non-access controlled highway, it needs to first exit the main lanes to frontage roads and then turn (may require a U-turn in case of a left turn) on the next highway. The route analysis in this research was at the macroscopic level, and therefore the research team did not intend to reconstruct such movements upon agreement by the project panel. Consequently, the roadway network used for this project did not contain microscopic navigation features such as frontage roads, ramps, and turnarounds.
- Link errors: Link errors refer to misrepresentations of ground conditions on the GIS roadway layer due to data accuracy or currentness. During the network construction, the researchers encountered a large number of link errors. Some of the most frequent link errors included overshoots, undershoots, and broken links (Figure 15). The research team manually corrected most, if not all, such cases to ensure connectivity.

Network attributes. Network attributes refer to the information needed for route determination, such as travel impedance (e.g., traffic information, travel speed, speed limit, and functional classification), directional travel restrictions, and link distances. Because the research team used an approach that reconstructed a permit route by linking the identified intersections using shortest paths and because the studied routes only involved on-system highways (i.e., major highways), the only attribute of interest to the research was the link distance that was readily available in the original centerline layer.

After making necessary improvements to the 2009 centerline layer, the researchers generated a route network layer using the Network Analyst tool available in ArcGIS Desktop. This route network was used during the subsequent steps for GIS mapping of the OW/OS permit routes.



a) Undershoot b) Broken link c) Overshoot

Figure 15. Example Connectivity Issues of the Original TxDOT Roadway Network.

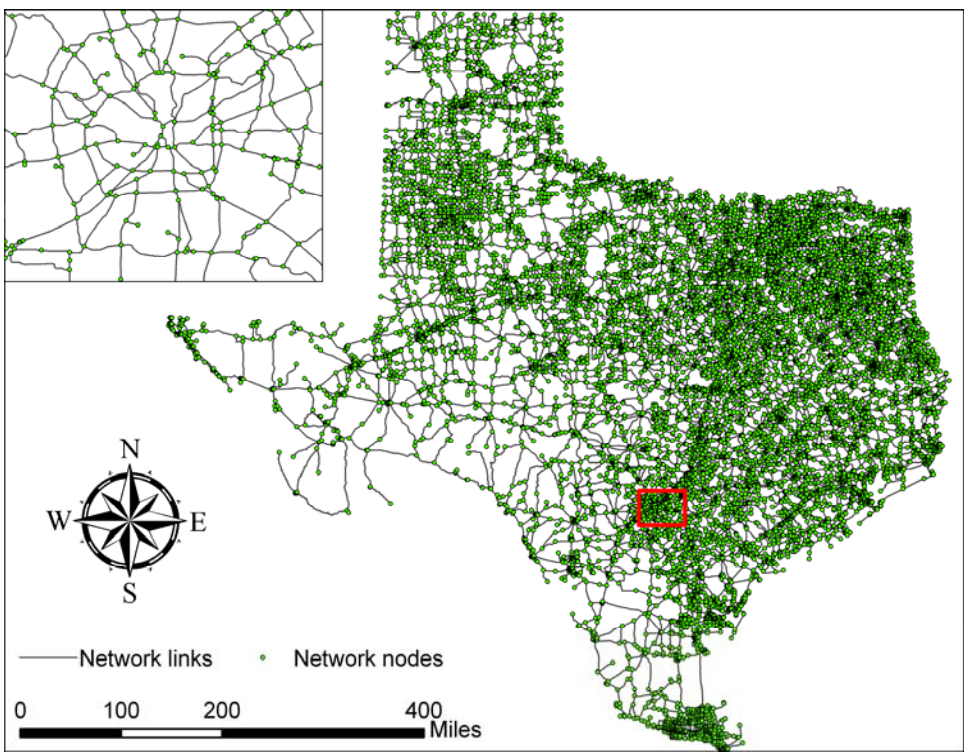


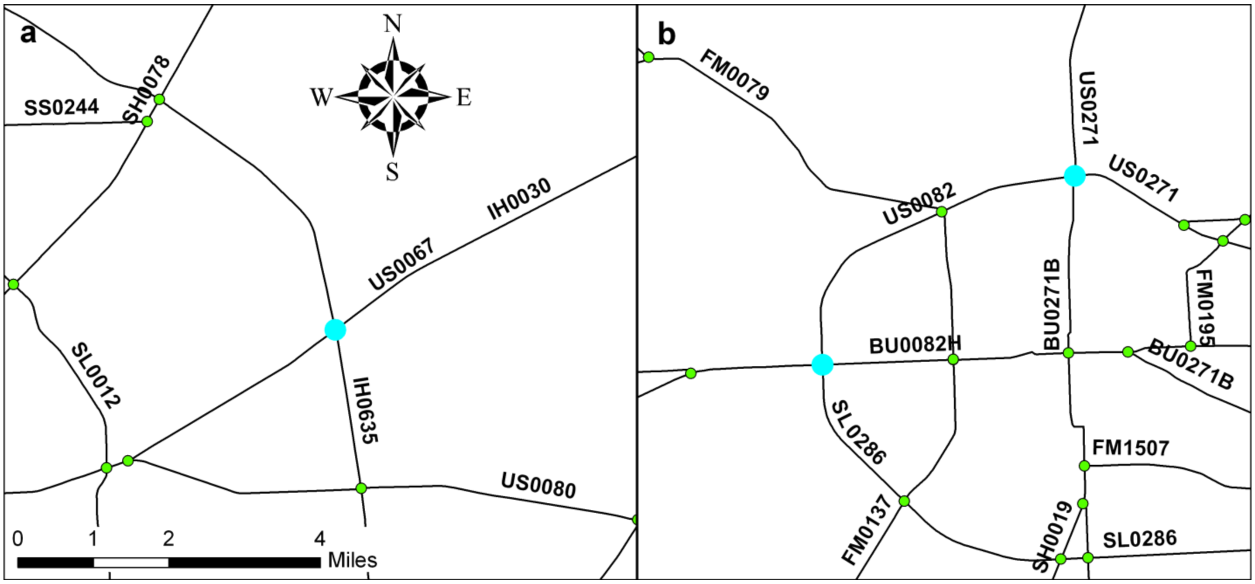
Figure 16. Final Route Network Used for GIS Route Reconstruction.

Junction Layer Creation

In order to enable route mapping, another critical piece of the puzzle was a point layer (named as the junction layer for convenience) that corresponded to all intersections, origins, and destinations in route descriptions and was spatially linked to the route network layer. This layer was needed so that for each permit route, the automated route generation program was able to identify the route origin, destination, and all intermediate intersections. This layer should include three types of point features:

- Highway-state line intersections: For interstate permit routes, the route descriptions only described the part of the routes that were within Texas state lines. For this reason, the origin or destination of such a route would be the intersection between the Texas state line and an on-system highway. The research team generated the highway-state line intersections by intersecting the 2009 roadway network layer with a Texas state polygon layer. To ensure accuracy, the research team checked through the resulting point layer and manually added those that the intersecting operation missed due to data errors.
- Texas cities: A majority of the intrastate OW/OS permit routes had Texas cities in their route descriptions as the origins and destinations. Therefore, to map the permit routes, it was necessary to include all Texas cities in the junction layer. For this purpose, the research team used the 2011 US GNIS Populated Place dataset. A point layer of Texas cities was created based on the coordinate information contained in the tabular dataset using the Display XY Data tool in ArcGIS Desktop.
- Highway intersections: The research team first generated a point layer of highway intersections by extracting all intersections of the on-system roadway network using the Intersect tool in ArcGIS. The result layer had many missing junctions and needed extensive manual edits in order to be used for GIS route reconstruction. Missing intersections could be due to several reasons, such as more than two highways intersecting at the same location and disconnected links at intersections that were not corrected through previous steps. The most frequent cases resulting in missing intersections, however, were single links representing multiple highways (Figure 17a) and highways changing names at intersections (Figure 17b).

Figure 17a shows a common situation, where a single link represented multiple highways (i.e., US 67 and IH 30) that used the same roadbed in Houston, Texas. In this case, because interstates are more important than US highways in the TxDOT functional classification hierarchy, the link on the TxDOT highway network layer used IH0030 as the highway name instead of using US0067 or using both. Therefore, there would be only one intersection generated by the automated process, and that was the one between IH0635 and IH0030. In this case, researchers had to manually add the intersection between IH0635 and US0067.



a) Single links representing multiple highways b) Highways changing names

Figure 17. Common Situations Resulting in Missing Intersections.

Figure 17b shows the other common situation, where two highways change their names at intersections in Paris, Texas (i.e., US0271 changes to BU0271B south of SL0286, and US0082 changes to BU0082H east of SL0286). Theoretically, the joint point of the two connecting highways (i.e., US0271 and BU0271B, or US0082 and BU0082H) should be exactly on top of the intersecting highway (i.e., SL0286), resulting in two intersections at each location during the Intersect operation. However, this was rarely the case in reality due to spatial data errors.

In the case of US0271, the Intersect operation only produced one intersection between US0271 and US0082 because BU0271B did not physically intersect with US0082 on the network layer. In the case of US0082, the operation only resulted in the intersection between US0082 (west of SL0286) and US0082 (SL0286). What complicated these two specific cases even more was that northeast SL0286 first merged with US0082 and then the two highways merged with US0271 later. Therefore, for the former case, researchers had to manually add the intersections between SL0286 and US0271, SL0286 and BU0271B, and US0082 and BU0271B. For the latter case, researchers had to manually add the intersections of SL0286 and BU0082H, and SL0286 and US0082.

The research team combined all three types of point features into a single junction layer (Figure 18). To match the junctions in route descriptions with the corresponding spatial point representations, the junction layer included the following two key attributes: Highway 1 and Highway 2. In the case of highway intersections, these two fields stored the names of the two intersecting highways with no particular sequence. In the case of highway-state line intersections, Highway 1 stored the name of the state line (e.g., LA STATE LINE, NM STATE

LINE, AR STATE LINE, OK STATE LINE, and MX STATE LINE). For cities, Highway 1 was "CITY" to indicate that the record represented a Texas city.

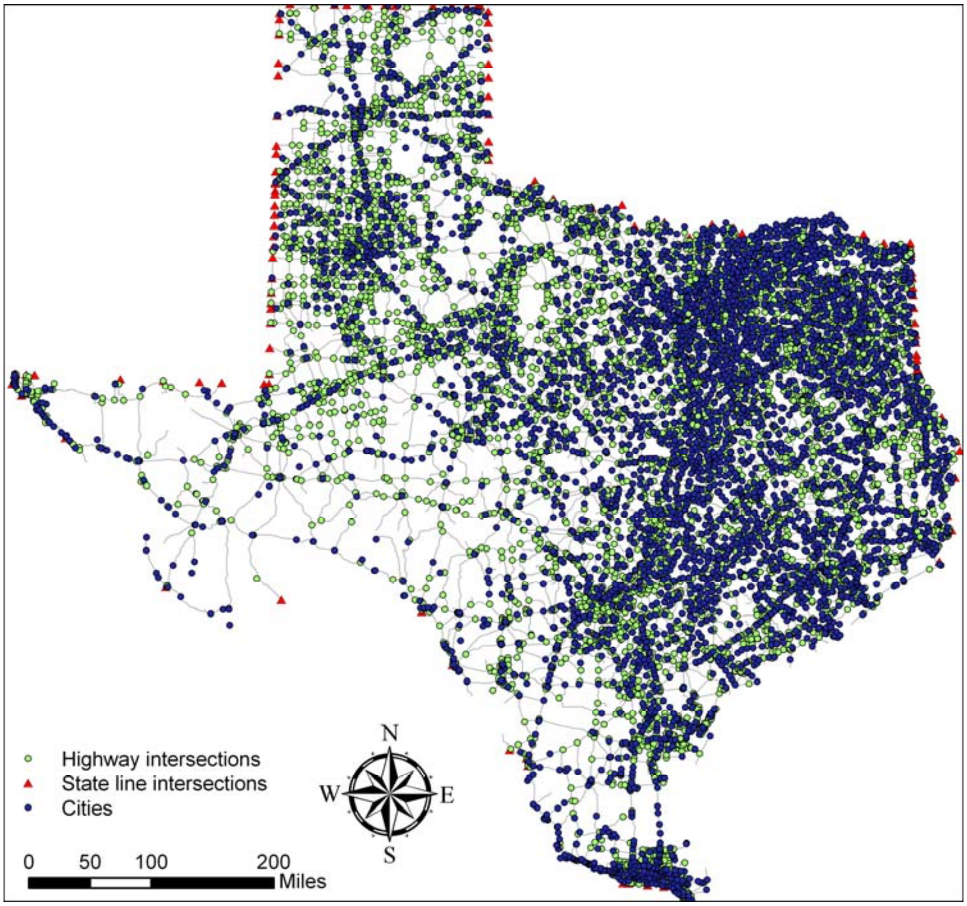


Figure 18. Final Junction layer for GIS Route Reconstruction.

GIS Route Mapping

Previous steps had standardized route descriptions using a syntax that was understandable through programming. However, what the standardized descriptions lacked was a list of all highway intersections of each permit route. In order to map a permit route into a GIS format, the research team's approach was to identify all intersections of the route and then generate the links between each pair of adjacent intersections. Therefore, it was necessary to convert the route descriptions into sequential lists of intersections that could be matched with the junction layer prepared earlier to facilitate the GIS route reconstruction.

A quick examination of the standardized route descriptions suggested that many OW/OS permits over the six study years had identical permit routes judged from their origins, destinations, and route descriptions. For efficiency, the research team created a separate Oracle table with all unique permit routes over the six study years. A route description parsing script was developed using C#.NET to extract each of the intersections involved in a permit route sequentially into a new field. The researchers used "~" to separate the two highways of each intersection and ";" to separate adjacent intersections. At the end of this process, each route description was replaced in the form of a sequential list of intersections. The following is an example of a permit route after this parsing:

```
[JCT Everman Parkway/IH0035Wn]IH0035W_n,IH0020_e, IH0045_s,
N.IH0610_e_s,IH0010_e,[JCT Sheldon Rd]
```

```
IH0035W_n~ IH0020_e;IH0020_e~IH0045_s;IH0045_s~IH0610_e_s;
IH0610_e_s~IH0010_e
```

Route Mapping Process

Researchers developed an automatic procedure consisting of three VBA programs that closely resembled the route analysis procedure of the ArcGIS Network Analyst. For each permit route, the three VBA programs corresponded to the following three steps:

- Generate a point Shapefile containing all intersections of the route: The VBA program completes this step in several sub-steps. It first creates an empty point Shapefile that will be used to store the intersection points. The program then reads the intersections sequentially into memory from the Oracle database table and matches them with the corresponding point features in the junction layer. Finally, it extracts the matched points from the junction layer and then appends them into the empty point Shapefile. Compared with the following two steps, this step consumes the most processing time and computing resources.
- Create the route leg between each pair of adjacent intersections and store them in a single layer file: To identify each leg of the permit route, the program reads the intersections from the point Shapefile that resulted from the last step and identifies the shortest path in distance between each pair of adjacent intersections following the correct sequence as defined in the original route description. These route legs are then stored in a layer file (i.e., .LYR) for further processing.
- Extract all route legs from the layer file and convert them into a single linear feature in a separate Shapefile.

The use of three programs each of which corresponded to a different step enabled the research team to run different steps simultaneously on the same or different workstations and therefore greatly improved the overall processing speed. Figure 19 graphically illustrates the procedure to construct a GIS permit route based on the route description, and Figure 20 shows a screenshot of creating the legs of a permit route.

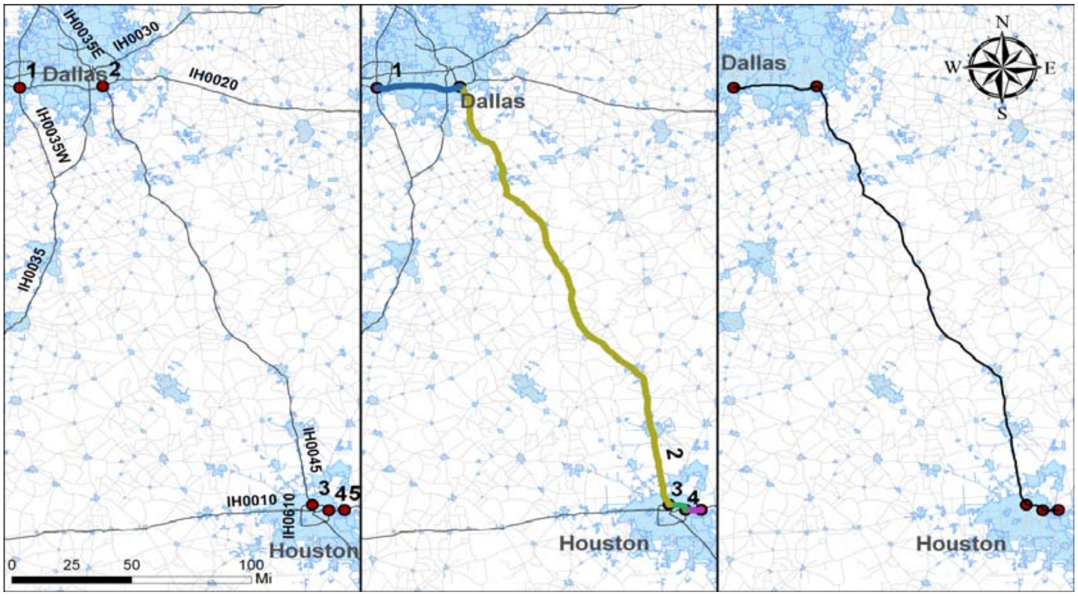


Figure 19. Three Steps Involved in GIS Route Reconstruction.

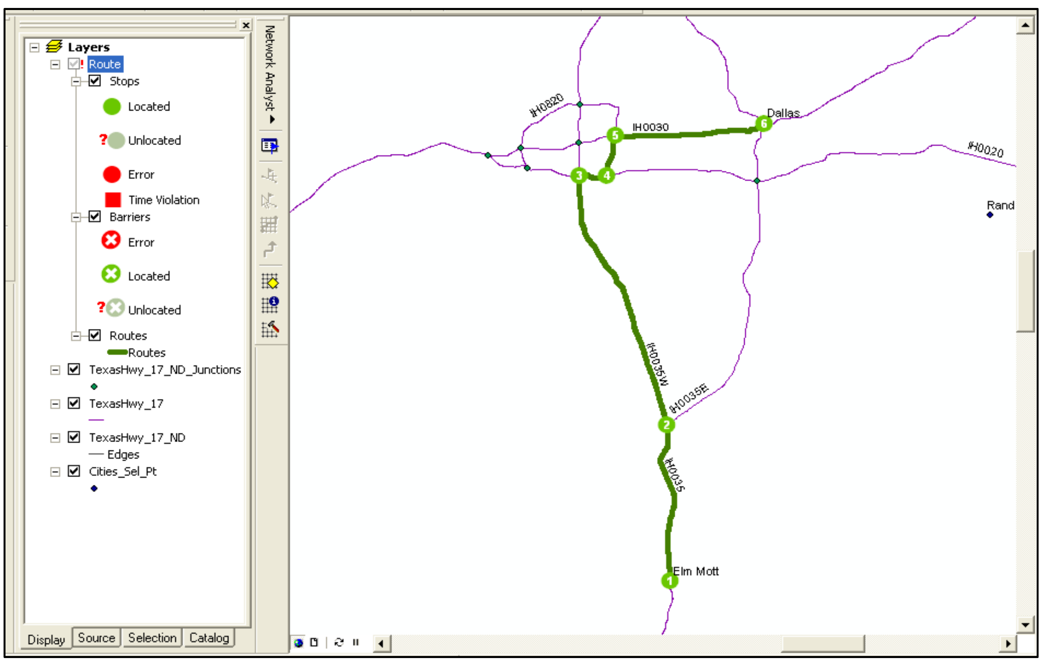


Figure 20. Generating Shortest Paths between Adjacent Intersections of a Permit Route.

When developing the VBA programs for GIS route generation, the research team used several mechanisms that resulted in significant reduction in overall processing time. Particularly worth noting are the direct connection with the Oracle database and the enabling of processing by batches.

For efficiency, the research team stored the cleaned route description data in the Oracle database, and ArcGIS was able to directly read from and write to the database tables through Microsoft Open Database Connectivity (ODBC) technology during the entire GIS route reconstruction process. ODBC is an interface that enables an application to access external relational databases in an open, vendor-neutral way (*77*). ArcGIS supports ODBC data connections through the use of Object Linking and Embedding database (OLE DB) providers (*78*), a tool conforming to the OLE standard used by ESRI products for communicating with and retrieving data from external databases. The use of the Oracle database during processing considerably improved the performance of the route reconstruction process by enabling much more efficient data storage, retrieval, and query.

During this research, there was an overwhelmingly large number of permit routes that needed to be converted into Shapefiles. For efficiency, the research team designed the VBA programs such that they processed the route permits by batches. A batch is a certain number of permit route records predefined generally based on the length of the permit route description measured in number of characters. An index table containing basic batch information, such as batch number, the range of route description length (e.g., 0–50 characters), and the end number of the last record of the batch as it appeared in the Oracle permit route table, was generated first. The route description length thresholds were designed such that the longer the route descriptions are in a batch, the smaller the number of the records the batch contains. This mechanism ensured that the times needed for processing different batches were generally balanced. During each program run, the operator needed to input the start and end batch numbers manually.

The use of batches provided maximum flexibility in processing schedule and computer usage. The research team was able to use multiple computers to process different batches. More importantly, the computer memory and the VBA programs were automatically reset after each batch, greatly improving the overall computing performance during processing and reducing the chances for computer errors. In addition, processing results for each batch were stored in a separate folder, enabling an additional layer in the resulting folder structure and making it easier to view, retrieve, and further process the resulting Shapefiles.

Routes Involving Loop Highways

There are loop highways in many Texas cities. A roadway can intersect with a loop at two locations, which in most cases share the same names on the junction layer, as described earlier. Due to this reason, it was difficult to programmatically identify the correct intersection on loop highways and the correct loop portions that were used in the permit routes. Therefore, programmers had to treat OS/OW permit routes involving loop highways in a special way to be mapped correctly.

The research team first developed a lookup table that contained the standard names of all loop highways in Texas. In many cases, it was relatively straightforward to identify loop highways based on their names (e.g., state loops and beltways). In other cases (e.g., IH 410 and IH 635), identification could be difficult and required familiarity with Texas highways. For many instances, the research team had to closely screen all major routes in a city to add them into the table. Then, they used the lookup table to compare against all roadway names contained in the cleaned permit route descriptions to identify the route descriptions involving loop highways. Those route descriptions were stored in a separate table for further processing.

Based on the lookup table, researchers then identified the loop portion of each standardized permit route description and extracted those portions into a new table (Figure 21). Then, they established a linking table to link each loop portion back to its corresponding permit route description records. For each loop section, the table included the following key information (Table 14):

- Frequency: The number of permits that involved the loop section.
- Loop portion: Contained the two junctions on the loop highway.
- Loop points: The feature IDs of the intersections on the loop portion.
- Previous loop junction: The highway intersection prior to the first loop intersection, as indicated in the permit route descriptions.
- Post-loop junction: The highway intersection next to the last loop intersection, as indicated in the permit route descriptions.

Because many different routes contained the same loop portions, the research team combined the duplicate records, resulting in only unique loop portions in the loop section table. Listed in Table 14 for example, are the four most frequent loop portions included in the permit route descriptions. The loop portions involved IH 820 in Fort Worth, IH 635 in Dallas, and IH 610 in Houston. For each of the loop portions, the research team manually inserted one or multiple intermediate intersections so that the program could correctly identify the entire routes. During this process, researchers utilized the intersections prior to and after the loop section and manually selected the logical loop section for each permit route. As illustrated in Figure 22, using the most frequent loop portions shown in Table 14 as an example (i.e., IH0035W_s~IH0820_w_s; IH0820_w_s~IH0020_e), researchers manually identified the two correct intersections on the loop highway and inserted two additional junction points in the Loop Points field (Table 14) to ensure that the automatic routing programs selected the correct loop section.

The research team was able to manually edit/check 1349 high-frequency records that represented more than 64 percent of the total permit routes involving loop highways. Then, researchers inserted edited loop portions of the route descriptions back to the corresponding route descriptions that were later mapped using the previously described VBA programs.

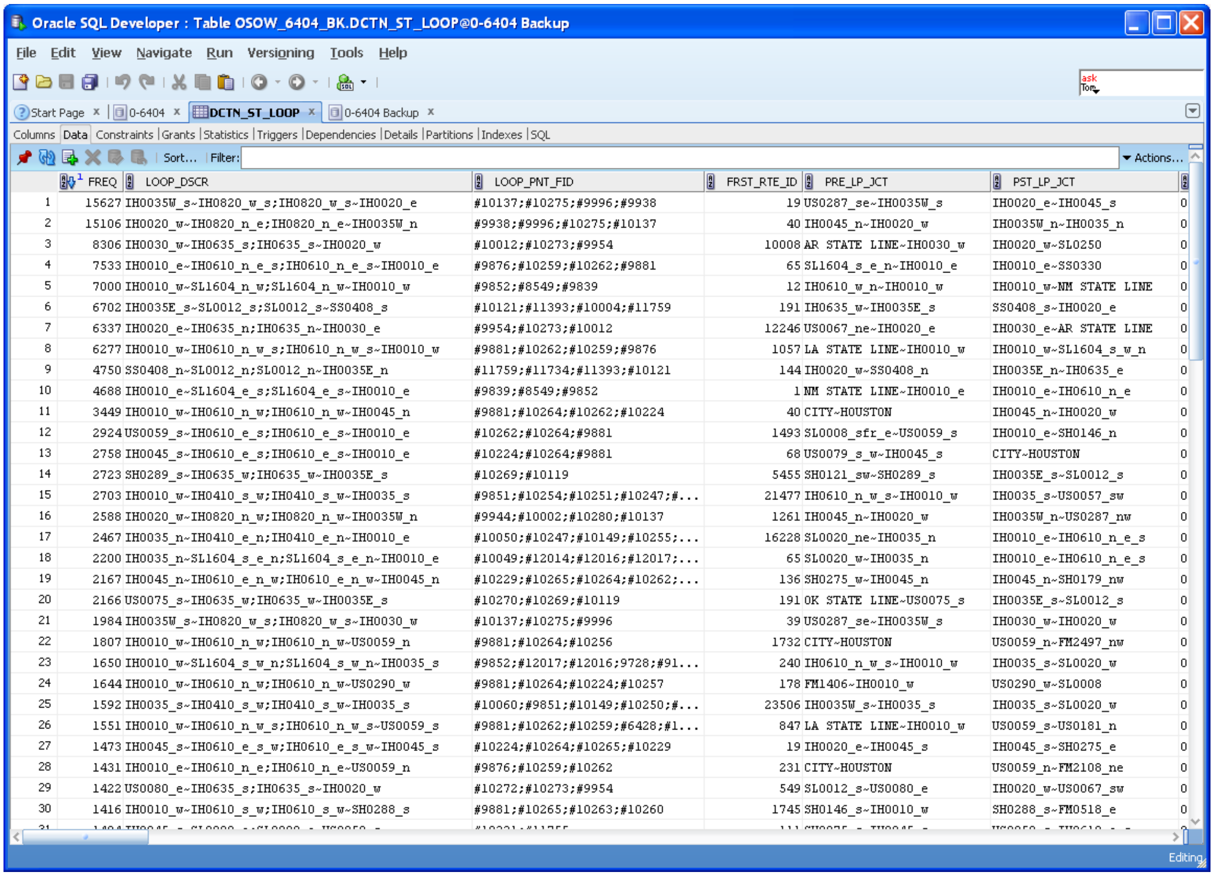


Figure 21. A Portion of the Loop Section Table in Oracle.

Table 14. Key Attributes in the Loop Section Table.

Frequency	Loop Portion	Loop Points	Previous Loop Junction	Post-Loop Junction
15627	IH0035W_s~IH0820_w_s; IH0820_w_s~IH0020_e	#10137;#10275; #9996;#9938	US0287_se~IH0035W_s	IH0020_e~IH0045_s
15106	IH0020_w~IH0820_n_e; IH0820_n_e~IH0035W_n	#9938;#9996; #10275;#10137	IH0045_n~IH0020_w	IH0035W_n~IH0035_n
8306	IH0030_w~IH0635_s; IH0635_s~IH0020_w	#10012;#10273; #9954	AR STATE LINE~IH0030_w	IH0020_w~SL0250
7533	IH0010_e~IH0610_n_e_s; IH0610_n_e_s~IH0010_e	#9876;#10259; #10262;#9881	SL1604_s_e_n~IH0010_e	IH0010_e~SS0330

Post-Processing of Route Shapefiles

The GIS route processing resulted in 590,480 processed permit routes, each of which was a separate PolyLine Shapefile. During the GIS processing, a small number of the processed route descriptions were not converted into Shapefiles due to a variety of reasons, such as:

- Extremely short routes, such as intra-city routes of which the on-system portion did not include at least two intersections between state highways.
- Routes with missing intersections. A small number of routes had intersections that were not recognized during GIS processing and therefore resulted in an invalid route (i.e., an empty line feature class).

Because all routes were stored in separate Shapefiles, it was necessary for the research team to merge all Shapefiles together for future analysis. The researchers originally attempted to merge all processed routes into one inventory Shapefile. However, they quickly realized that it was not practical to merge all Shapefiles together, due to limits on file size and number of features. In addition, the merged file would be too large for personal workstations.

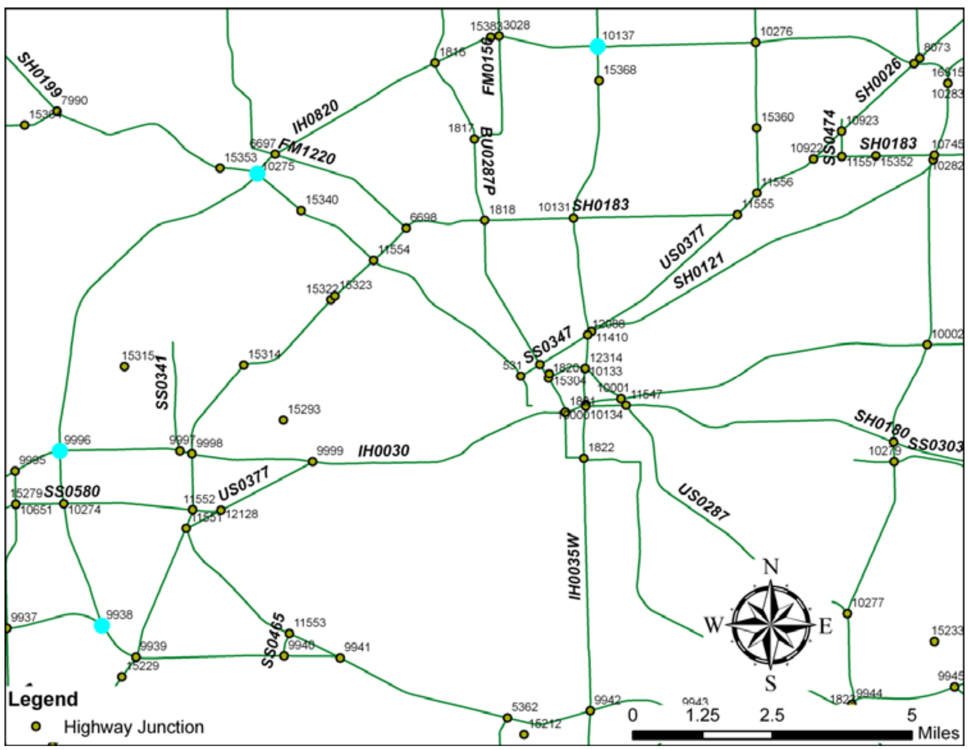


Figure 22. Junctions Manually Identified on IH 820 in Fort Worth.

It would be straightforward to use the Merge tool available in ArcGIS Desktop to merge all separate Shapefiles into a few larger line feature classes. However, a few trials indicated that using the ArcGIS tool would be extremely time-consuming due to the overwhelmingly large number of Shapefiles that needed to be merged. In particular, ArcGIS frequently generated error messages and aborted the merging operations, especially when there was a relatively large group of Shapefiles being merged simultaneously.

For efficiency, the research team used an external program named GeoMerge (*79*) to merge the route Shapefiles. Unlike the ArcGIS Merge tool, GeoMerge reads and outputs only three files associated with a Shapefile—an SHP file that stores shape type and other geometric data, an SHX file that stores spatial index data, and a DBF file that stores feature attributes. In addition, it enables the merging of a large number of Shapefiles simultaneously and thus makes the merging operation much less time-consuming. However, the output files of GeoMerge have to be in the format of Shapefile, resulting in an additional step if users prefer the geodatabase feature class to be the file format.

Using GeoMerge, the research team merged the separate Shapefiles into several large Shapefiles that contained GIS permit routes regardless of their permit years. To facilitate GIS route analysis, researchers imported the Shapefiles into a file geodatabase and separated the permit routes into feature classes based on permit year. However, to improve usability, researchers decided on 15 feature classes instead of six, which would have resulted from using one file per year between 2004 and 2009. Table 15 is a summary of the GIS permit routes processed, and Figure 23 shows the resulting feature classes as stored in a file geodatabase.

Table 15. Summary of Final Processed GIS Permit Routes.

Fiscal Year	Total Original Permits	Number of Final GIS Routes	Number of Permits Represented	Percent of Total
2004	444,326	99,739	225,077	51%
2005	447,876	79,723	170,464	38%
2006	522,696	83,440	181,152	35%
2007	554,198	86,123	186,024	34%
2008	580,410	109,051	210,776	36%
2009	527,447	134,011	254,452	48%
Total	3,076,953	592,087	1,227,945	40%

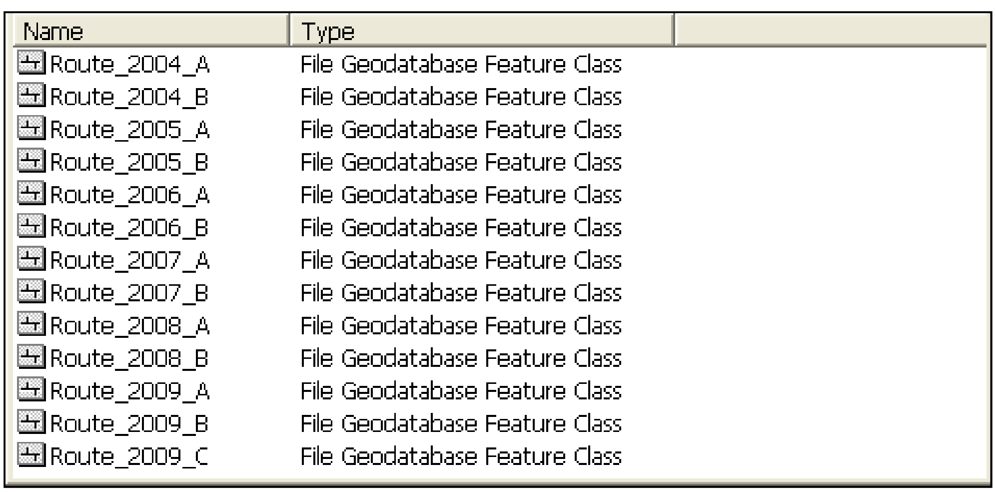


Figure 23. Final Merged Feature Classes Grouped by Year.

MAPPING OD PAIRS USING GIS

One of the major tasks of this research was to map OD pairs involved in the OS/OW permit data for analyses such as the identification of most frequent ODs for significant OS/OW load groups. Upon discussion with the project panel, researchers decided to map each OD pair into a linear feature with a direction from the origin to the destination. This presentation format would allow researchers to append any permit information to the feature and therefore enable spatial analysis and visualization of the OD pairs. The previous data cleaning process resulted in standardized origins and destinations, which were used for the OD mapping.

The OD mapping process generally involved the following steps:

- Preparing OD mapping: For simplicity and to facilitate multi-year analysis of permit OD data, researchers decided to map all OD pairs between 2004 and 2009 into one feature class and therefore generate a table that contained only unique OD pairs. A linking table was also generated in this process to establish a linkage between each OD pair and the corresponding permit numbers. Among all the permits based upon standardizing the origin and destination descriptions, there were a total of 147,728 unique OD pairs representing the approximately 1.2 million cleaned permits (Table 16).

Table 16. Counts of the Processed OD Pairs.

Fiscal Year	Number of Permits with Clean OD	Number of Distinct OD Pairs
2004	224,886	47,810
2005	170,196	39,977
2006	181,198	39,461
2007	185,646	38,643
2008	210,993	41,582
2009	255,486	49,516
Total	1,228,405	147,728[a]

[a]This is not the sum of the column. A distinct OD pair in this cell could represent a distinct OD pair counted in multiple years.

- Creating a point layer containing origins and destinations: To enable the location of all origins and destinations on a map, the research team created another table where each unique OD pair was converted into two data records with a common OD pair identifier (ID), the origin or destination name, and a value indicating the OD sequence, i.e., the record with the origin was assigned a value of 1 and the record with the destination was assigned a value of 2, indicating the OD pair was from the origin to the destination.
- Enabling mapping: To enable mapping, the research team joined the resulting table containing origins and destinations with the attribute table of the junction layer created previously for permit route mapping and then extracted the XY coordinates for each standardized origin or destination. The resulting table contained all origins and destinations of the cleaned permits and their coordinates. This table was used as the

foundation upon which the OD pairs were mapped into ESRI line features. Figure 24 shows the structure of the two tables and their relationship.

	OD Pair	Origin	Destination
	…	…	…
	Houston TO San Antonio	Houston	San Antonio
	Houston TO Dallas	Houston	Dallas
	Houston TO LA State Line @ IH0010	Houston	LA State Line @ IH0010
	…	…	…

	OD Pair	Origin or Destination	Order
	…	…	…
	Houston TO San Antonio	Houston	1
	Houston TO San Antonio	San Antonio	2
	Houston TO Dallas	Houston	1
	Houston TO Dallas	Dallas	2
	Houston TO LA State Line @ IH0010	Houston	1
	Houston TO LA State Line @ IH0010	LA State Line @ IH0010	2
	…	…	…

	OD Pair	Origin or Destination	Order	X (ft)[a]	Y (ft)[a]
	…	…	…	…	…
	Houston TO San Antonio	Houston	1	3873545	9911670
	Houston TO San Antonio	San Antonio	2	2882373	9759454
	Houston TO Dallas	Houston	1	3873545	9911670
	Houston TO Dallas	Dallas	2	3383688	10992684
	Houston TO LA State Line @ IH0010	Houston	1	3873545	9911670
	Houston TO LA State Line @ IH0010	LA State Line @ IH0010	2	4392079	10072585
	…	…	…	…	…

[a]XY coordinates are based on the ESRI predefined NAD_1983_StatePlane_Texas_Central_FIPS_4203_Feet XY Coordinate System that uses the Lambert_Conformal_Conic projection and the GCS_North_American_1983 geographic coordinate system.

Figure 24. Conversion from Unique OD Pair Table to Origin and Destination Table.

- Converting OD pairs into ESRI line features. Based on the table generated during the last step, researchers first mapped all origins and destinations involved in the OD pairs into a point feature class using the ArcGIS Display XY Events tool. Using OD pair (Figure 24) as the identifier, researchers used an ArcGIS script to generate a linear feature link of the origin and destination of each OD pair following the correct sequence indicated in the Order field.
- Post-processing of GIS OD pairs. There were a limited number of permits involving cities that shared the same names in the TxDOT OS/OW permit data. During the GIS

mapping process, those cities resulted in multi-part line features that connected more than two origins and/or destinations. For example, there are two instances of "City of Centerville" in Texas. If an OD pair was going from another city (e.g., San Antonio) to Centerville, the mapping process would result in a multi-part feature consisting of two lines connecting San Antonio to both cities of Centerville. A close examination suggested that such cities were mostly small cities and were involved only in very low-frequency OD pairs. For simplicity, researchers converted those multi-part features into multiple line features and only kept the shortest OD pairs.

The final product of the OD mapping process was a line feature class containing all unique OD pairs as found in the FY04–09 OS/OW permit data, each of which was represented by a straight line connecting the origin to the destination. Figure 25 shows the resulting linear OD pairs in GIS format for the six-year study period, and Figure 26 shows the OD pairs for origins or destinations in Houston.

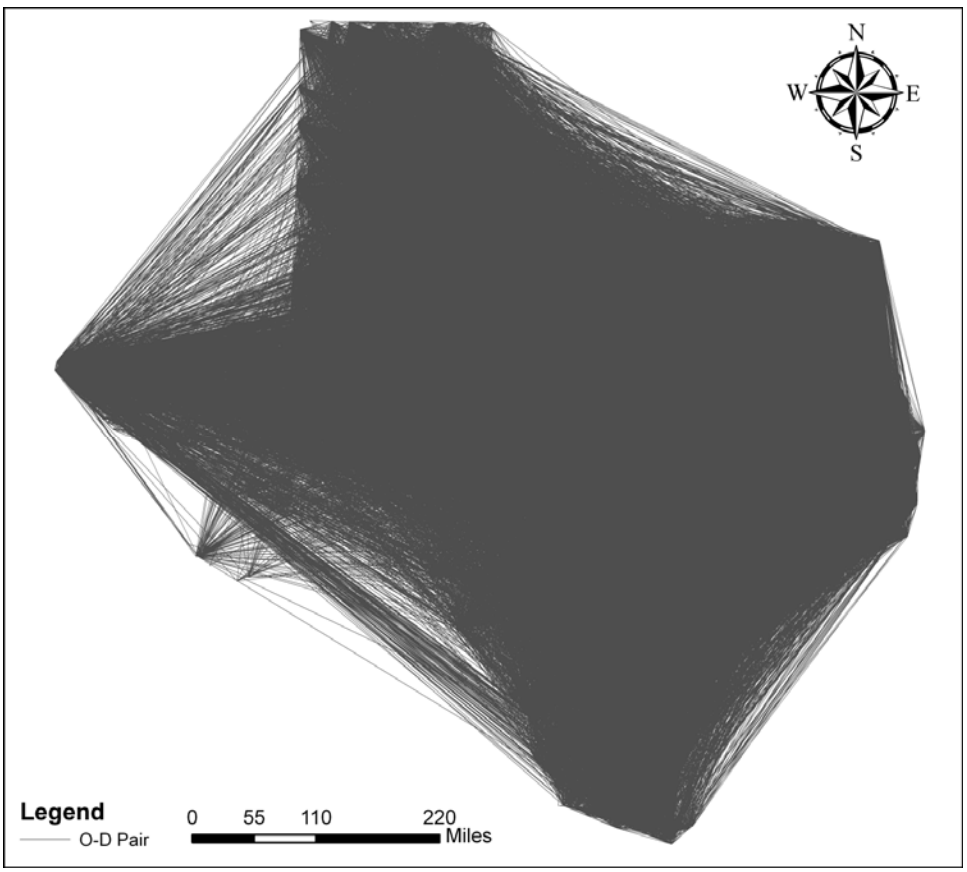


Figure 25. Feature Class Resulting from the OD Mapping Process (FY04–09).

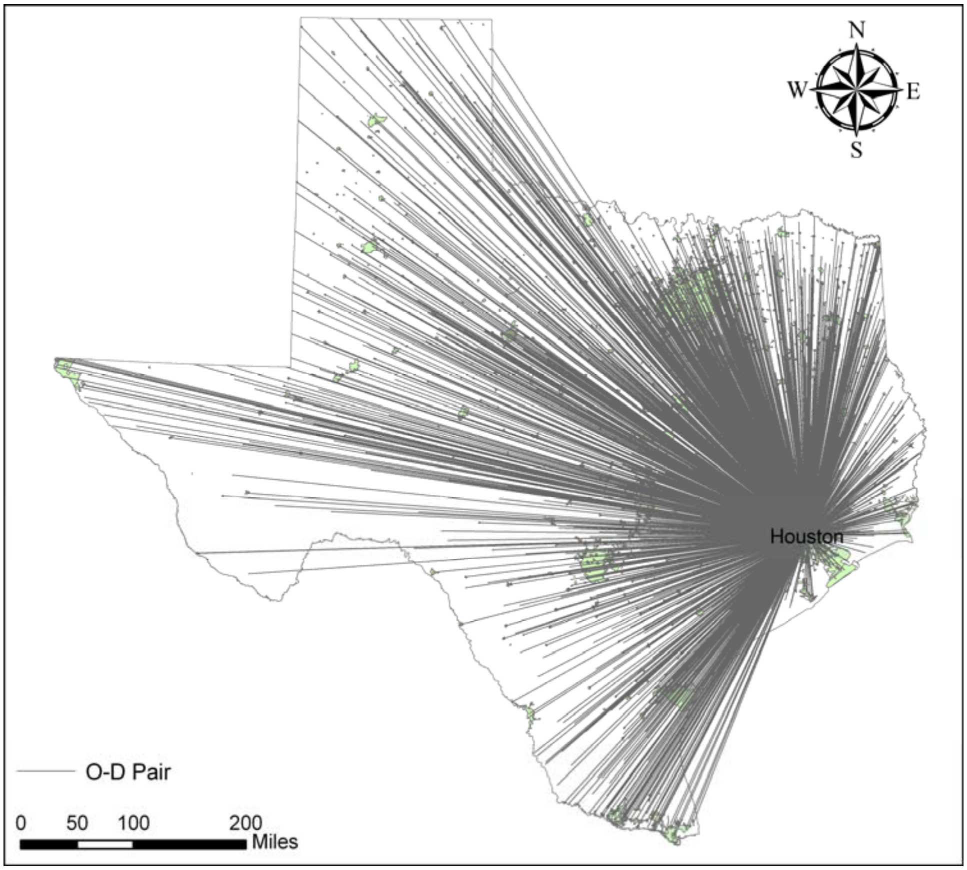


Figure 26. OD Pairs with Houston as Origin or Destination (FY 04–09).

SUMMARY AND DISCUSSION

This chapter described in detail the process of mapping OS/OW permit routes and OD pairs into a GIS format. The GIS route mapping process included the following major steps, many of which involved labor-intensive manual edits and quality controls:

- **Route description cleansing**. Due to the lack of data integrity and standards for the permit route descriptions in the original OS/OW data, the research team developed a multi-phase data cleansing process to standardize the original text descriptions into a format that was understandable by automated computer programs. During this process, researchers used multiple steps to conquer different data cleansing challenges. At the end, the research team was able to successfully clean and standardize about 1.5 million records for the six-year study period, which represented about 48 percent of the total OS/OW permits, or 56 percent of those permits that had valid route descriptions.
- **GIS route generation preparation**. This step involved several sub-steps. Researchers first generated a junction layer that contained all highway intersections, Texas cities, and intersections between highways and the Texas state line. This layer served as the inventory for all origins, destinations, and intermediate intersections for the OS/OW

permit routes to be processed. In addition, the research team built a navigable highway network based on the TxDOT PMIS route centerline layer so that the permit routes could be correctly mapped. When preparing the layers, the research team had to manually check the entire layers and make modifications to features as needed to ensure accuracy.

- **GIS route mapping**. The research team developed a shortest-path algorithm consisting of three VBA programs to map the cleaned text route descriptions into ESRI line features based on a junction layer and the route network prepared previously. The programs enabled direct connection with the Oracle database for more efficient data query, retrieval, and storage. In addition, the programs processed the route descriptions in batches and therefore reduced processing errors, improved processing speed by releasing computer memory, and provided maximum flexibility for processing using multiple computers. At the end of this process, researchers were able to generate about 600,000 permit routes representing more than 1.2 million permits, or about 84 percent of the permits with cleaned route descriptions.

To map a permit route into the GIS format, researchers first identified the intersections involved in the route and then used the shortest path to connect each pair of adjacent intersections. Although highly efficient, the shortest-path assumption resulted in problematic GIS routes in two rare types of cases. There were a very limited number of cases where the assigned highway between two adjacent intersections as described in the original route description was not necessarily the shortest path, resulting in the selection of incorrect segments between the intersections by the VBA program. Therefore, a potential improvement to the mapping programs involved mechanisms that ensured the linkage between each pair of adjacent intersections followed the same highway as listed in the route description.

There were a few cases where two roadways (excluding loop highways) intersected multiple times, resulting in several intersections with the same name. In that case, the programs randomly selected one intersection (not necessarily the correct intersection) and used it for route mapping. Strategies need to be developed to identify and use the correct intersection in those cases to reduce problematic routing.

In addition to the route mapping, the research team also mapped the OD pairs of a large number of OS/OW permits into ESRI linear features. The OD map processing included the following major steps:

- **OD description cleansing**. Similar to route descriptions, the OD descriptions in the original OS/OW data lacked data integrity and standards, so standardization had to occur first using an automated, computer-based procedure. The research team used a similar approach as for permit route description to standardize the route origin and destination descriptions. For those that could not be standardized using scripts, researchers identified meaningful records and manually processed the common entries among them. Because the future analysis would require the association between OD pairs and the actual mapped routes, the OD description cleansing primarily focused on records that contained valid route descriptions. However, a significant effort was required to process origins and destinations of additional permit records. In total, researchers standardized 147,728 unique OD pairs, which represented more than 1.2 million (i.e., 1,228,405) permits over the six-year study period.

- **OD mapping**. For simplicity and to facilitate multi-year analysis of permit OD data, all unique OD pairs were mapped into a single feature class regardless of data year. To map the OD pairs, the research team first created a table that included both origin and destination of each OD pair, their XY coordinates, and a value indicating whether a record represented a destination or an origin. This table was later mapped to a point feature class using the ArcGIS Display XY Data function. Using an ArcGIS script facilitated generating a straight-line feature to represent each OD pair from the origin to the corresponding destination.

CHAPTER 7: SPATIAL ANALYSIS OF OS/OW PERMIT ROUTES

INTRODUCTION

The previous chapter described in detail the process of mapping the routes and ODs involved in the FY04–09 OS/OW permits into a GIS format. The GIS routes and ODs enabled a myriad of opportunities for understanding how OS/OW loads had historically traveled and what restrictions affected their routes. Based on the mapped permit routes and ODs, this chapter enumerates OS/OW route analysis focusing on the most frequent OS/OW routes and ODs in conjunction with the predominant load configuration types.

FREQUENT ROADWAYS FOR OS/OW LOADS

To identify most frequent roadway segments taken by OS/OW loads during the study period, programmers had to associate each mapped permit route with the individual roadway segments it involved. The association would first require a roadway network with all roadway sections used by the mapped OS/OW permit routes. The research team developed this roadway network based on the 2009 PMIS centerline layer by splitting all roadways at intersections. The researchers then spatially joined the roadway network with the mapped permit routes to obtain the following basic statistics at the roadway segment level:

- Number of OS/OW permits that were routed on each roadway segment each year between 2004 and 2009.
- Number of legal-weight permits (these were presumably OS loads) that were routed on each roadway segment each year between 2004 and 2009.
- Sum of the total weight in pounds of the OW loads routed on each roadway segment each year between 2004 and 2009.

Figure 27, Figure 28, and Figure 29 show the total number of OS and/or OW permits routed on each roadway segment between FY04 and FY09. Figure 30 further illustrates the total weight of OW loads traveling on each roadway segment during the same period. Clearly, MCD routed most of the OS/OW loads on major roadways, including mostly interstates that were designed to a higher standard.

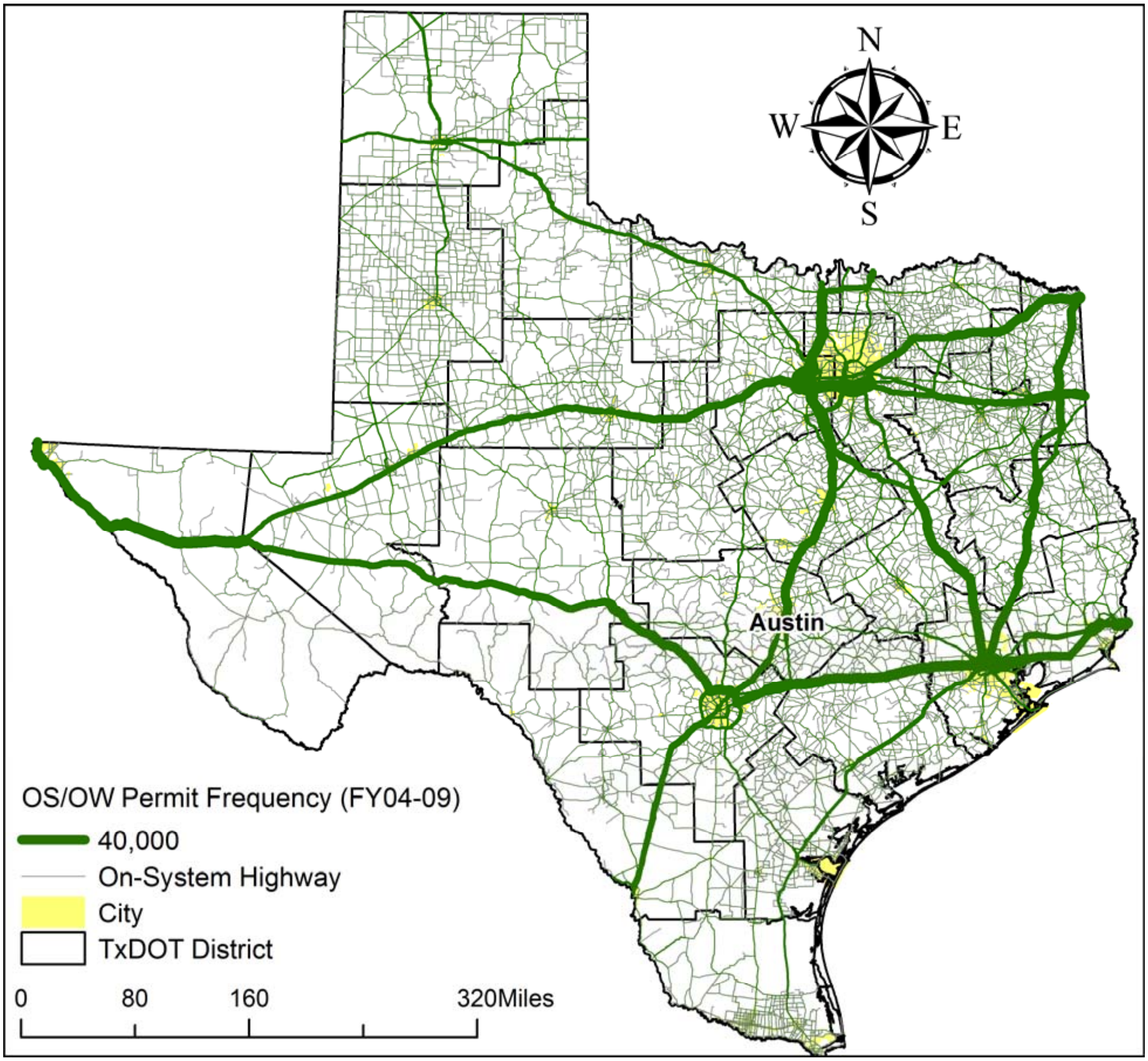


Figure 27. Total Number of OS/OW Permits during Study Period.

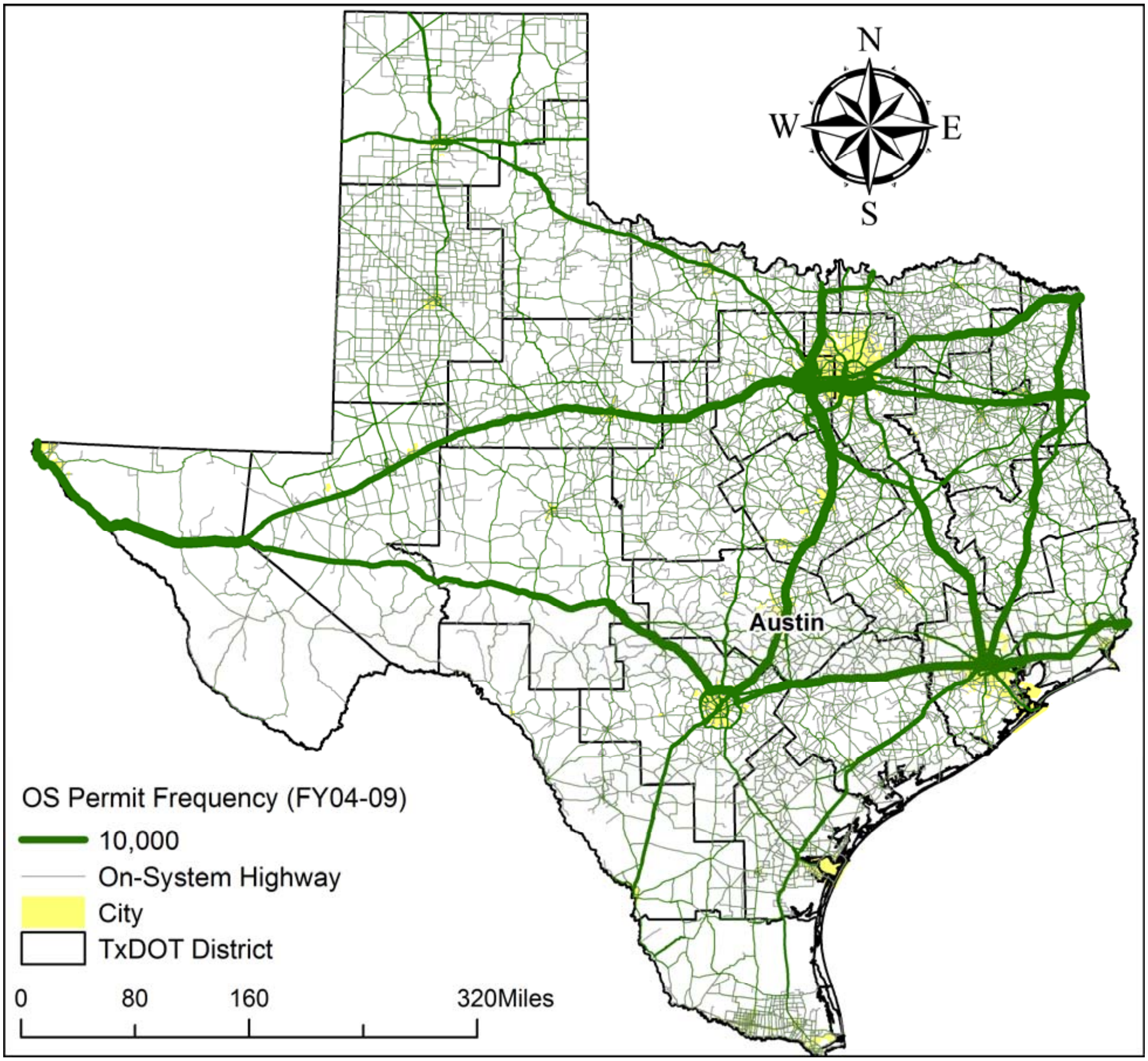


Figure 28. Total Number of OW Permits during Study Period.

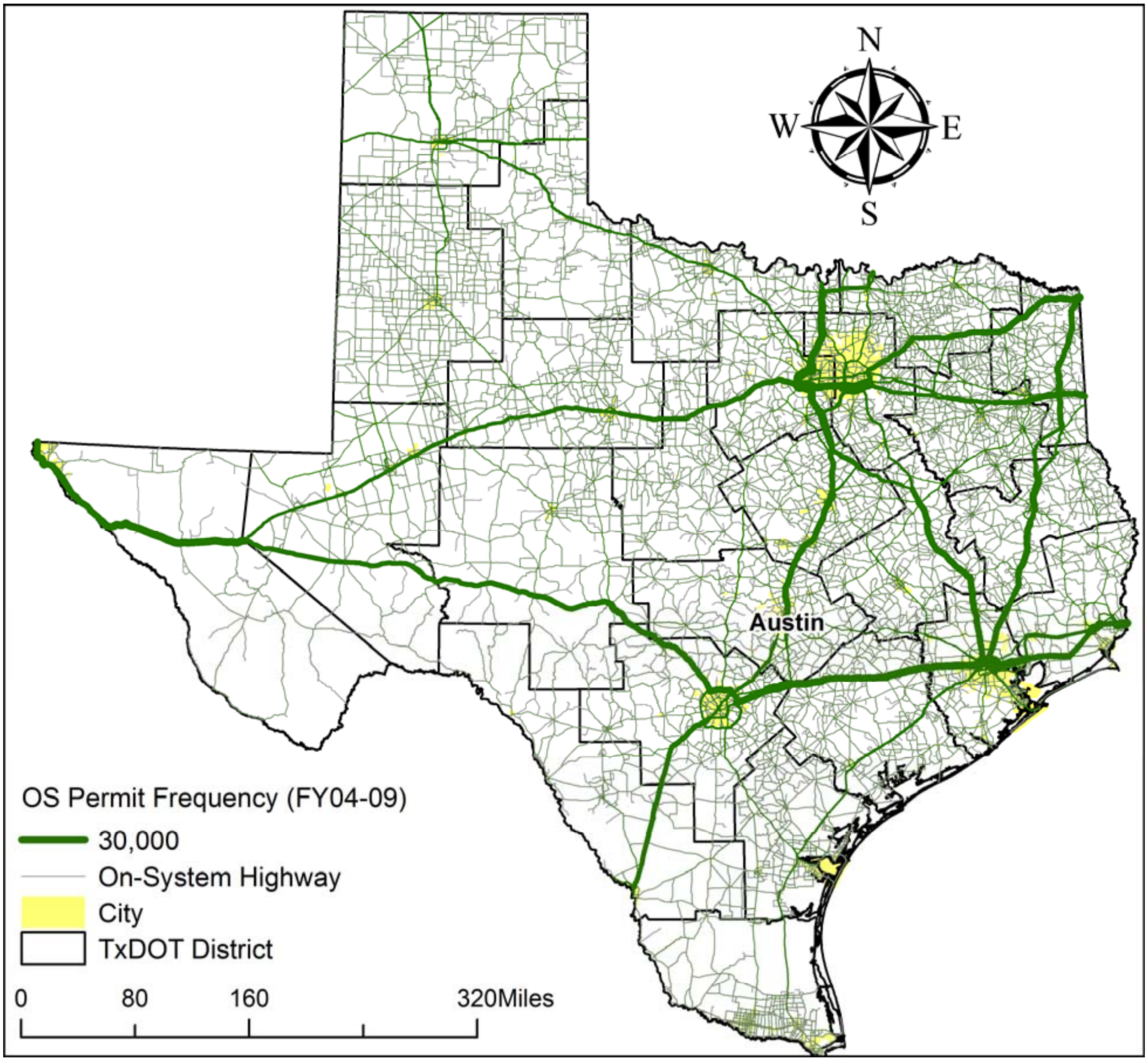


Figure 29. Total Number of OS Permits during Study Period.

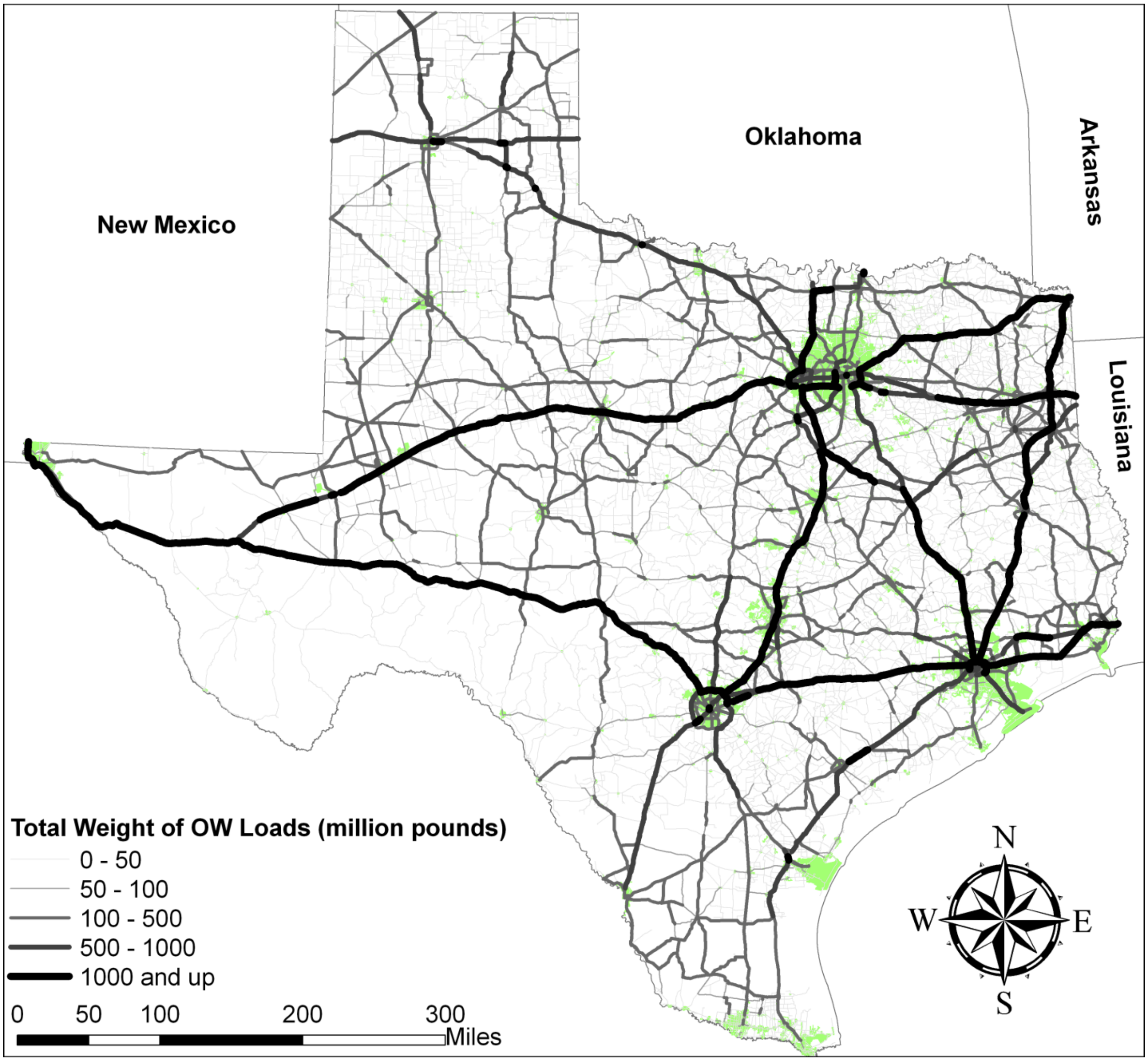


Figure 30. Total Weight of OW Loads during Study Period.

Table 17 and Figure 31, Figure 32, Figure 33, and Figure 34 illustrate the distribution of OS/OW trips on different types of roadways during the study period (i.e., FY04–FY09). To better demonstrate the load/trip distributions over the different roadway types, the numbers shown in the illustrations reflect the productions of numbers of permits or total permit weight in pounds and the length of the traveled roadways in centerline miles. The illustrations confirm that most of the OS/OW trips were on major state routes, such as IH, US, and SH/SL highways. In addition, the distribution by roadway type remained relatively stable during the six-year study period. The illustrations also show that there had been roughly twice as many OS loads as OW loads for all highway types during the study period. Although not clearly shown, the OS/OW loads routed on

IH highways seemed to be proportionally decreasing, suggesting a possible decrease in long-haul trips of those loads.

Table 17. OS/OW Permit-Miles by Highway Type.

Highway Type	IH 3234 mi*		US 12,093 mi		SH/SL 15,425 mi		FM 37,978 mi		Other 4288 mi		Total (million miles)
	million miles**	%	million miles	%	million miles	%	million miles	%	million miles	%	
FY 2009											
OS/OW Permits	18	42	13	30	8	19	3	6	1	3	44
OS Permits	12	42	9	30	5	19	2	7	1	3	29
OW Permits	6	42	4	30	3	19	1	6	0	3	14
Total Wt of OW Permits (lb)	815,394	41	598,196	30	392,132	20	129,351	6	61,797	3	1,996,871
FY 2008											
OS/OW Permits	17	44	11	28	8	20	2	6	1	3	39
OS Permits	12	44	7	28	5	19	2	6	1	3	26
OW Permits	5	42	4	28	3	21	1	6	0	3	13
Total Wt of OW Permits (lb)	701,414	41	491,942	28	376,249	22	108,982	6	52,438	3	1,731,025
FY 2007											
OS/OW Permits	13	43	9	29	6	19	2	6	1	3	30
OS Permits	9	45	6	29	4	18	1	6	1	3	20
OW Permits	4	41	3	30	2	20	1	6	0	3	10
Total Wt of OW Permits (lb)	530,874	39	421,258	31	286,549	21	84,836	6	40,415	3	1,363,933
FY 2006											
OS/OW Permits	13	45	8	28	5	18	1	5	1	4	30
OS Permits	9	46	6	28	4	18	1	5	1	4	20
OW Permits	4	43	3	29	2	19	0	5	0	4	9
Total Wt of OW Permits (lb)	508,832	42	347,093	29	230,473	19	64,871	5	48,199	4	1,199,467
FY 2005											
OS/OW Permits	12	43	8	29	5	18	2	6	1	4	27
OS Permits	8	44	5	28	3	18	1	6	1	4	18
OW Permits	4	42	3	30	2	18	1	6	0	4	9
Total Wt of OW Permits (lb)	488,836	42	345,567	30	207,442	18	68,655	6	40,951	4	1,151,452
FY 2004											
OS/OW Permits	10	44	6	29	4	18	1	5	1	3	22
OS Permits	7	44	5	29	3	19	1	6	0	3	16
OW Permits	3	45	2	29	1	18	0	5	0	4	7
Total Wt of OW Permits (lb)	367,301	45	235,959	29	149,630	18	40,496	5	30,201	4	823,587

Table 17. OS/OW Permit-Miles by Highway Type (continued).

Highway Type	IH 3234 mi*		US 12,093 mi		SH/SL 15,425 mi		FM 37,978 mi		Other 4288 mi		Total (million miles)
	million miles**	%	million miles	%	million miles	%	million miles	%	million miles	%	
FY 2004–FY 2009											
OS/OW Permits	83	43	55	29	36	19	11	6	6	3	191
OS Permits	57	44	37	29	24	19	7	6	4	3	130
OW Permits	26	42	18	29	12	19	4	6	2	3	62
Total Weight of OW Permits (lb)	3,412,651	41	2,440,015	30	1,642,475	20	497,191	6	274,002	3	8,266,334

*Total centerline miles are based on the PMIS 2009 centerline layer and may not precisely reflect ground condition.
**The numbers in the table are in million centerline miles.

OS/OW Permits = $\sum_i^n \frac{N_i \times L_i}{1,000,000}$ where N_i is the number of OS/OW permits on the i^{th} roadway segment and L_i is the length of the roadway segment in miles.

OS Permits = $\sum_i^n \frac{N_i \times L_i}{1,000,000}$ where N_i is the number of OS permits on the i^{th} roadway segment and L_i is the length of the roadway segment in miles.

OW Permits = $\sum_i^n \frac{N_i \times L_i}{1,000,000}$ where N_i is the number of OW permits on the i^{th} roadway segment and L_i is the length of the roadway segment in miles.

Total Weight of OW Permits (lb) = $\sum_i^n \frac{W_i \times L_i}{1,000,000}$ where W_i is the total weight of OW loads in pounds traveled on the i^{th} roadway segment and L_i is the length of the roadway segment in miles.

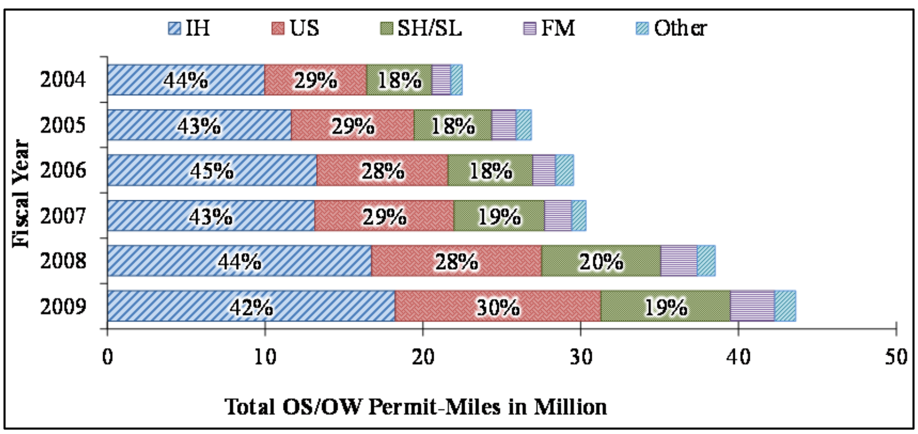


Figure 31. OS/OW Permit-Miles by Highway Type.

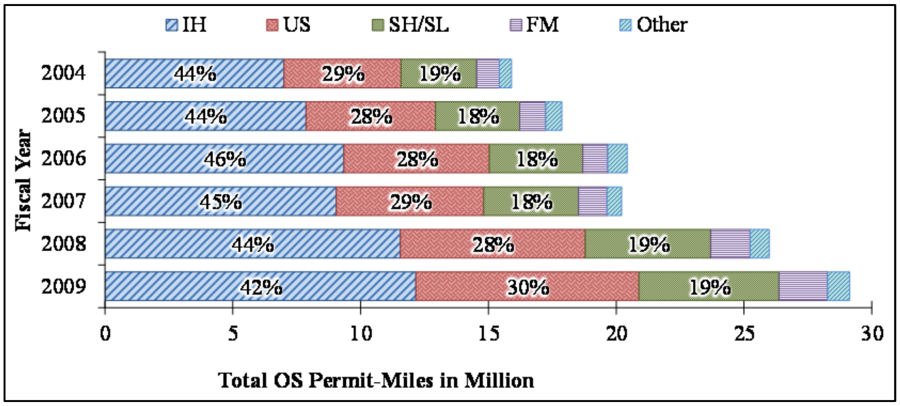


Figure 32. OS Permit-Miles by Highway Type.

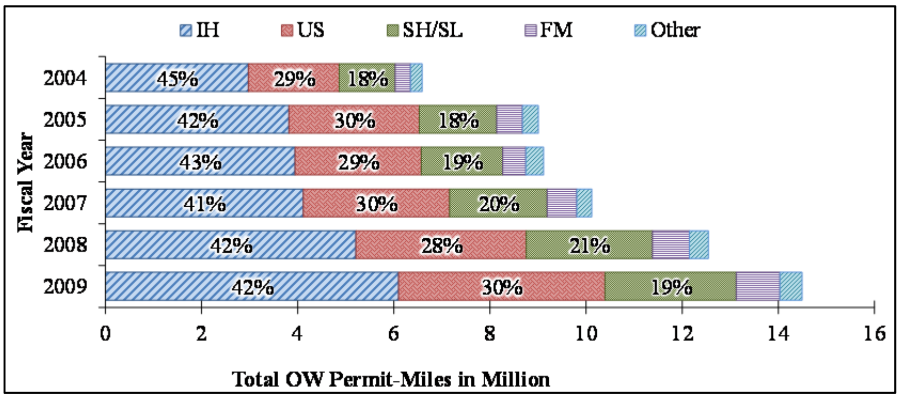


Figure 33. OW Permit-Miles by Highway Type.

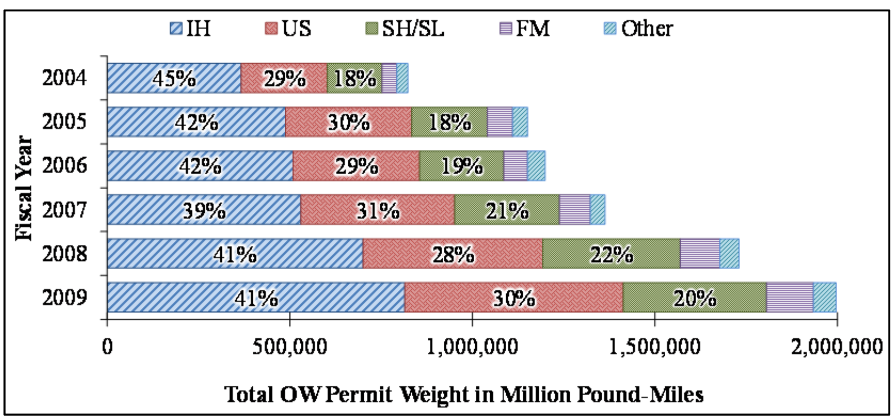


Figure 34. OW Permit Weight-Miles by Highway Type.

Figure 35 to Figure 38 illustrate the distribution of OS/OW permit trips for each type of roadway by comparing the accumulative permit-miles (for each roadway segment, this is the production of number of OS/OW permits on it and its length in miles) and the accumulative roadway-miles. Clearly, the figures suggest that OS/OW load trips were relatively widespread on major roadways such as interstates. On the other hand, a small proportion of FM highways were exposed to the majority of OS/OW load trips on FM roads, suggesting a much more localized and intensive impact to those roadway segments. As shown in Figure 38, 90 percent of the OS/OW load trips concentrated on about a third of FM roadway-miles. In addition, 20 percent of the FM roadways did not carry any OS/OW loads during the study period.

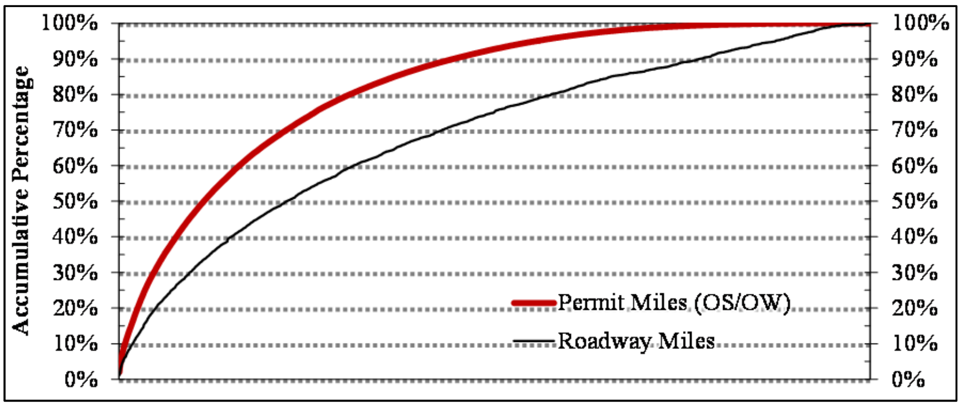


Figure 35. Accumulative OS/OW Permit-Miles versus Roadway-Miles (IH Highways).

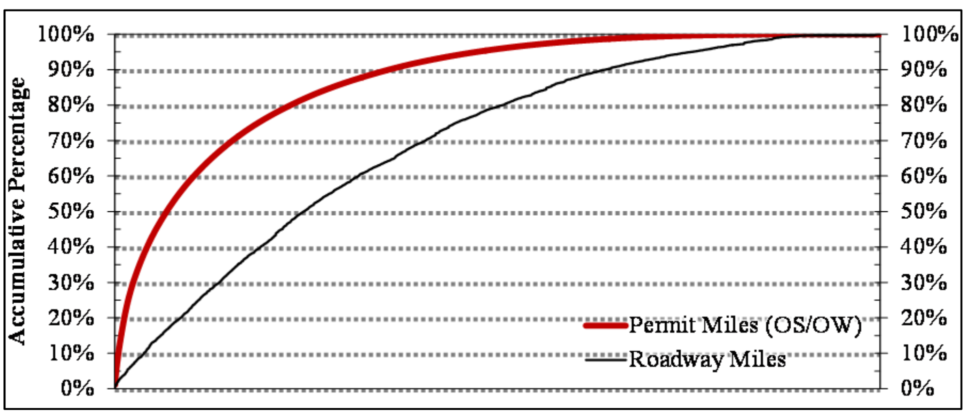


Figure 36. Accumulative OS/OW Permit-Miles versus Roadway-Miles (US Highways).

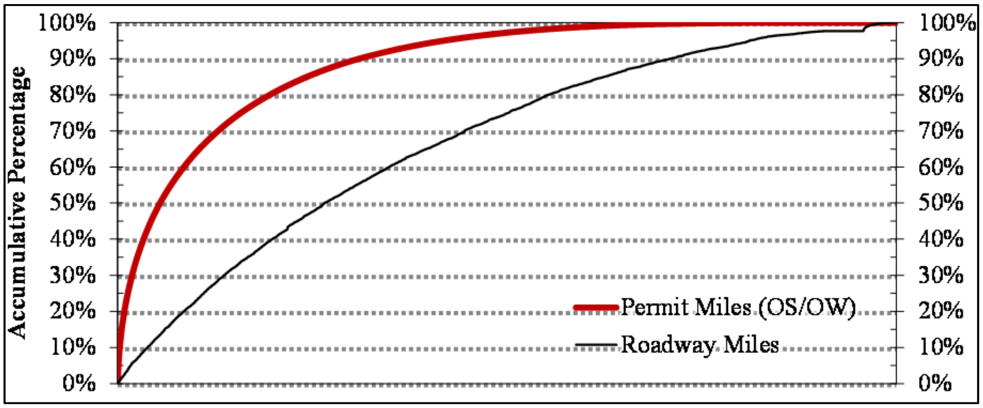


Figure 37. Accumulative OS/OW Permit-Miles versus Roadway-Miles (SH/SL Highways).

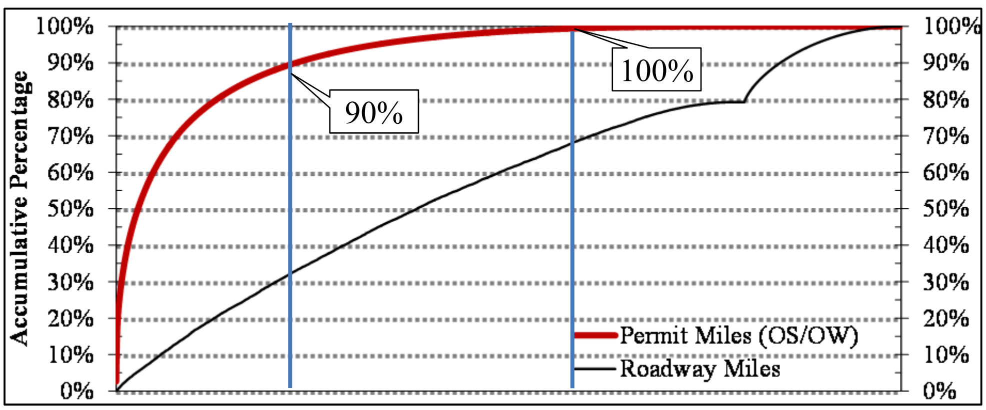


Figure 38. Accumulative OS/OW Permit-Miles versus Roadway-Miles (FM Highways).

Table 18 summarizes the average numbers of OS/OW permits (weighted by highway segment length) for each district by highway type. Figure 39 illustrates the weighted average numbers of permits graphically. As shown in the illustration, on average, Houston, El Paso, and Atlanta had the largest numbers of OS/OW loads routed on their highways. In addition, a relatively large proportion of OS/OW loads traveled on FM roadways in districts such as Atlanta, Odessa, Pharr, and Laredo.

Table 18. Average Number of OS/OW Permits by Highway Type and District.

District	IH Highways		US Highways		SH/SL Highways		FM Highways		Other Highways		Avg. (All Rds)
	Total Miles	Avg. Permits	Total Miles	Avg. Permits	Total Miles	Avg. Permits	Total Miles	Avg. Permits	Total Miles	Avg. Permits	
Houston	207	7392	231	3258	722	658	1166	116	83	828	1230
El Paso	187	6866	475	142	447	1327	372	10	258	55	1128
Atlanta	109	7195	461	2139	474	758	1541	259	17	1768	984
Beaumont	83	8706	310	2619	589	731	1120	131	75	26	970
Odessa	304	4539	463	483	821	590	962	194	292	907	893
Fort Worth	209	7184	474	1028	561	645	1433	70	124	222	886
Dallas	339	4480	353	1398	612	482	1508	31	72	1113	844
San Antonio	362	4222	428	587	956	873	1613	76	332	152	755
Bryan	111	9652	316	1106	608	425	1842	81	48	210	628
San Angelo	152	7928	817	535	610	255	615	39	904	114	621
Amarillo	174	3970	671	1578	828	427	1850	48	215	162	596
Lufkin	0	0	397	2684	677	439	1762	94	33	3106	568
Yoakum	96	10,311	560	897	748	317	1953	36	56	1023	544
Waco	115	5683	242	566	748	918	1977	54	51	539	514
Childress	37	3743	493	1685	526	415	1381	29	20	707	505
W. Falls	37	4944	535	1461	466	393	1572	41	65	2107	504
Tyler	83	5847	529	1219	858	592	2080	59	61	117	490
Abilene	161	4624	590	614	503	447	1973	36	89	1885	473
Austin	96	6457	496	670	705	440	844	88	910	22	446
Laredo	82	5042	550	386	462	373	787	137	218	68	439
Paris	75	4211	365	1627	606	289	1988	19	56	771	377
C. Christi	84	1562	430	1346	538	271	1486	55	109	95	358
Pharr	0	0	415	859	338	432	1276	176	115	283	354
Brownwood	40	6408	596	353	392	332	1525	26	60	4	243
Lubbock	90	1186	897	553	629	268	3354	59	24	279	196

Note: For each highway type, the number of average permits is weighted by its total highway miles, i.e., Average Permits = $\sum_i^n N_i \times L_i / \sum_i^n L_i$ where N_i is the number of OS/OW permits on i^{th} highway segment and L_i is the length of the segment in miles.

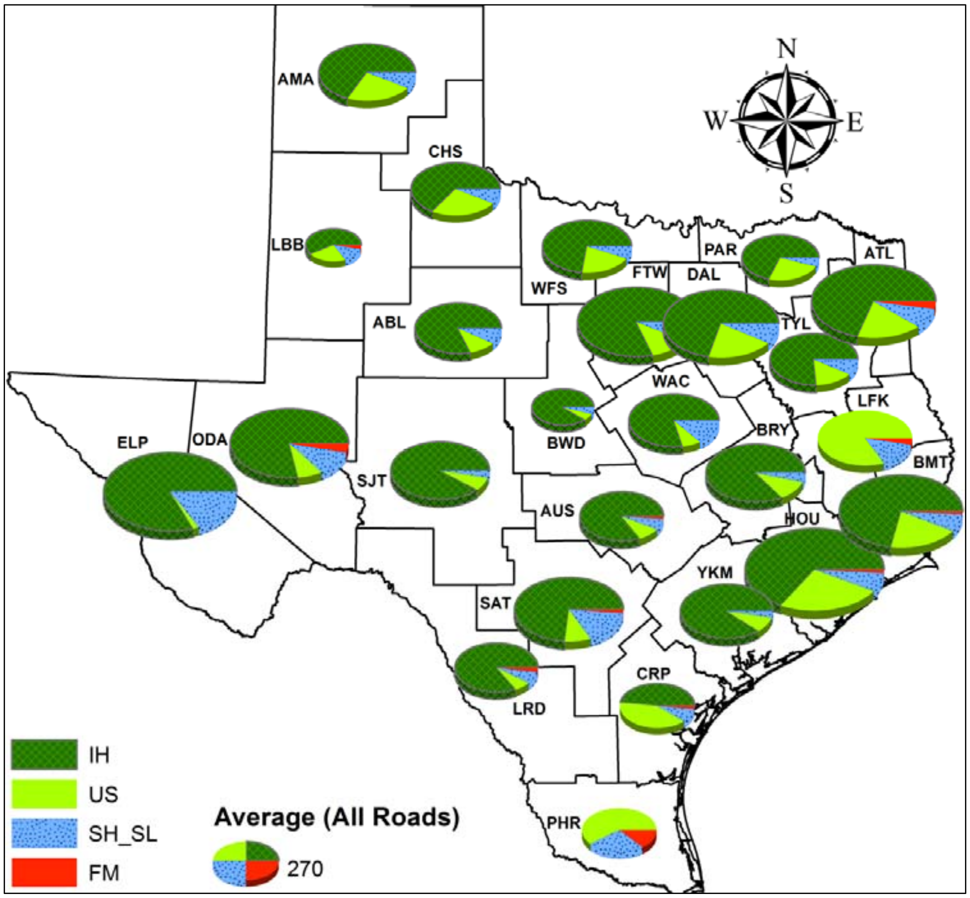


Figure 39. Average Number of OS/OW Permits by Highway Type.

Figure 40 shows the top 50 OS/OW corridors for IH, US, SH/SL, FM, and other highways. Researchers defined a corridor as a continuous section of the same highway (i.e., with the same highway name/number) separated from the rest of that highway in each direction by another segment where the average number of total OS/OW loads was different by more than 50 (if the larger of the two numbers was less than 200), or 25 percent otherwise. As shown, the busiest IH corridors included many sections of IH 10, IH 20, IH 30, and IH 35. The major US corridors used by OS/OW loads included many sections of US 59, US 90, and US 287. In addition, the busiest SH/SL and FM corridors used by OS/OW loads were generally detours/shortcuts along the major IH and US corridors or short corridors impacted by local activities.

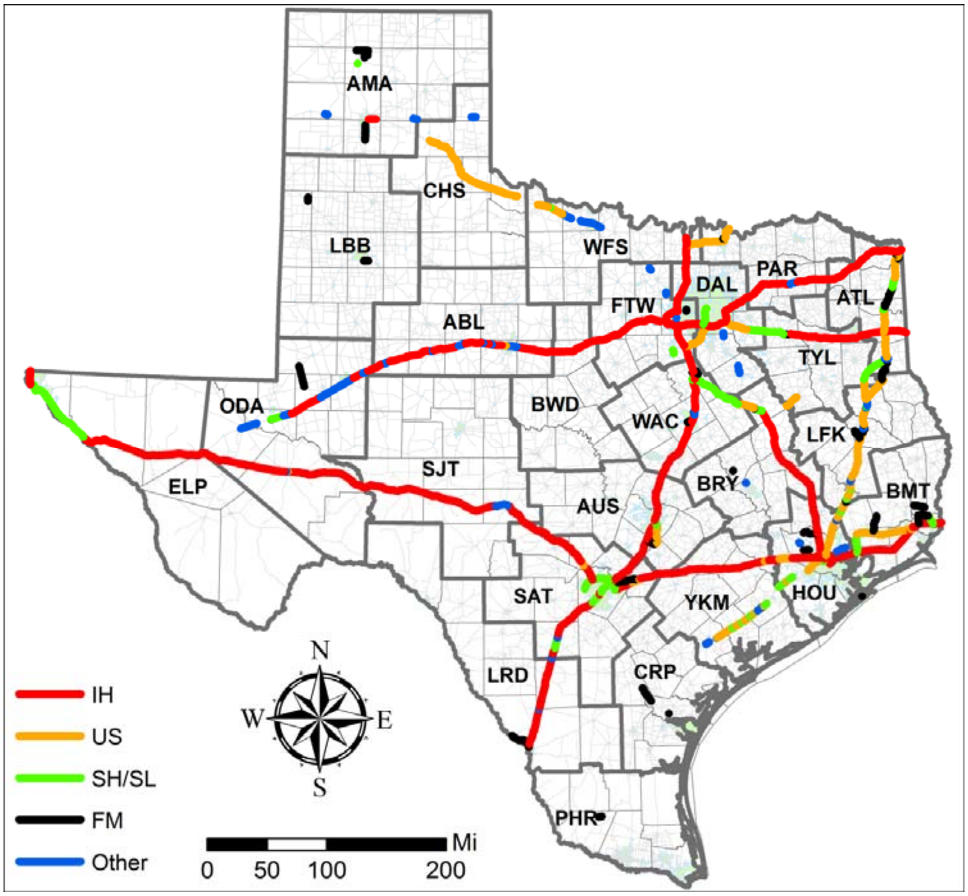


Figure 40. Top 50 OS/OW Corridors by Highway Type.

Table 19 lists the top 10 OS/OW corridors that were longer than 3 mi and their average daily permits by highway type. The daily averages are results of the routes that were successfully mapped using GIS that represented about 40 percent of the total OS/OW permits (see Table 15). As seen in the table, on average, between 20 and 32 OS/OW loads every day traveled on the busiest sections of IH highways. In addition, some busy FM roadway corridors carried more than five OS/OW loads every day.

Table 19. Top 10 OS/OW Corridors (Longer Than 3 Mi) by Highway Type.

Highway	Length (miles)	District	Avg. Daily Permits (FY04–09, weighted by length)		
			Overweight	Oversize	Total
IH Highways					
IH0020	9	Fort Worth	10	22	32
IH0020	19	Dallas	10	21	31
IH0610	14	Houston	9	22	31
IH0820	17	Fort Worth	8	17	25
IH0030	3	Atlanta	7	17	24
IH0010	7	Beaumont	7	16	23
IH0035W	42	Waco	7	15	22
IH0020	22	Fort Worth/Dallas	8	14	22
IH0010	107	El Paso	7	15	22
IH0035W	28	Fort Worth/Dallas	7	15	21
US Highways					
US0090	4	Beaumont	6	16	23
US0090	15	Yoakum/Houston	5	15	20
US0059	14	Lufkin	6	14	20
US0059	40	Lufkin	5	12	17
US0059	6	Beaumont	5	12	17
US0087	4	San Antonio	6	12	17
US0059	41	Atlanta	5	12	17
US0059	30	Houston	5	12	17
US0059	21	Atlanta	5	11	16
US0090	8	San Antonio	3	13	16
SH/SL Highways					
SH0020	66	El Paso	6	12	18
SL1604	26	San Antonio	5	12	17
SH0043	9	Atlanta	5	11	16
SH0049	3	Atlanta	5	11	15
SL0424	3	Lufkin	4	10	14
SL0293	3	Odessa	4	9	13
SH0171	42	Waco	4	9	13
SL0111	4	Austin	2	10	13
SS0581	8	San Antonio	2	9	12
SS0408	4	Dallas	5	7	12
FM Highways					
FM0248	18	Atlanta	5	10	15
FM0016	6	Tyler	3	6	10
FM0010	10	Atlanta	3	6	8
FM0999	3	Atlanta	2	6	8
FM1970	7	Lufkin/Atlanta	2	6	8
FM0078	4	San Antonio	2	3	5
FM0078	14	San Antonio	2	3	5
FM1472	19	Laredo	1	4	5
FM0105	7	Beaumont	1	3	4
FM2497	9	Lufkin	1	3	3

Table 19. Top 10 OS/OW Corridors (Longer Than 3 Mi) by Highway Type (continued).

Highway	Length (miles)	District	Avg. Daily Permits (FY04–09, weighted by length)		
			Overweight	Oversize	Total
Other Highways					
BU0059F	7	Lufkin	0.6	1.4	2
BU0067V	4	Paris	0.5	1.2	2
RM1674	10	San Angelo	0.5	1.1	2
BU0059J	4	Lufkin	0.4	1.1	2
BU0077L	5	Waco	0.5	1.0	1
BI0020M	6	Abilene	0.5	0.9	1
BI0020F	5	Odessa	0.4	0.8	1
BI0035E	4	San Antonio	0.2	0.9	1
BI0035D	4	San Antonio	0.2	0.9	1
BI0020J	6	Abilene	0.4	0.7	1

OS/OW Load Categories by Roadway

Figure 41 highlights the major routes taken by permitted loads where width and height were both greater than 16 ft. Because 16 ft was the 95th percentile of the studied OS/OW loads for load width and height (see Table 9), such loads became known as the top 5 percent of loads for convenience. Due to their large dimensions, panel members suggested that these big loads needed special attention and frequently caused problems such as damage to roadside/overhead structures on FM roadways. As illustrated in Figure 41, such loads frequently traveled in the Odessa and Atlanta Districts. A known factor contributing to frequent large loads in those areas was concentrated oil/gas and/or wind energy activities.

As indicated by the project panel and based on past research experience, FM highways are frequently subject to more severe damage of pavement and roadside/overhead infrastructure caused by OS/OW loads. FM roads are typically low-volume highways built with flexible pavement. They were originally developed to provide access to rural areas and to enable farmers and ranchers to bring their goods to market. Therefore, they are not designed and constructed to withstand frequent large and/or heavy loads. Using the generated GIS routes based on FY09 OS/OW permit data, the research team conducted a relatively detailed analysis of the major characteristics of those OS/OW loads on FM highways.

Figure 42, Figure 43, Figure 44, and Figure 45 show the OS/OW permit-miles on FM highways within individual TxDOT districts. To accurately assess the OS/OW load trips in each district, researchers used total permit-miles that were the summations of the number of OS/OW permits on each FM highway segment multiplied by its length (in miles). In addition, the figures also include the total FM miles in each district for comparison. Figure 42 illustrates that FM highways in districts such as Atlanta, Pharr, and Odessa carried many large loads. Odessa and Pharr, in particular, had proportionally many more loads that were taller than 14 ft compared to other districts.

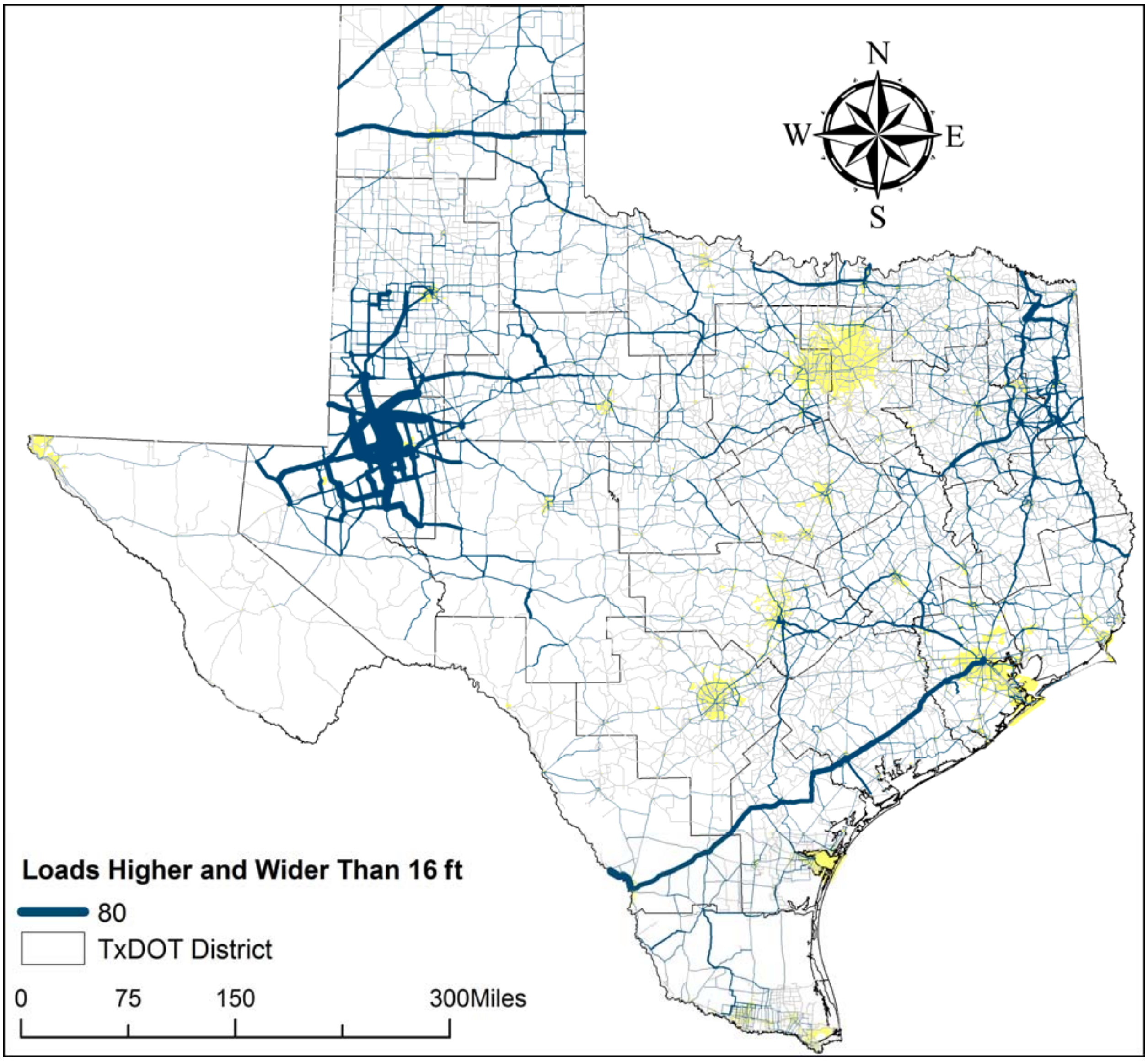


Figure 41. Distribution of the Top Five Percent OS/OW Loads (FY 2009).

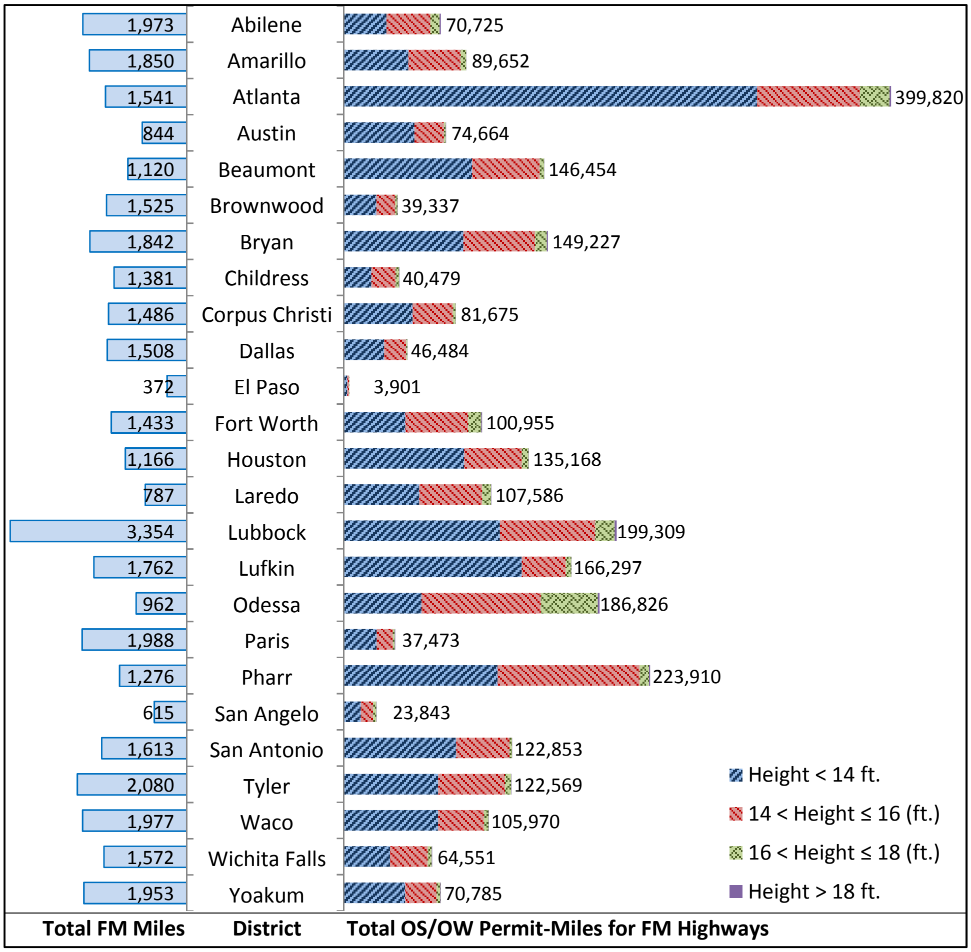


Figure 42. Total Permit-Miles on FM Highways by Load Height (FY09).

Figure 43 illustrates the distribution of OS/OW load trips in various TxDOT districts by load width. As shown, the majority of the OS/OW permit-miles involved large loads wider than 8.5 ft (the legal width). In addition, most of the loads on FM roads fell in the range between 8.5 ft and 16 ft. It is worth mentioning that loads wider than 12 ft were the dominant OS group for several districts, such as Pharr, Odessa, Bryan, and Fort Worth.

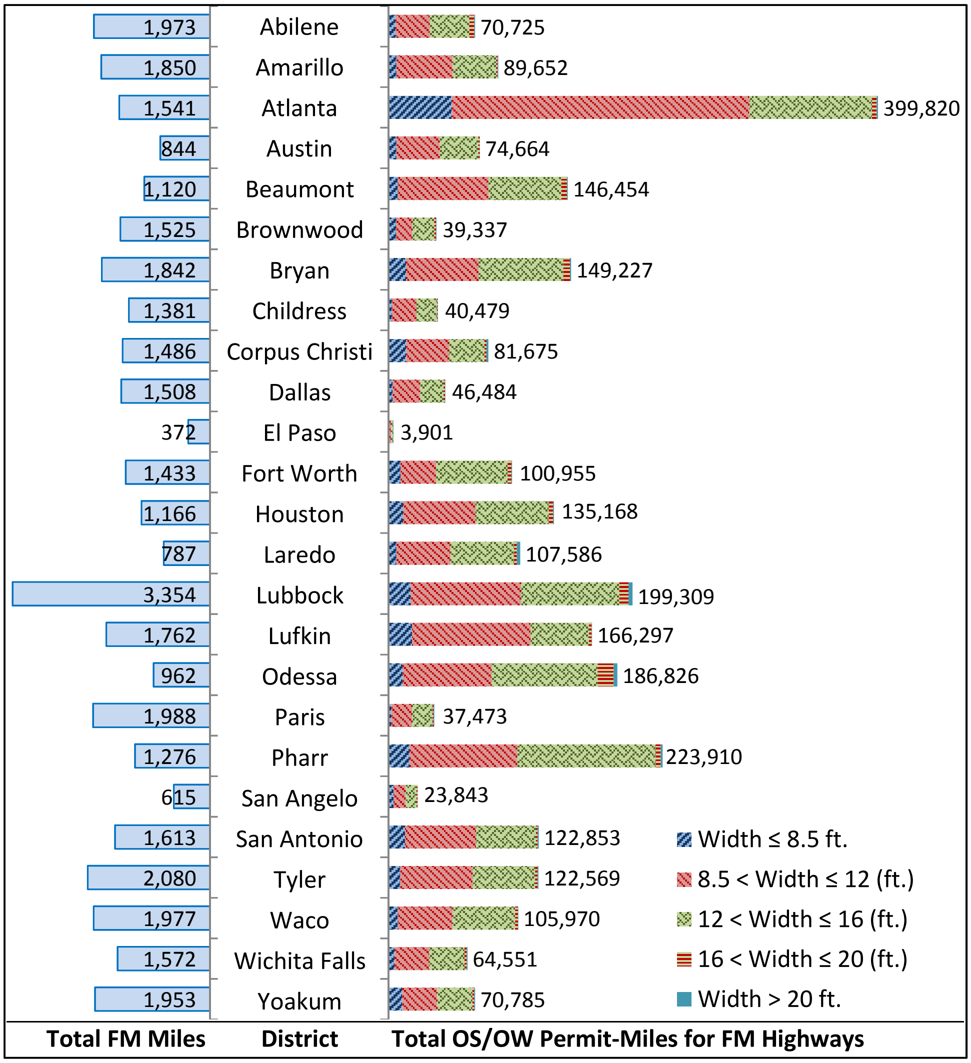


Figure 43. Total Permit-Miles on FM Highways by Load Width (FY09).

Figure 44 shows the distribution of OW load trips on FM roadways by gross vehicle weight. Again, Atlanta and Pharr were the two districts where FM highways carried the most overweight permit loads. Districts such as Odessa, Atlanta, and Pharr had a significant number of trips involving heavy vehicles weighing between 120,000 lb and 150,000 lb. In addition, the Atlanta, Pharr, and Bryan Districts had a large number of overweight permits involving vehicles weighing more than 175,000 lb. Among all districts, Abilene FM highways carried the most loads weighing more than 200,000 lb. This finding probably results from local wind farm development activities.

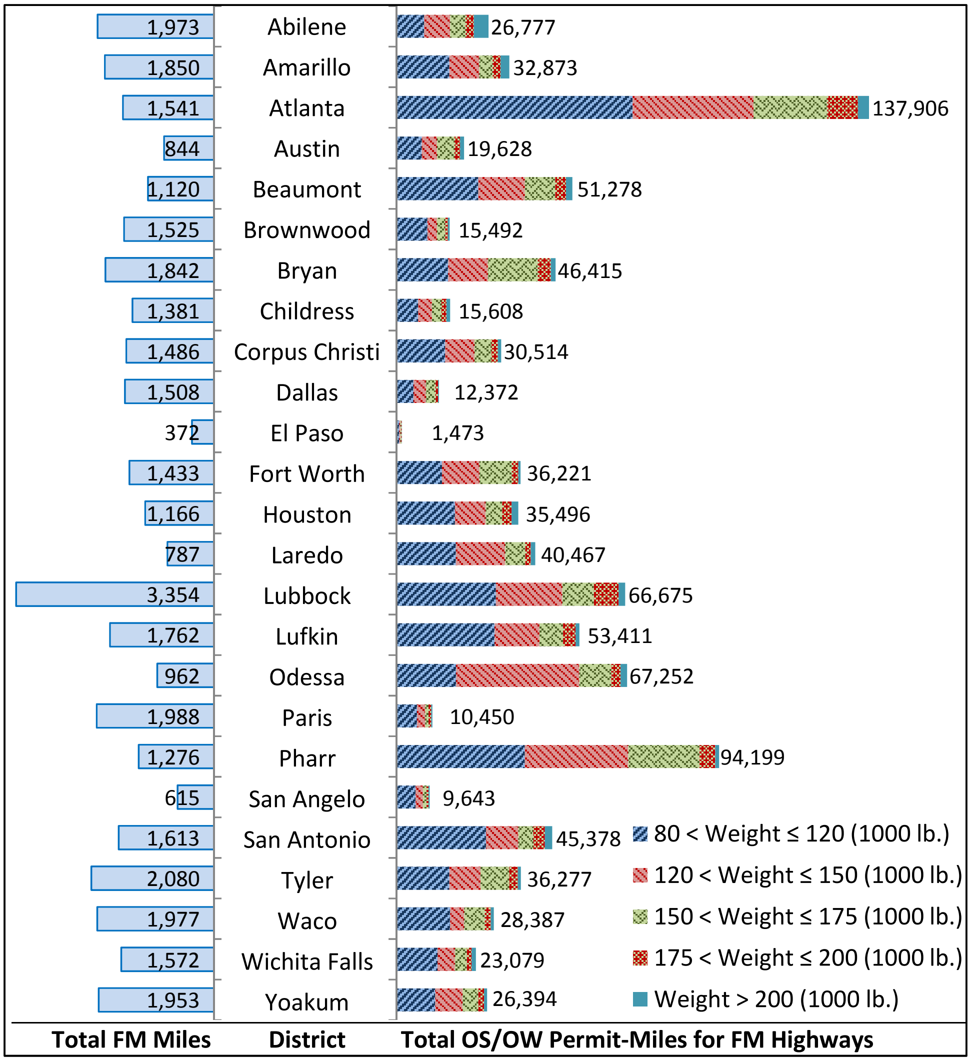


Figure 44. Total Permit-Miles on FM Highways by Load Weight.

Figure 45 further illustrates the OS/OW load trips related to energy development activities. The research team used a number of keywords to identify such loads (Table 10), realizing that it is virtually impossible to identify all such loads through this method. From the figure, FM roads in Odessa, Pharr, and Atlanta carried most loads related to oil/gas development, while Abilene had the largest proportion of permits involving loads associated with wind farm development.

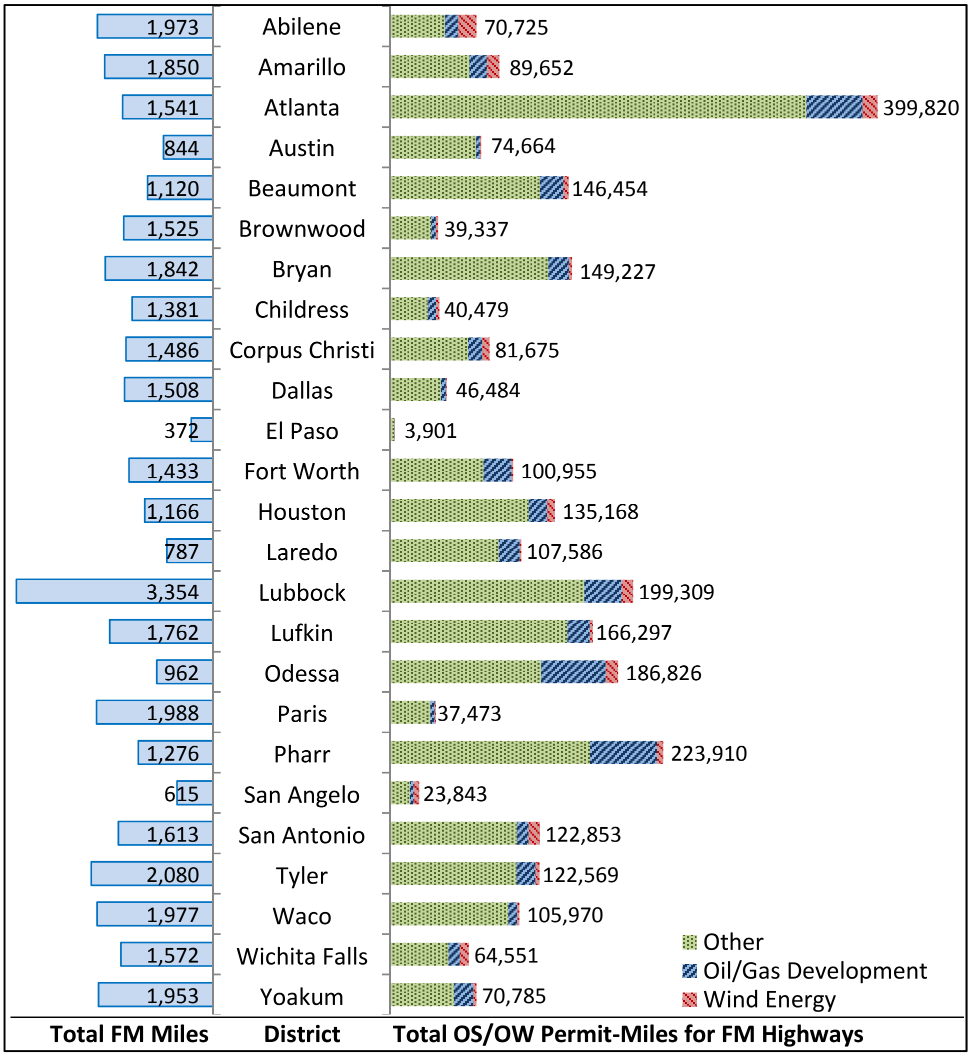


Figure 45. Total Permit-Miles on FM Highways by Load Type.

ORIGIN-DESTINATION ANALYSIS

Most Frequent OD

Table 20 lists the top 50 OD pairs in FY09 for the analyzed OS/OW permits, and Figure 46 graphically illustrates the major OD pairs. As seen from the illustrations, Houston, Dallas–Fort Worth, and El Paso were some of the major hubs generating/attracting OS/OW loads. Among those major hubs, Houston further stands out with highly frequent OS/OW trips originating or destined for the Houston area. This finding is undoubtedly due, at least in part, to activities at the Port of Houston. Based on the top OD pairs, there were a significant number of OS/OW permits from Louisiana and Arkansas destined for Houston. In addition, many OS/OW loads traveled between Oklahoma and New Mexico via the Texas panhandle. A significant number of trans-state OS/OW trips occurred between El Paso, Laredo, or Houston and the surrounding states.

Table 20. Top 50 OS/OW Origin-Destination Pairs.

No.	Origin-Destination	Number of Permits Originated						
		FY04	FY05	FY06	FY07	FY08	FY09	Total
1	HOUSTON TO LA STATE LINE @ IH0010	1438	494	1150	2261	2528	3098	10,969
2	HOUSTON TO HOUSTON	3940	2737	1907	2039	1519	2561	14,703
3	LA STATE LINE @ IH0010 TO HOUSTON	974	435	2187	2692	2626	2319	11,233
4	OK STATE LINE @ IH0040 TO NM STATE LINE @ IH0040	2798	2409	2530	2007	4296	2268	16,308
5	NM STATE LINE @ IH0040 TO OK STATE LINE @ IH0040	1902	1508	1646	1285	2476	2043	10,860
6	AR STATE LINE @ US0067 TO HOUSTON	6	0	2	500	979	1448	2935
7	ELM MOTT TO DALLAS	129	23	79	203	1269	1301	3004
8	SAN ANTONIO TO SAN ANTONIO	1373	784	822	898	888	1239	6004
9	OK STATE LINE @ SH0152 TO NM STATE LINE @ IH0040	1	0	2	0	65	1089	1157
10	HOUSTON TO AR STATE LINE @ US0067	1	1	0	184	673	1040	1899
11	LAREDO TO LAREDO	926	415	317	692	740	989	4079
12	LA STATE LINE @ IH0020 TO NM STATE LINE @ IH0010	1440	883	1552	822	986	943	6626
13	LAREDO TO LA STATE LINE @ IH0010	141	29	114	668	714	879	2545
14	AR STATE LINE @ IH0030 TO HOUSTON	1155	1317	1600	1140	866	852	6930
15	HOUSTON TO OK STATE LINE @ IH0035	242	320	537	570	791	841	3301
16	MEX STATE LINE @ SH0255 TO LAREDO	2	3	16	9	566	782	1378
17	ODESSA TO ODESSA	318	266	288	355	467	765	2459
18	HOUSTON TO NM STATE LINE @ IH0010	854	340	358	486	720	738	3496
19	HOUSTON TO AR STATE LINE @ IH0030	906	867	811	813	569	691	4657
20	NM STATE LINE @ IH0010 TO LA STATE LINE @ IH0020	780	841	1345	391	732	677	4766
21	LAREDO TO HOUSTON	411	228	220	359	490	638	2346
22	HOOKS TO AR STATE LINE @ IH0030	84	50	239	302	303	607	1585
23	FORT WORTH TO FORT WORTH	247	237	234	230	261	597	1806
24	OK STATE LINE @ IH0035 TO HOUSTON	300	185	192	360	489	593	2119
25	NM STATE LINE @ IH0010 TO LA STATE LINE @ IH0010	274	152	147	635	792	588	2588
26	BELTON TO SAN ANTONIO	25	9	4	3	0	576	617
27	NM STATE LINE @ IH0010 TO HOUSTON	505	315	307	538	668	554	2887
28	NM STATE LINE @ IH0010 TO EL PASO	290	200	353	262	331	550	1986
29	SAN MARCOS TO EL PASO	1	0	0	0	121	546	668
30	HOUSTON TO OK STATE LINE @ US0075	447	417	573	647	662	515	3261
31	AR STATE LINE @ US0067 TO NM STATE LINE @ IH0010	0	0	0	126	256	480	862
32	FORT WORTH TO LA STATE LINE @ IH0020	205	180	455	345	354	474	2013
33	LA STATE LINE @ IH0010 TO NM STATE LINE @ IH0010	349	94	413	608	600	457	2521
34	FORT WORTH TO OK STATE LINE @ IH0035	194	151	116	172	280	450	1363

Table 20. Top 50 OS/OW Origin-Destination Pairs (continued).

No.	Origin-Destination	Number of Permits Originated						
		FY04	FY05	FY06	FY07	FY08	FY09	Total
35	OK STATE LINE @ US0259 TO HOUSTON	84	90	161	237	287	438	1297
36	GALVESTON TO LA STATE LINE @ IH0010	139	68	248	420	479	436	1790
37	AR STATE LINE @ US0067 TO LAREDO	0	1	0	140	323	424	888
38	NM STATE LINE @ IH0010 TO LAREDO	152	223	158	197	344	421	1495
39	LA STATE LINE @ IH0010 TO LAREDO	135	70	294	436	493	411	1839
40	OK STATE LINE @ US0075 TO HOUSTON	566	617	378	435	566	406	2968
41	HOUSTON TO OK STATE LINE @ US0287	104	82	102	65	106	394	853
42	LA STATE LINE @ IH0020 TO OK STATE LINE @ US0287	166	135	185	66	83	389	1024
43	ODESSA TO NM STATE LINE @ SH0176	304	342	410	323	331	388	2098
44	AR STATE LINE @ IH0030 TO LAREDO	708	526	844	496	459	383	3416
45	HOUSTON TO LAREDO	374	319	272	194	323	381	1863
46	LA STATE LINE @ IH0020 TO OK STATE LINE @ IH0035	275	134	212	194	346	373	1534
47	LA STATE LINE @ IH0010 TO GALVESTON	133	45	160	237	283	350	1208
48	OK STATE LINE @ IH0035 TO LA STATE LINE @ IH0020	175	139	142	179	232	349	1216
49	LA STATE LINE @ SH0012 TO HOUSTON	486	27	94	80	49	346	1082
50	EL PASO TO EL PASO	228	152	109	196	208	345	1238

Note: OD pairs ranked based on total number of permits in FY09; the numbers of permits reflect the permits that were successfully processed in GIS.

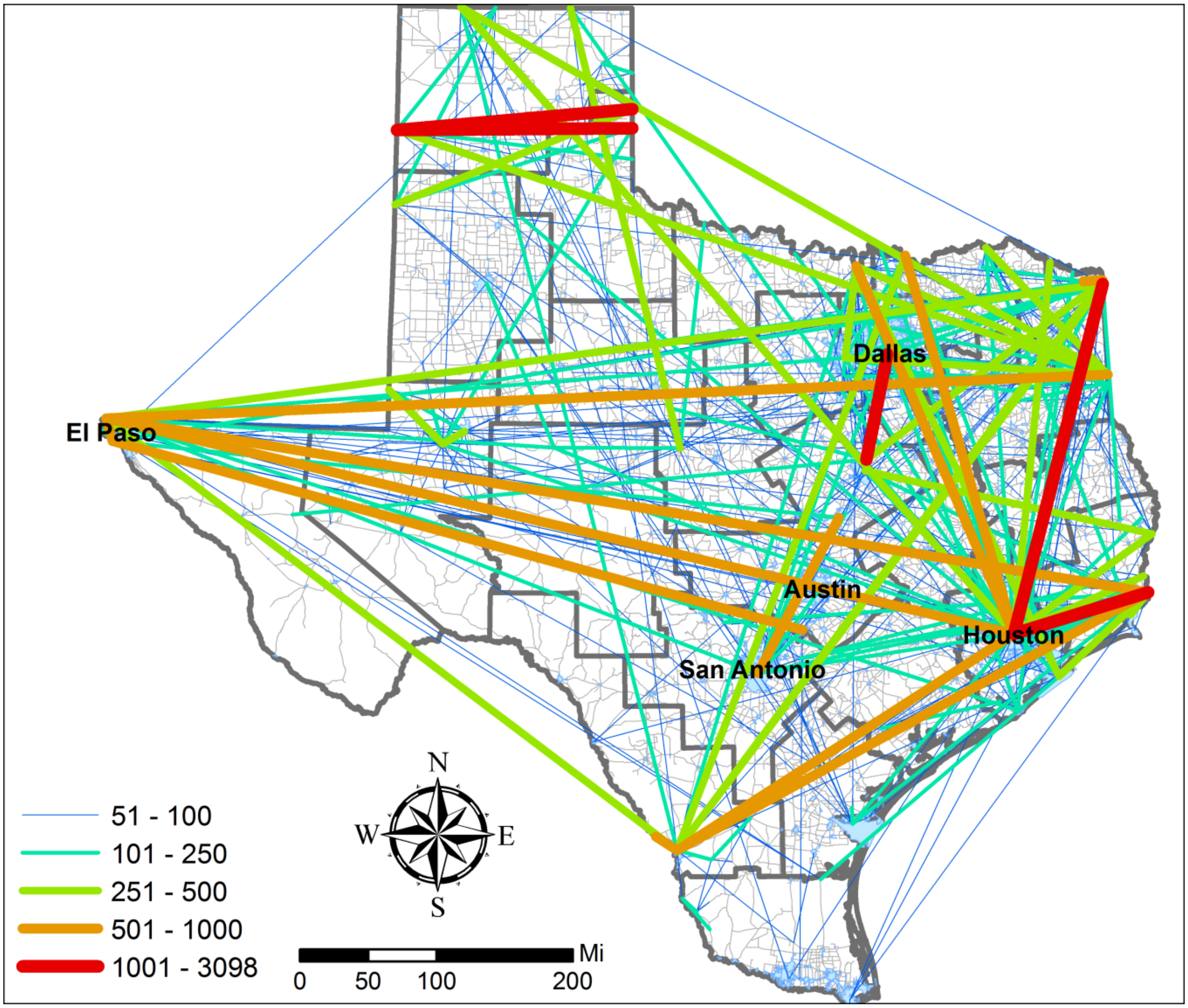


Figure 46. Major OS/OW Origin-Destination Pairs in Texas (FY09).

Table 21 lists the top 50 origins for OS/OW loads in Texas, and Figure 47 further shows the major origins of OS/OW loads on a map. As shown by the illustrations, Houston, Louisiana, Arkansas, and New Mexico were among the most popular areas generating OS/OW trips. Notice that Fort Worth and Odessa generated large numbers of OS/OW trips in FY09, which coincided with the intense oil/gas activities in the two areas.

Table 21. Top 50 OS/OW Origins.

No.	Origin	Number of Permits Originated						
		FY04	FY05	FY06	FY07	FY08	FY09	Total
1	HOUSTON	16,060	11,230	11,381	13,954	14,300	17,249	84,174
2	LA STATE LINE @ IH0010	2933	1848	5874	7743	7754	7434	33,586
3	LA STATE LINE @ IH0020	5686	4591	6581	5229	4914	6166	33,167
4	AR STATE LINE @ US0067	23	8	7	1807	3770	6110	11,725
5	FORT WORTH	5491	3601	3985	3498	4146	5804	26,525
6	NM STATE LINE @ IH0010	4413	3361	4155	3649	5527	5621	26,726
7	LAREDO	3957	2709	3094	3443	4234	5448	22,885
8	SAN ANTONIO	6308	4774	5062	4994	4902	4977	31,017
9	ODESSA	3193	2726	3359	2799	3153	4413	19,643
10	OK STATE LINE @ IH0035	1986	1571	1619	2427	3058	3820	14,481
11	AR STATE LINE @ IH0030	7999	6978	8409	5375	3737	3646	36,144
12	NM STATE LINE @ IH0040	2335	1904	1998	1624	3068	3019	13,948
13	OK STATE LINE @ IH0040	3775	3184	4000	2953	5879	2813	22,604
14	ELM MOTT	1693	1186	900	718	2041	2688	9226
15	WACO	4691	2689	2136	972	1812	2600	14,900
16	CORPUS CHRISTI	1814	1220	907	1892	2366	2193	10,392
17	LONGVIEW	1688	1544	1532	1477	1572	2151	9964
18	MIDLAND	1399	968	1027	1326	1728	2086	8534
19	OK STATE LINE @ SH0152	271	434	699	537	615	2081	4637
20	OK STATE LINE @ US0075	3698	3389	2725	2660	3412	2009	17,893
21	GALVESTON	1060	740	1109	1180	1757	1784	7630
22	OK STATE LINE @ US0287	843	712	884	684	1258	1680	6061
23	BEAUMONT	1255	865	858	1420	1426	1622	7446
24	DALLAS	2014	1570	1485	1136	1217	1577	8999
25	AUSTIN	2116	1395	1384	1181	1114	1465	8655
26	TYLER	1948	1436	991	908	1064	1455	7802
27	LA STATE LINE @ US0079	989	933	887	1324	1315	1404	6852
28	CENTER	1331	1064	1093	1191	1157	1292	7128
29	OK STATE LINE @ US0271	1009	811	774	937	938	1288	5757
30	VICTORIA	1785	1963	1119	932	1202	1234	8235
31	LA STATE LINE @ US0190	193	118	221	465	633	1170	2800
32	BURLESON	2056	1432	1407	721	729	1138	7483
33	OK STATE LINE @ US0377	924	530	1195	793	666	1092	5200
34	OK STATE LINE @ US0083	364	482	462	646	816	1076	3846
35	EL PASO	1174	641	608	787	1086	1072	5368
36	SEGUIN	603	402	393	485	691	1068	3642
37	BEEVILLE	693	356	350	441	575	1060	3475
38	LA STATE LINE @ SH0012	1669	291	349	355	277	1032	3973
39	LA PORTE	805	651	726	879	730	1031	4822
40	LUBBOCK	883	509	495	486	581	1006	3960
41	OK STATE LINE @ US0054	436	485	750	714	880	991	4256
42	HOOKS	197	134	326	505	602	987	2751
43	FREEPORT	167	129	125	261	346	969	1997
44	SAN ANGELO	1057	857	802	1149	1190	966	6021
45	BELTON	822	427	407	293	300	965	3214
46	OK STATE LINE @ US0259	311	293	485	522	606	959	3176
47	ZAPATA	569	481	477	467	365	902	3261
48	MEX STATE LINE @ SH0255	2	3	16	11	597	899	1528
49	CLEBURNE	397	288	405	678	727	883	3378
50	ABILENE	493	452	365	421	429	862	3022

Note: OD pairs ranked based on total number of permits in FY09; the numbers of permits reflect the permits that were successfully processed in GIS.

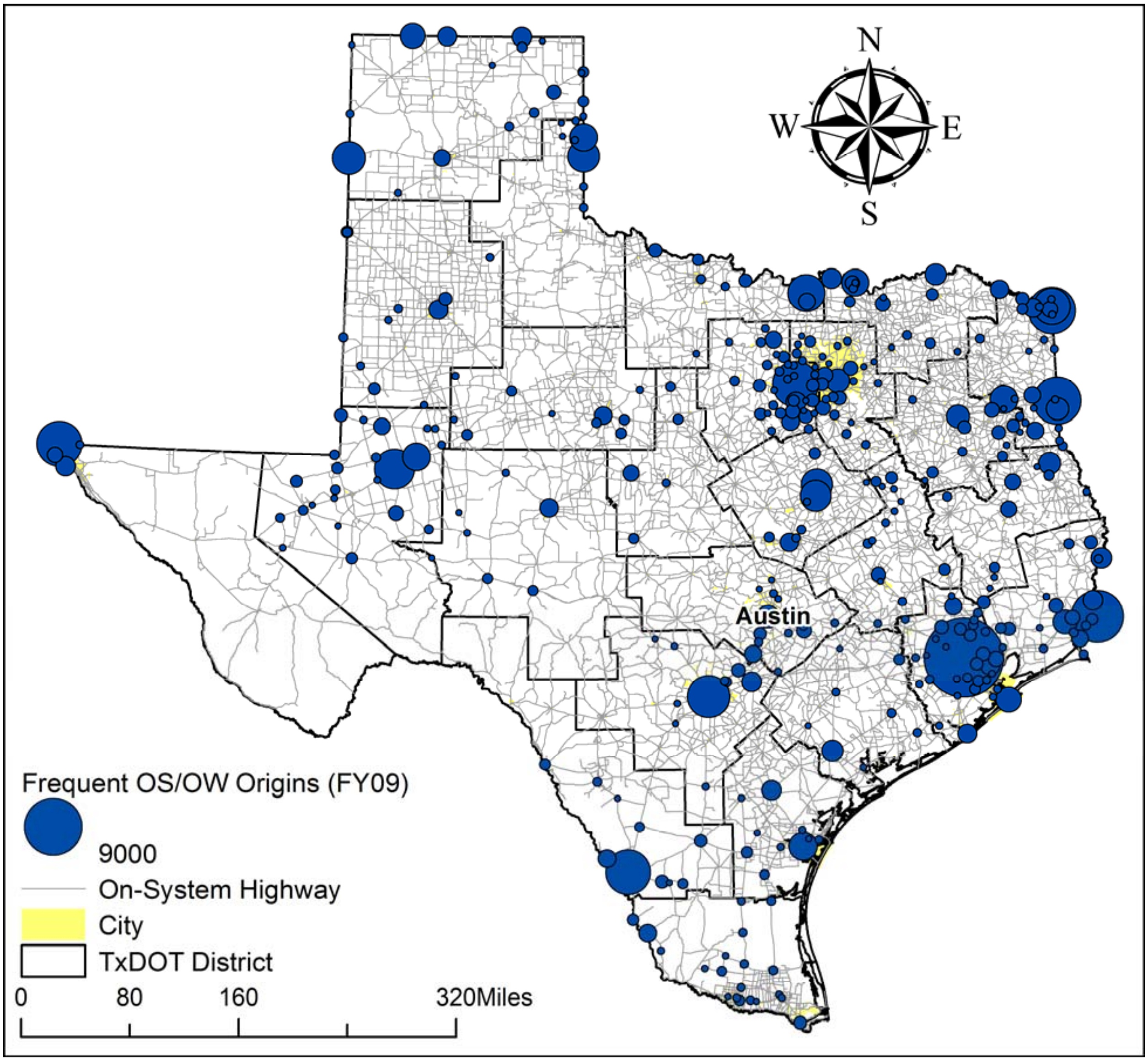


Figure 47. Major OS/OW Origins in Texas (FY09).

Table 22 and Figure 48 show the major OS/OW trip destinations in Texas. The illustrations suggest that the most popular destinations for OS/OW trips were generally popular origins as well. However, compared with the distribution pattern of OS/OW trip origins, the destinations were concentrated in much fewer locations. As illustrated, port or border locations such as Houston, Beaumont, and El Paso attracted many more OS/OW loads than they originated.

Table 22. Top 50 OS/OW Destinations.

No.	Destination	Number of Permits Originated						
		FY04	FY05	FY06	FY07	FY08	FY09	Total
1	HOUSTON	15,496	11,172	11,603	14,248	13,945	17,083	83,547
2	LA STATE LINE @ IH0010	3287	1509	3033	6560	8157	8856	31,402
3	LAREDO	4116	3095	3165	3657	5171	5956	25,160
4	LA STATE LINE @ IH0020	3918	3476	5354	3637	4211	5318	25,914
5	NM STATE LINE @ IH0010	6017	3716	5003	4457	5473	5281	29,947
6	OK STATE LINE @ IH0035	2505	2020	2006	2412	3721	4663	17,327
7	NM STATE LINE @ IH0040	3642	3089	3092	2522	5031	4613	21,989
8	AR STATE LINE @ US0067	18	14	12	717	2338	4591	7690
9	SAN ANTONIO	4206	2790	3167	3048	3178	4162	20,551
10	ODESSA	1963	1701	1758	1910	2166	3728	13,226
11	FORT WORTH	3417	2689	2587	2341	2310	3591	16,935
12	AR STATE LINE @ IH0030	5944	4935	6644	3471	2726	3385	27,105
13	DALLAS	3198	2052	1933	1778	3319	3309	15,589
14	EL PASO	1310	981	1498	1510	1615	3171	10,085
15	OK STATE LINE @ IH0040	2437	1891	2389	1791	3186	2685	14,379
16	OK STATE LINE @ US0287	1038	833	1183	877	1086	2259	7276
17	MIDLAND	1117	978	1127	1593	1574	2005	8394
18	OK STATE LINE @ US0075	3534	3033	2655	2562	2743	1850	16,377
19	LA STATE LINE @ US0079	976	769	681	1016	881	1780	6103
20	CORPUS CHRISTI	1714	1261	933	1564	1865	1754	9091
21	PORT ARTHUR	701	679	692	626	856	1559	5113
22	GALVESTON	730	490	648	770	1228	1507	5373
23	LONGVIEW	1886	1099	1058	1017	1243	1387	7690
24	BEAUMONT	1227	671	769	971	1044	1378	6060
25	LA STATE LINE @ US0190	608	465	770	787	818	1304	4752
26	AUSTIN	1859	1460	1824	1937	1535	1276	9891
27	TYLER	1752	1264	936	906	969	1208	7035
28	OK STATE LINE @ US0083	412	372	431	718	646	1103	3682
29	LA PORTE	1177	722	765	863	878	1043	5448
30	VICTORIA	945	793	732	755	881	1022	5128
31	IRVING	2345	1726	1008	925	823	944	7771
32	NM STATE LINE @ US0060	625	506	979	485	880	927	4402
33	OK STATE LINE @ US0377	1669	708	1693	810	632	916	6428
34	CLEBURNE	445	454	675	648	871	914	4007
35	CARTHAGE	490	411	319	740	737	904	3601
36	STERLING CITY	32	68	45	712	830	871	2558
37	NM STATE LINE @ SH0176	621	642	695	761	742	852	4313
38	DECATUR	430	313	222	285	419	852	2521
39	CONROE	1079	681	547	527	769	835	4438
40	TEXARKANA	638	544	491	410	804	818	3705
41	MARSHALL	553	489	545	458	480	784	3309
42	LUFKIN	675	508	569	424	473	768	3417
43	ABILENE	495	414	463	711	505	740	3328
44	ANDREWS	423	338	417	417	582	734	2911
45	AMARILLO	869	669	563	497	633	729	3960
46	LUBBOCK	784	547	510	521	892	721	3975
47	OK STATE LINE @ US0081	588	504	114	233	418	687	2544
48	ARLINGTON	382	361	261	367	536	683	2590
49	ZAPATA	636	631	494	603	551	665	3580
50	BROWNSVILLE	421	209	296	455	500	662	2543

Note: OD pairs ranked based on total number of permits in FY09; the numbers of permits reflect the permits that were successfully processed in GIS.

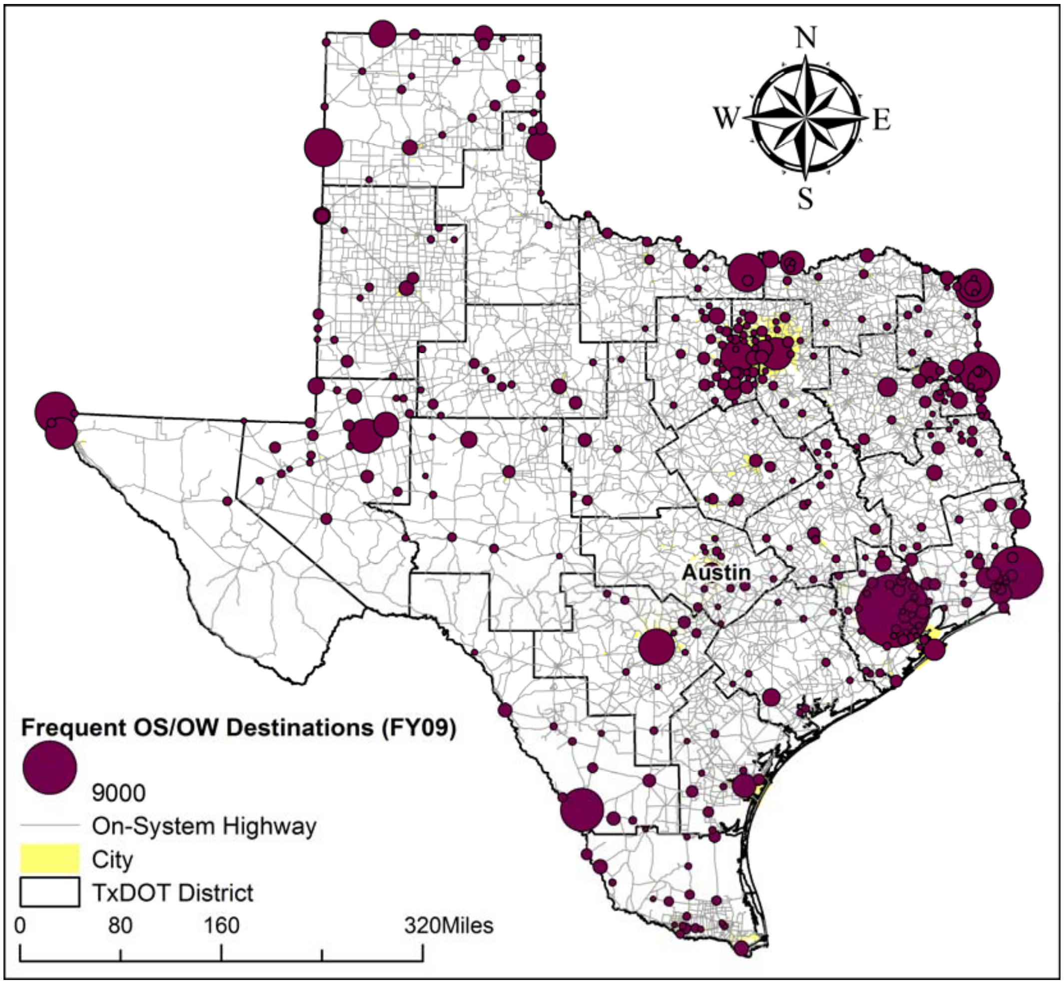


Figure 48. Major OS/OW Destinations in Texas (FY09).

Table 23 and Figure 49 illustrate the composition of the OS/OW permits in FY09 by trip type. As shown by the illustrations, among the OS/OW trips analyzed in FY09, about 45 percent were interstate trips and 55 percent were intra-Texas trips. Among the inter-Texas trips, about 7 percent of the total involved OS/OW loads transported from or to a neighboring state passing through Texas. As illustrated by Figure 46, most of those trans-Texas trips were between Oklahoma and New Mexico, passing through the Texas panhandle. In this analysis, an intrastate trip is one that either originated or terminated at a Texas border. Trans-Texas trips are those that both originated and terminated at a Texas border.

Table 23. Numbers of Interstate, Intrastate, and Trans-State OS/OW Trips.

Trip Type	Number	Percent of Total
Interstate Trips	**108,565**	**44.9%**
From Texas	**62,492**	**25.8%**
To Texas	**63,352**	**26.2%**
Trans-Texas Trips	**17,279**	**7.1%**
Intrastate Trips	**133,440**	**55.1%**
Total	**242,005**	**100.0%**

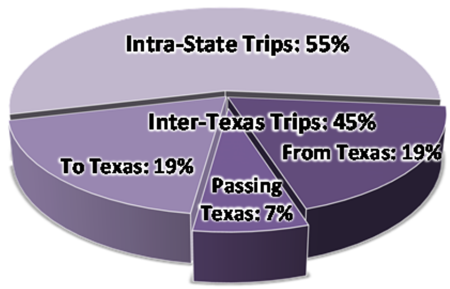


Figure 49. Types of OS/OW Trips.

Table 24 further lists the proportions of the OS/OW trips involving the individual neighboring states. As illustrated, most of the interstate OS/OW trips involved Louisiana and Oklahoma, followed by New Mexico and Arkansas. A small portion of the trips involved Mexico. Interestingly, there were more OS/OW loads transported from Oklahoma than to Oklahoma, whereas more loads were transported to Louisiana than from Louisiana.

Table 24. Numbers of OS/OW Trips from and to Neighboring States.

Origin/Destination	Trips From		Trips To	
Arkansas	10,591	4.4%	9004	3.7%
Louisiana	18,391	7.6%	20,078	8.3%
New Mexico	11,660	4.8%	14,391	5.9%
Oklahoma	21,565	8.9%	18,517	7.7%
Mexico	1134	0.5%	513	0.2%
Total	63,341	26.2%	62,503	25.8%

Figure 50 and Figure 51 show the major OS/OW OD pairs based on the FY09 data. Again, Houston, El Paso, Dallas, and Laredo were some of the major origins and/or destinations for the studied OS/OW permits. Notice that there was a large volume of OW traffic traveling between Waco and Dallas (Figure 50).

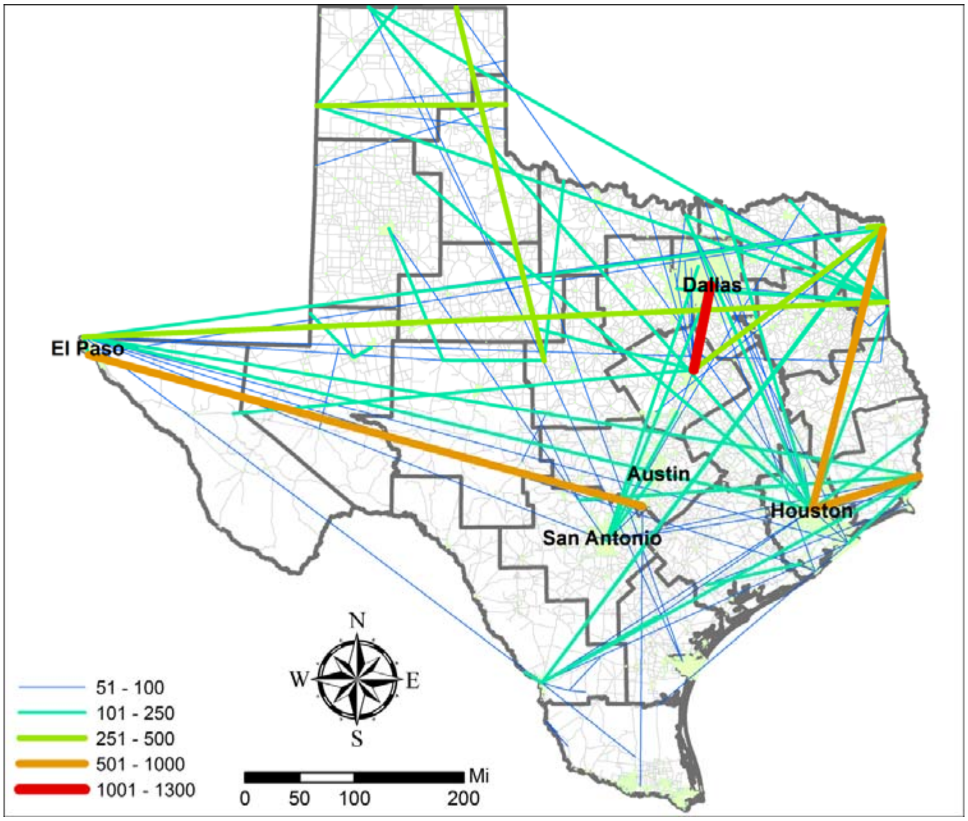


Figure 50. Major Origin-Destination Pairs for Overweight Loads (FY09).

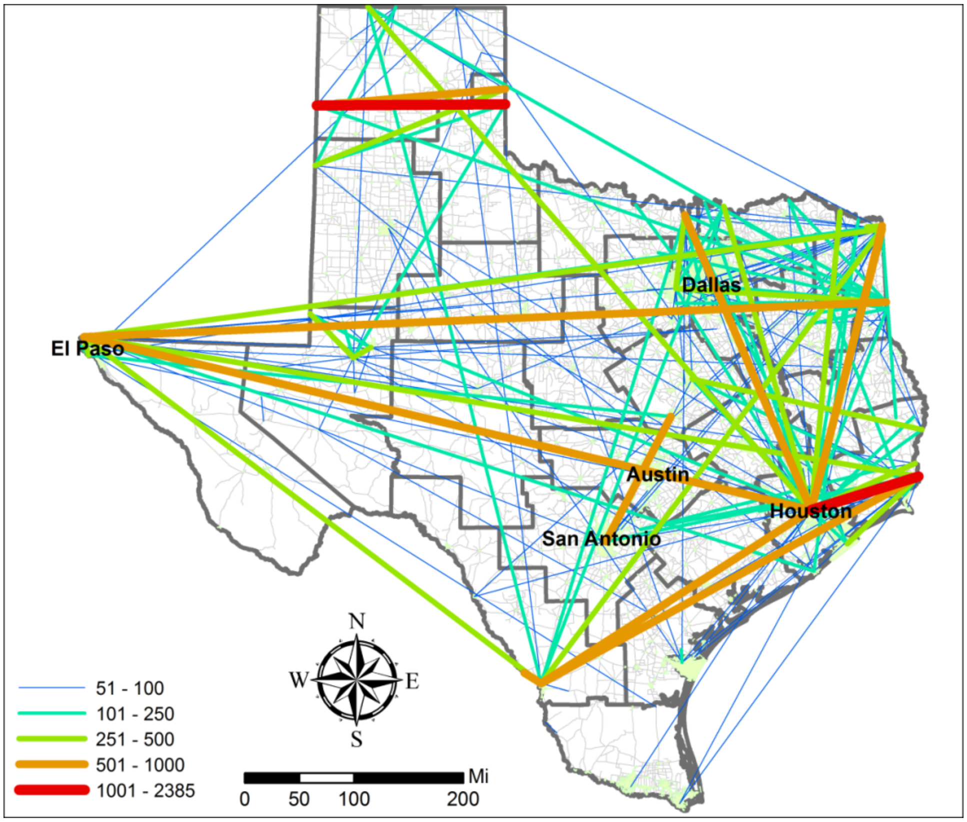


Figure 51. Major Origin-Destination Pairs for Oversize Loads (FY09).

Analysis of OS/OW Load Types for Major ODs

To better understand the travel patterns of OS/OW loads in Texas, the research team further analyzed the OD pairs by load type. Figure 52 shows the major OD pairs for the top 5 percent of OS loads in FY09. Odessa and Dallas were clearly two focal points that generated and/or attracted the largest and heaviest loads. Also, many such loads were transported for relatively shorter distances as compared to the OD pairs in general.

Table 25 lists the 20 most frequent origins and destinations for the top 5 percent of OS loads during the six-year study period. Figure 53 and Figure 54 further illustrate the locations of the major origins and destinations. As illustrated, many such large loads traveled from or to cities in the Lubbock and Odessa Districts, possibly relevant to the local oil/gas activities.

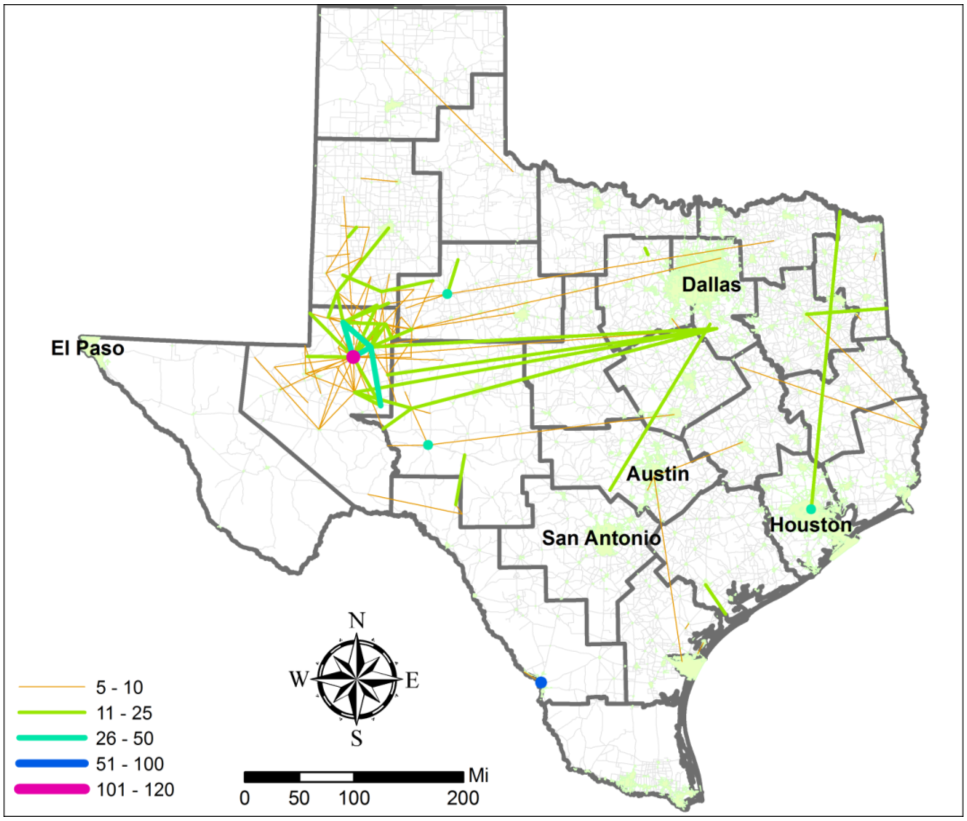


Figure 52. Origin-Destination Pairs for Top 5 Percent OS Loads (FY09).

Table 25. Twenty Most Frequent Origins and Destinations of Top 5 Percent OS Loads.

Most Frequent Origins		Most Frequent Destinations	
City	Frequency	City	Frequency
CITY OF ODESSA	329	CITY OF MIDLAND	291
CITY OF CRANE	277	CITY OF CRANE	267
CITY OF MIDLAND	239	CITY OF ODESSA	264
CITY OF ANDREWS	209	CITY OF MONAHANS	132
CITY OF LUBBOCK	161	CITY OF ANDREWS	124
CITY OF MONAHANS	119	CITY OF RANKIN	99
CITY OF KERMIT	101	CITY OF SEMINOLE	99
CITY OF HOUSTON	99	CITY OF LEVELLAND	84
CITY OF SEMINOLE	88	CITY OF KERMIT	80
CITY OF RANKIN	72	CITY OF PENWELL	69
CITY OF TYLER	68	CITY OF FORT STOCKTON	69
CITY OF PATRICIA	65	CITY OF LAREDO	63
CITY OF PENWELL	63	CITY OF BIG LAKE	62
CITY OF LEVELLAND	63	NM STATE LINE @ SH0176	60
CITY OF FORT STOCKTON	61	TOWN OF DENVER	60
CITY OF HENDERSON	57	CITY OF SUNDOWN	55
TOWN OF DENVER	55	CITY OF WICKETT	53
CITY OF WICKETT	53	CITY OF MENTONE	48
CITY OF SUNDOWN	52	CITY OF HOUSTON	48
CITY OF AUSTIN	47	CITY OF CITRUS	42

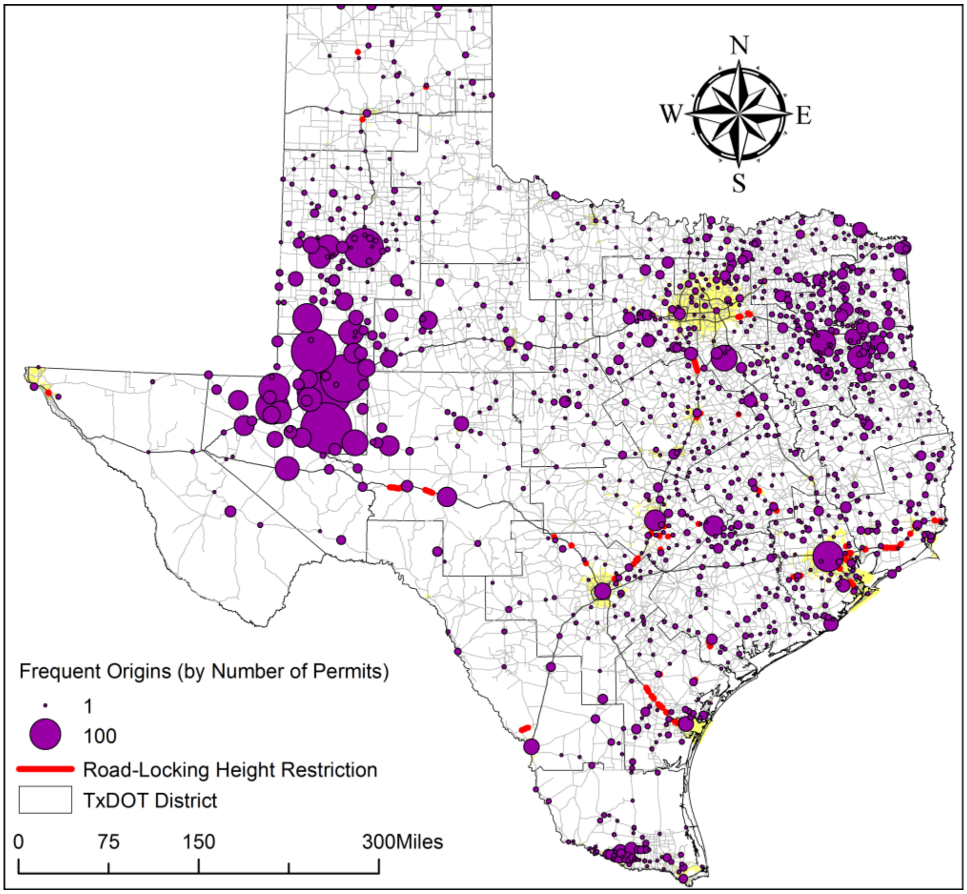


Figure 53. Frequent Origins for Top 5 Percent OS Loads.

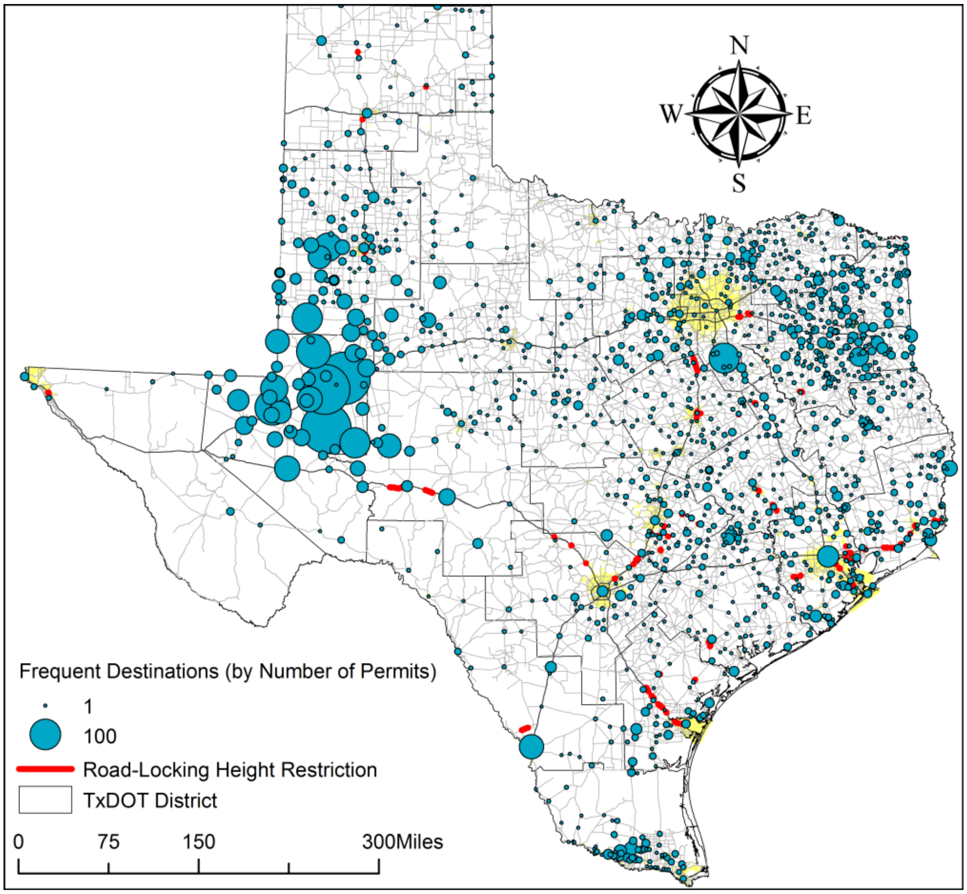


Figure 54. Frequent Destinations for Top 5 Percent OS Loads.

Figure 55 and Figure 56 depict the dimensions of the OS/OW loads for the top 15 origins and destinations in FY09, respectively. As shown in the figures, Fort Worth and Odessa proportionally generated much more wide and tall loads than other major origins in the state. Loads generated from Elm Mott, on the other hand, were primarily not oversize. In general, proportionally, many more loads were over-width than over-height. Among the over-width loads, 10 to 12 ft was the dominant category, as shown by several top origins and destinations.

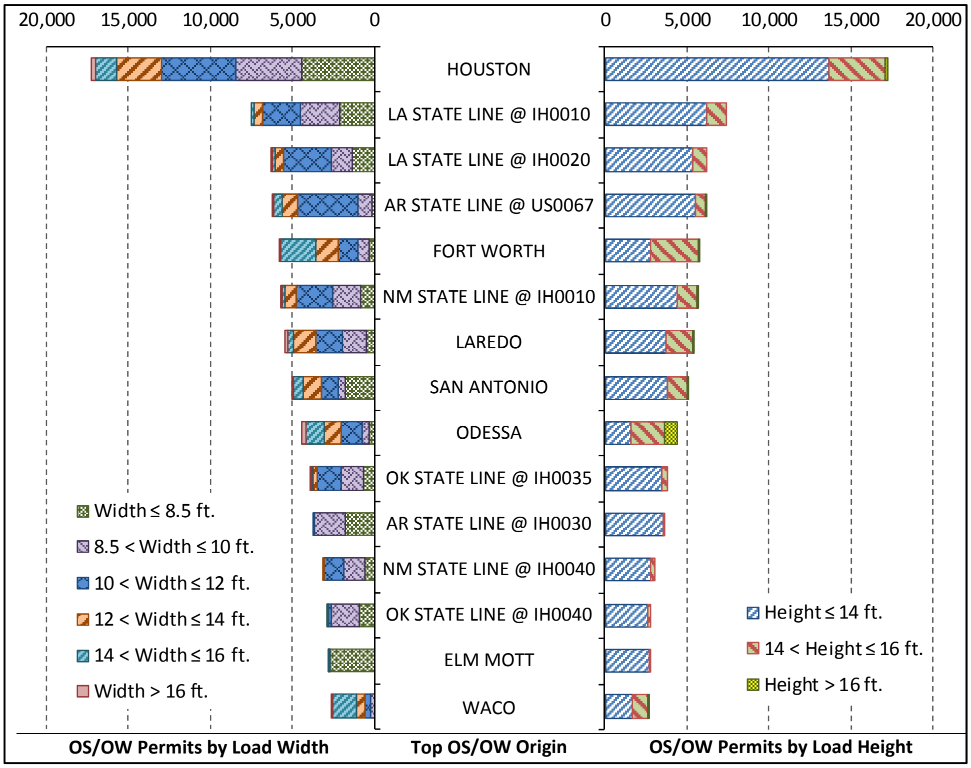


Figure 55. Top OS/OW Trip Origins and Load Dimensions (FY09).

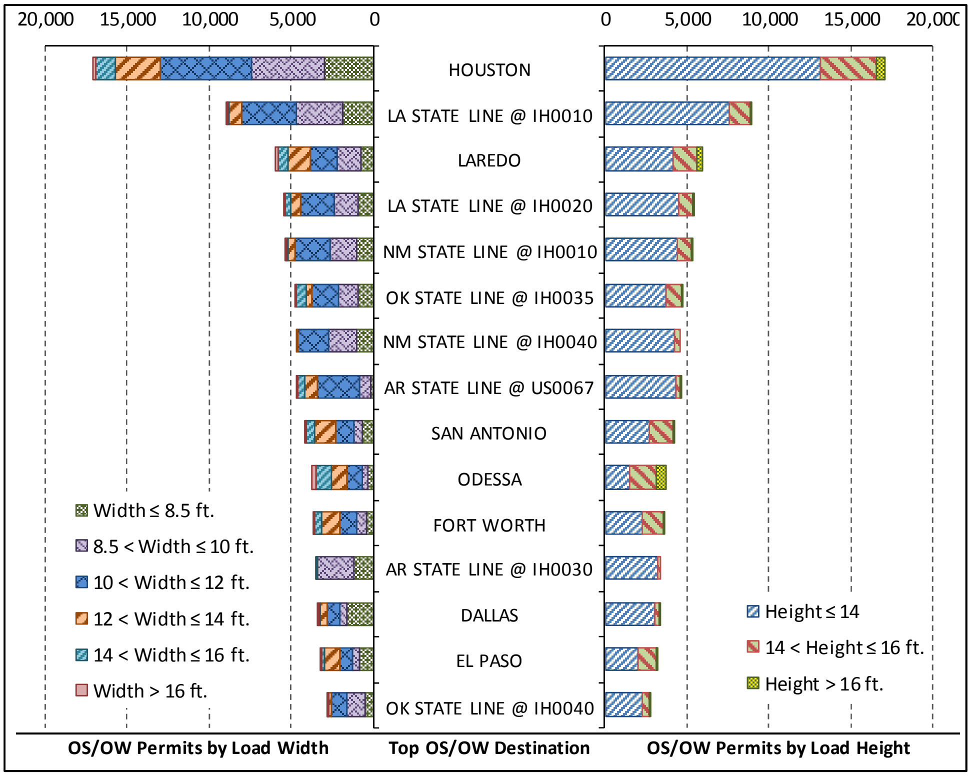


Figure 56. Top OS/OW Trip Destinations and Load Dimensions (FY09).

Figure 57 and Figure 58 illustrate the composition of the OW loads by weight for the top 15 OS/OW origins and destinations in FY09, respectively. Among the popular OS/OW origins, most had proportionally more permits involving loads between 80,000–120,000 lb. However, areas such as Odessa, San Antonio, Elm Mott (near Waco), Fort Worth, and El Paso had proportionally more loads that were heavier than 120,000 lb than those between 80,000–120,000 lb.

Figure 59 and Figure 60 demonstrate the proportions of OS/OW loads generated by the wind and oil/gas industries in FY09. Energy-related activities in some areas in Texas have resulted in noteworthy impact on local roadways, especially pavement deterioration. The figures once again suggest that areas such as Houston, Odessa, and Fort Worth were associated with larger proportions of oil/gas-related loads. In addition, many wind-energy-related loads were transported from New Mexico to Texas via IH 10 and to Oklahoma via IH 35.

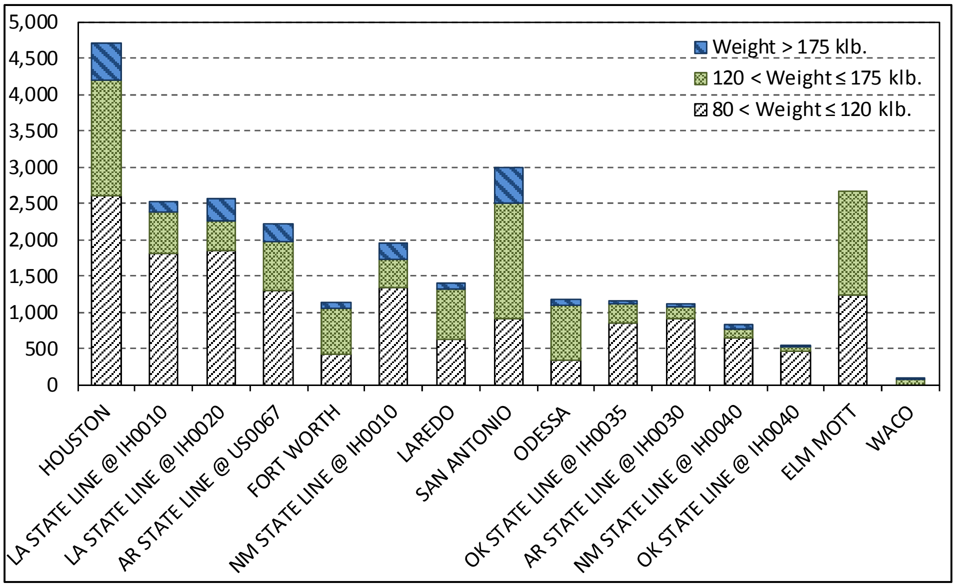


Figure 57. OW Loads for Top OS/OW Trip Origins (FY09).

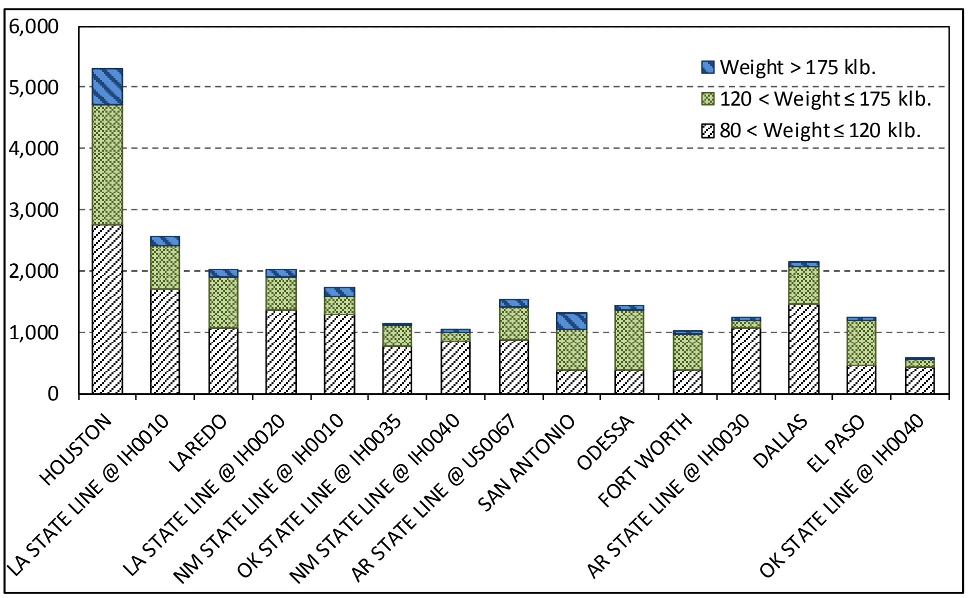


Figure 58. OW Loads for Top OS/OW Trip Destinations (FY09).

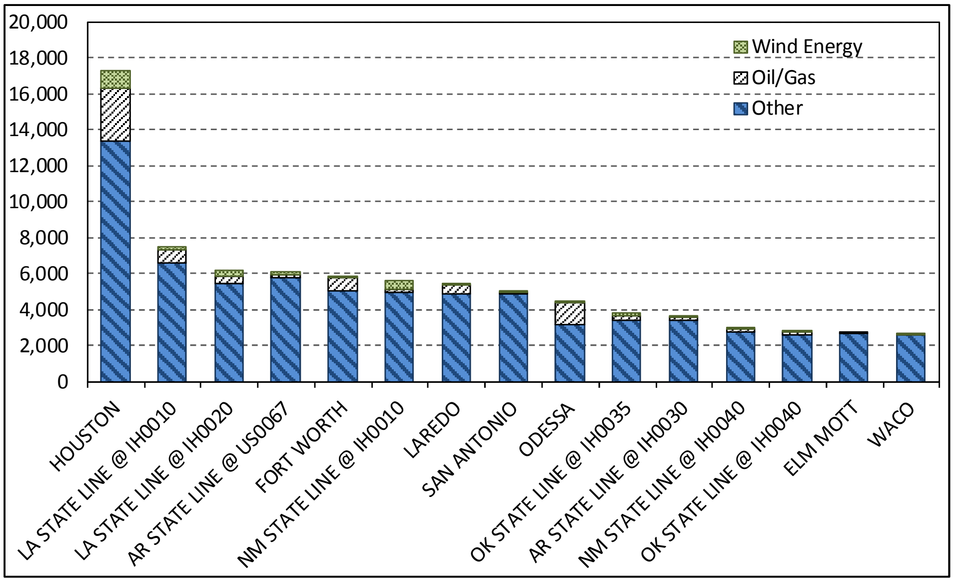


Figure 59. Top OS/OW Trip Origins and Commodity Types (FY09).

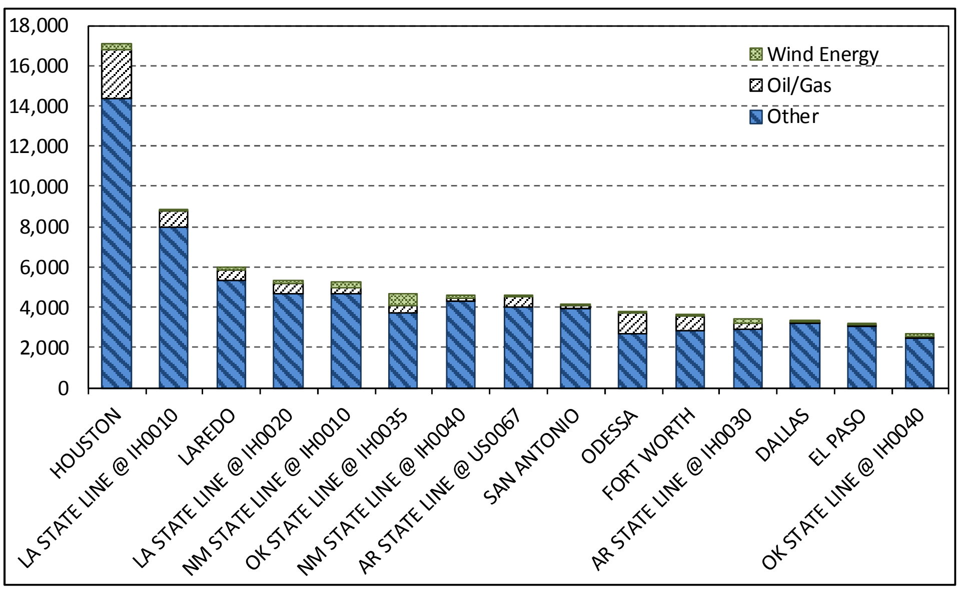


Figure 60. Top OS/OW Trip Destinations and Commodity Types (FY09).

CHAPTER 8: RESTRICTION DATA ANALYSIS

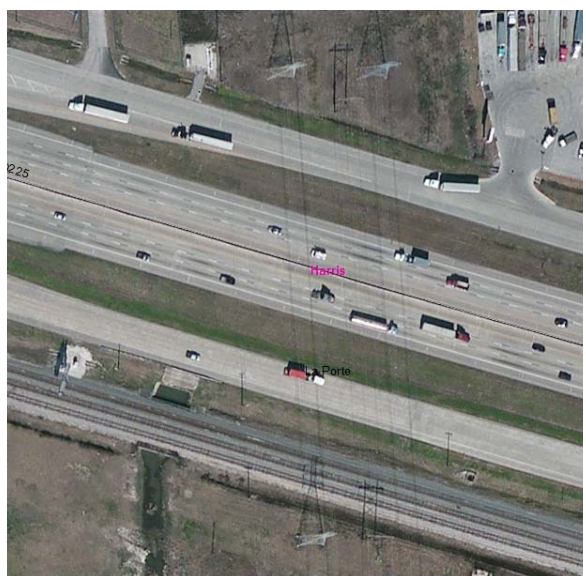
INTRODUCTION

One of the objectives of this research was to understand the barriers on the state highway network that restrict the movements of OS/OW loads. Identification of critical restrictions that had the most significant impact on OS/OW load routing would help transportation officials improve OS/OW routing and make informed decisions on needed infrastructure improvements. During this analysis, the research team focused on those critical restrictions that either require OS/OW loads to take a lengthy bypass or impact a significant number of loads.

DESCRIPTION OF RESTRICTION DATA

MCD considers two types of restrictions for OS/OW routing—temporary and permanent. Temporary restrictions such as construction or maintenance work zones typically constrain routing options for a limited period of time. MCD constantly updates its information on a real-time basis as it becomes available. Permanent restrictions, on the other hand, remain in effect for a much longer period of time and are typically caused by overhead structure clearance limitations or bridge load carrying capacity. Examples occurring along the roadway include bridges, overhead power lines, overhead traffic signs, and load-zoned roadways. Figure 61 shows two examples of permanent height restrictions.

a) Pedestrian bridge (IH 35 in Waco)



b) Overhead power lines (SH 225 in La Porte)

Figure 61. Examples of Permanent Height Restrictions.

TxDOT maintains paper maps of the temporary restrictions for all districts. When a district reports a temporary restriction to MCD, permit personnel mark it on the map and distribute the revisions to all route processers. Due to this practice, the research team was not able to obtain the temporary restriction data in a digital format for immediate use in this research project. In addition, because of the temporary nature of such restrictions, it would be difficult to account for their impacts on OS/OW routes, especially considering that this study was focused on data spanning six fiscal years. Therefore, this research focused on permanent restrictions.

TTI received the permanent height and weight restriction data from TxDOT's contractor for TxPROS, ProMiles, in two separate comma-delineated TXT files. Within the files, each restriction was represented as a series of latitude/longitude coordinates representing a roadway segment followed by a maximum allowable height or weight. During the analysis, researchers had to first convert the restriction data into a GIS format that could be overlaid on a map. The GIS mapping of the restriction data involved the following major steps:

- Convert multi-point records into single-point records for mapping: Each record in the original data contained an indefinite number of points (i.e., pairs of latitude/longitude coordinates). To enable automated mapping of the points, the research team had to first convert those records into single-point records such that each record only contained a pair of coordinates, the maximum allowable height or weight, an order value indicating the sequence of the point in its original series, and an ID indicating to which restriction segment the point originally belonged (Figure 62).

Height Restriction	LAT1	LONG1	LAT2	LONG2	LAT3	LONG3	…
…	…	…	…	…	…	…	…
17'0"	33.1575	-99.7274	33.1575	-99.7275			…
16'0"	32.6094	-99.8206	32.6097	-99.8196			…
16'0"	32.0908	-100.136	32.0916	-100.135	32.0922	-100.134	…
…	…	…	…	…	…	…	…

Restriction ID	Height Restriction	LAT	LONG	Order
…	…	…	…	
00023	17'0"	33.1575	-99.7274	1
00023	17'0"	33.1575	-99.7275	2
00024	16'0"	32.6094	-99.8206	1
00024	16'0"	32.6097	-99.8196	2
00025	16'0"	32.0908	-100.136	1
00025	16'0"	32.0916	-100.135	2
00025	16'0"	32.0922	-100.134	3
…	…	…	…	…

Figure 62. Converting Multi-Point Records into Single-Point Records for Mapping.

- Map all points into a GIS point layer: During this step, researchers imported the newly created table into ArcGIS and used the Display XY Events function to create a point layer where each point corresponded to a pair of coordinates included in a single record. The resulting point layer therefore contained all valid points included in the restriction sections of the original TXT files.
- Generate restriction segments from the GIS points and associated attribute information: Using a customized function, researchers linked all points following the original sequence into individual restriction segments.

Figure 63 and Figure 64 illustrate the mapped height and weight restrictions in the state, respectively. In general, the restriction data included both restrictions applicable to on-system roads and restrictions created by on-system highways that are applicable to off-system roads. In addition, researchers found cases where restrictions were neither created by on-system roadways nor applicable to on-system roadways. More detailed examinations suggested that those seemed to be off-system restrictions or outdated on-system restrictions.

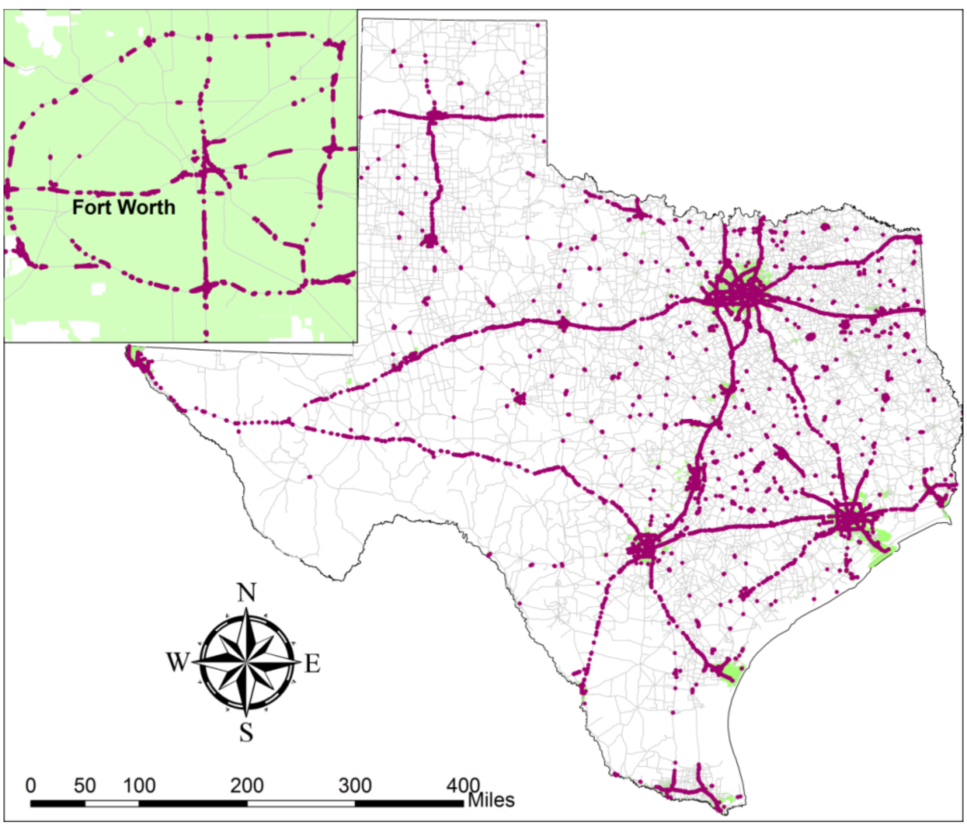


Figure 63. Height Restriction Segments in GIS Format.

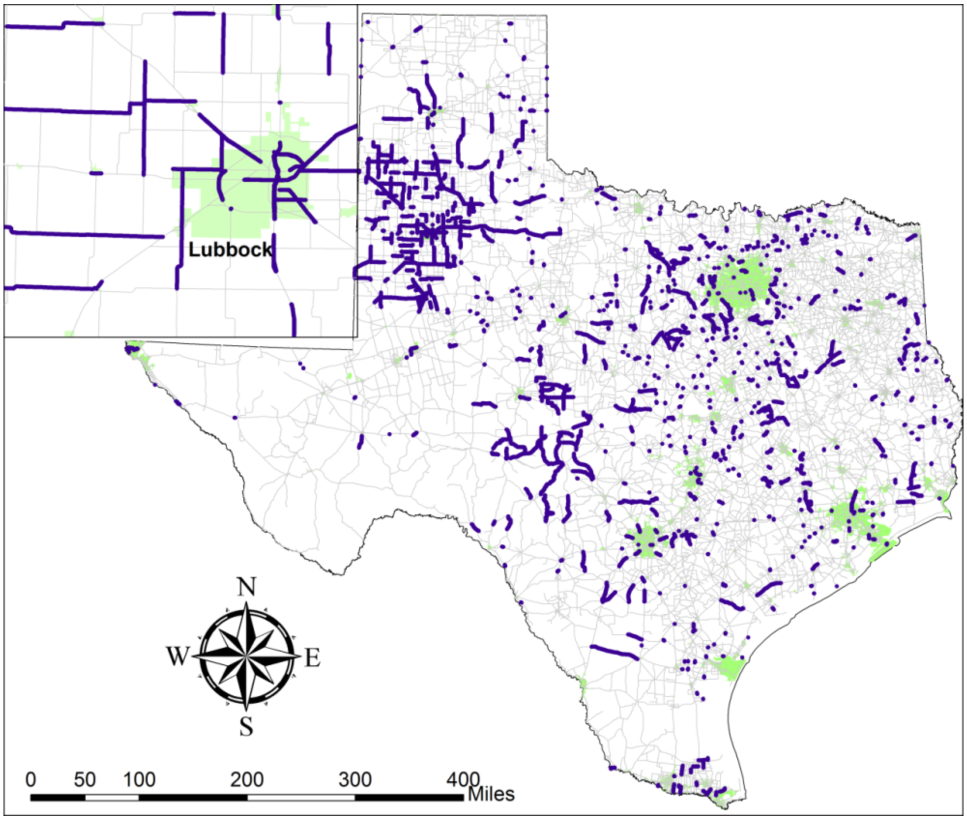


Figure 64. Weight Restriction Segments in GIS Format.

RESTRICTION DATA ANALYSIS

Visual Analysis of Statewide Restrictions

The original restriction data did not include detailed information about the restrictions, which created major challenges for clearly understanding how the restrictions could have affected OS/OW routing. For example, an apparent height restriction on a highway as it appeared on a map might actually be an overhead bridge imposing a height restriction to another highway crossing underneath. In addition, in many cases it was difficult to tell if a restriction was part of a highway or another nearby road, especially when a frontage road was involved. At highway interchanges, many overpasses were included in the dataset as restrictions, which further cluttered the picture. For example, Figure 65 shows a height restriction on IH 27 in the Amarillo area that was actually a bridge on the freeway causing a height restriction for the road passing underneath. Figure 66 shows examples of height restrictions on main lanes, but the assigned route can bypass the restriction by using frontage roads.

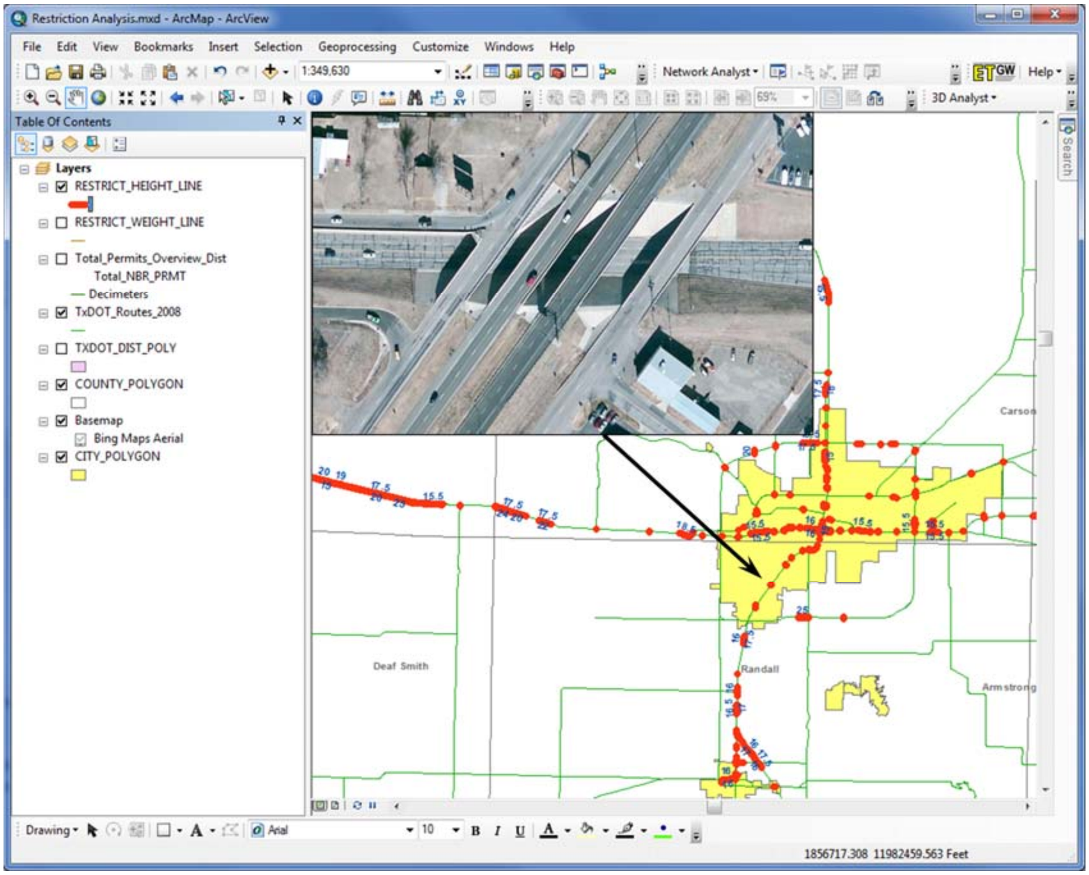


Figure 65. Height Restriction on IH 27 Applicable to an Off-System Road.

a) Bridge on IH 35W main lanes (Hill County) b) Bridges on IH 27 main lanes (Amarillo)

Figure 66. Height Restrictions with Bypasses.

To better understand the restrictions and their impact, researchers visually examined the restrictions in each of the 256 counties in Texas to identify those that locked the entire roadway section without an immediate bypass (so-called road-locking restrictions). Examining the restrictions at the county level allowed researchers to visually check through the restrictions at a relatively detailed zoom level without requiring too many additional zooming operations. Within each county, analysts compared restrictions against Bing™ maps (available in ArcGIS 10 as a base map) for an accurate assessment. For simplicity, researchers used a two-level examination method. First, they visually inspected all restrictions on popular OS/OW routes, including all interstate highways. These highways carry significant numbers of OS/OW loads, so restrictions on IH routes impact many OS/OW loads.

For those on less frequently traveled routes, the research team used a backward analysis method by comparing overall OS/OW load frequencies with height and weight restrictions. During the comparison, critical locations on the roadway network within each county were first identified where a relatively large number of OS/OW loads diverged from seemingly rational routes. The research team then examined the restrictions on the involved highway sections and tried to develop a rational explanation for the divergence.

While avoiding unnecessary examination time, this two-level method might have resulted in some road-locking restrictions on less popular routes not being identified if they did not result in significant route divergences or if short detours were available for bypassing such restrictions. Researchers did not spend significant time identifying these restrictions due to their relatively less significance to this study.

Figure 67 through Figure 70 show the statewide road-locking height and weight restrictions, respectively. Visual analysis of the restrictions showed more evident relationships between height restrictions and OS/OW load distributions. This observation is consistent with district experience since the axle weights of the loads with gross weight exceeding legal limits in most cases satisfy pavement requirements.

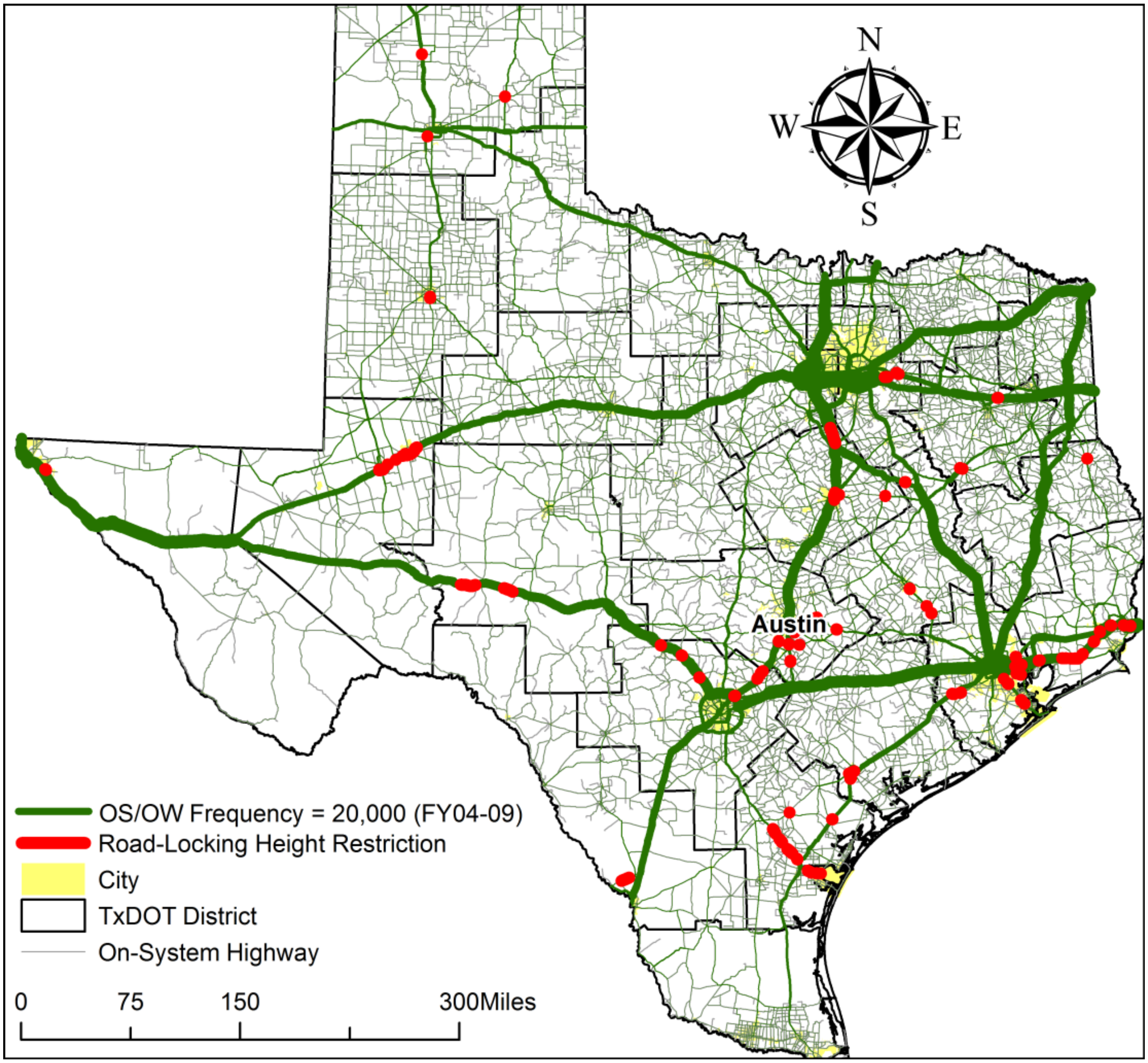


Figure 67. Statewide Road-Locking Height Restrictions.

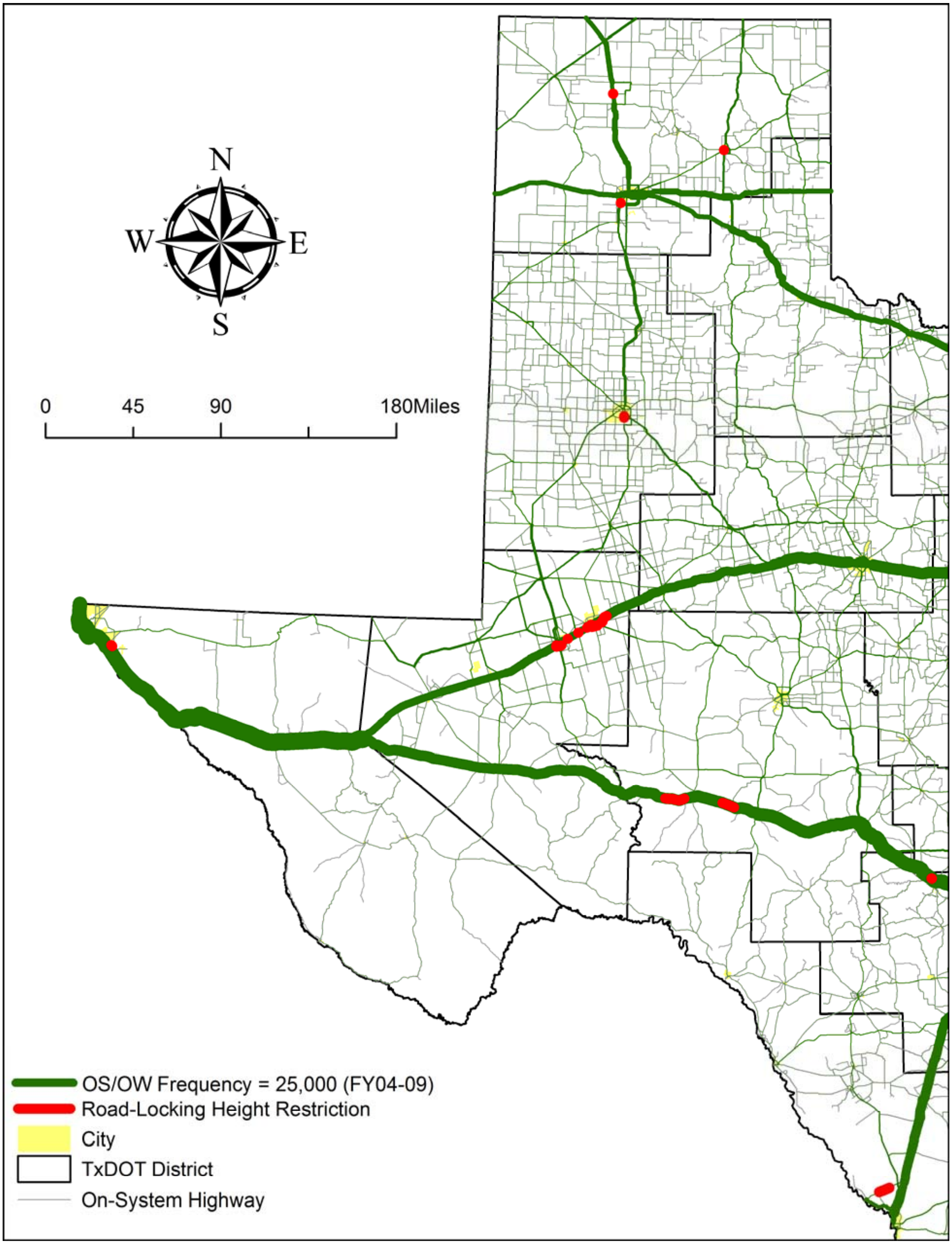


Figure 68. Road-Locking Height Restrictions in West Half of Texas.

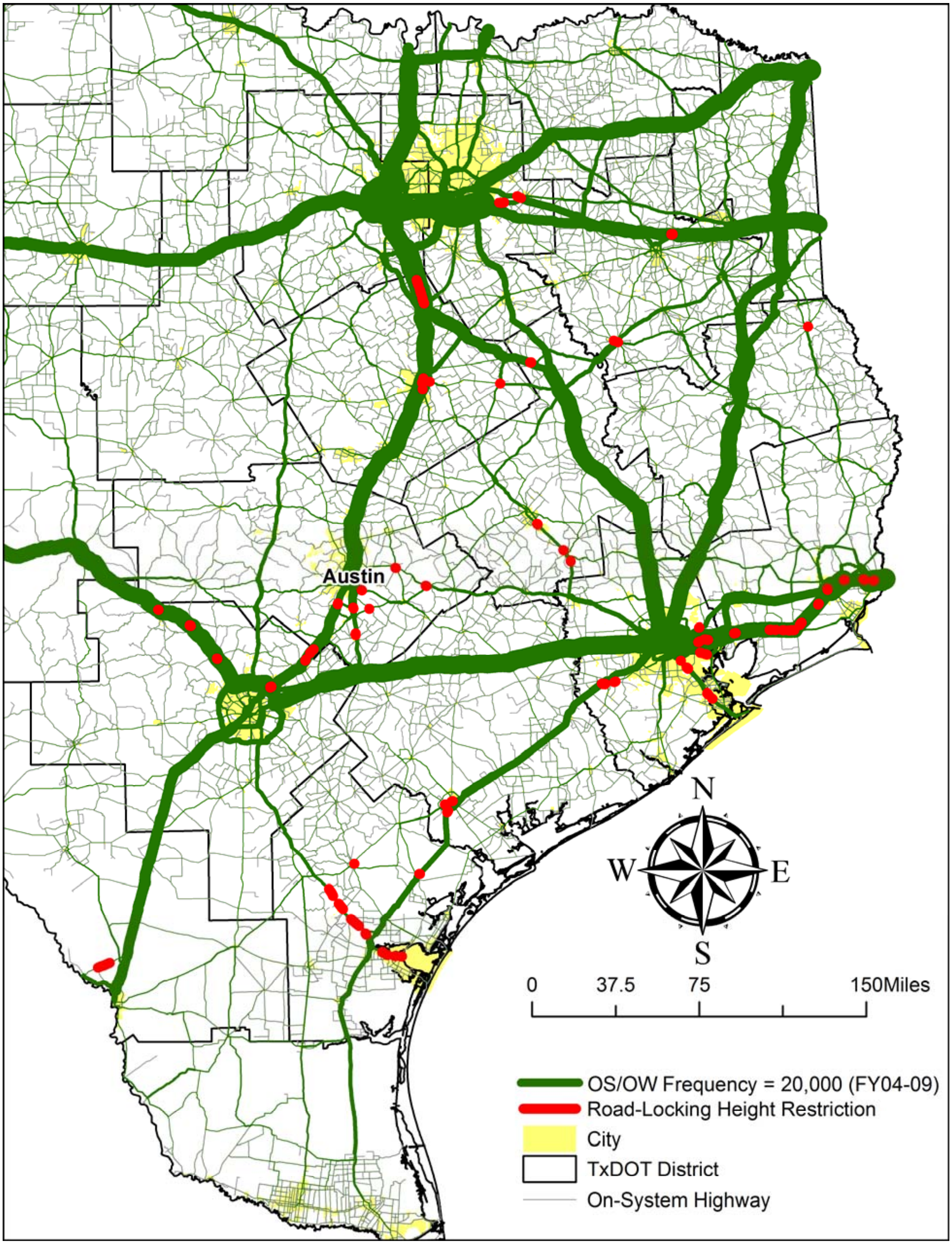


Figure 69. Road-Locking Height Restrictions in East Half of Texas.

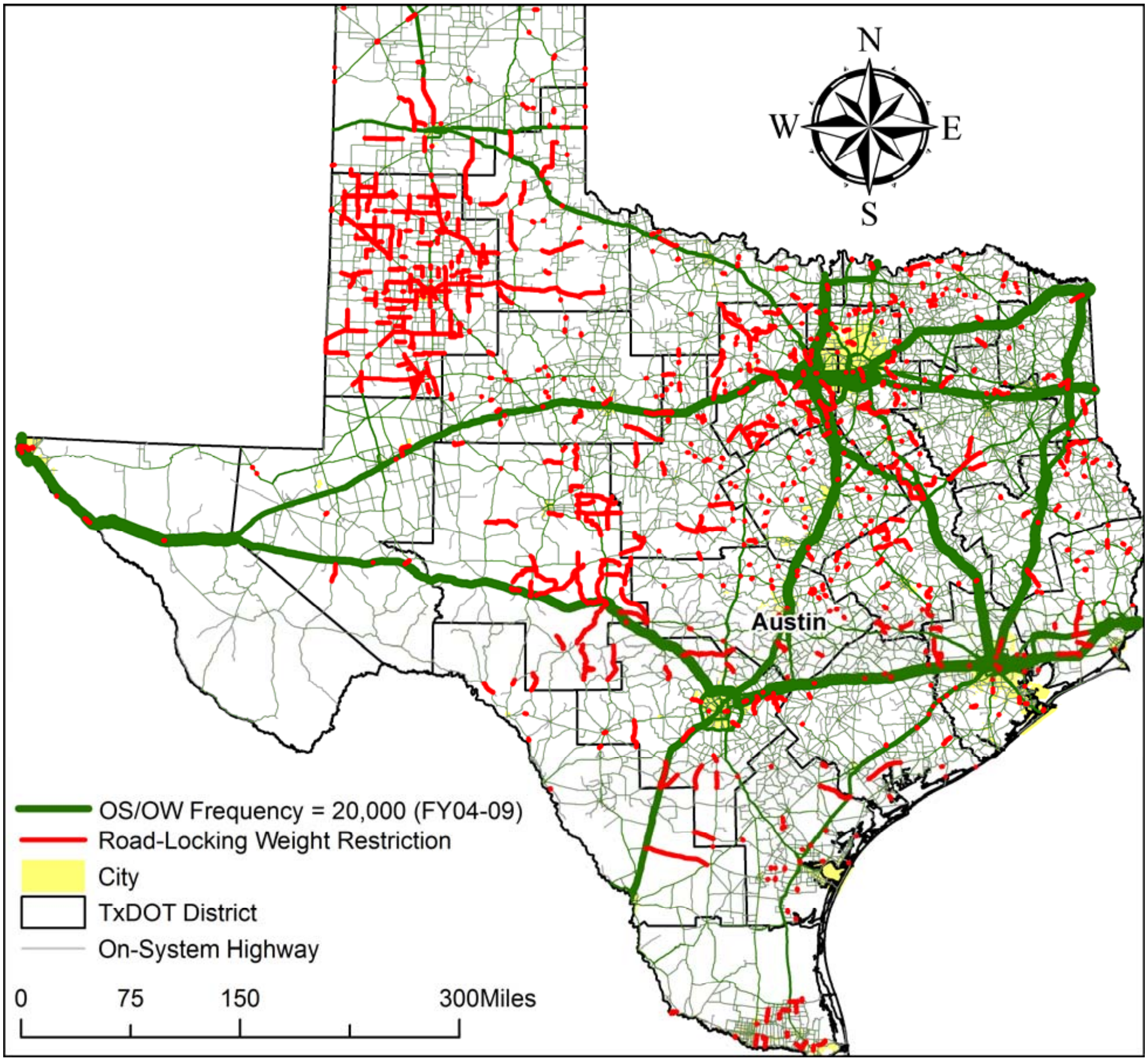


Figure 70. Statewide Road-Locking Weight Restrictions.

Figure 71 and Figure 72 show examples where height restrictions on major highways caused MCD to route OS/OW loads onto minor highways and use them as bypasses. In Figure 71, a 17 ft railroad bridge caused MCD to route over-height loads to nearby FM roads to bypass the railroad bridge, resulting in much longer travel distances. In Figure 72, several height restrictions on IH 10 north of San Antonio caused a significant number of over-height vehicles to be routed onto US 281 and US 290 as bypasses. Figure 73 shows another interesting example where OS/OW traffic possibly used a much longer detour on IH 35 and FM 1472 to avoid a weigh station and a height restriction on SH 255.

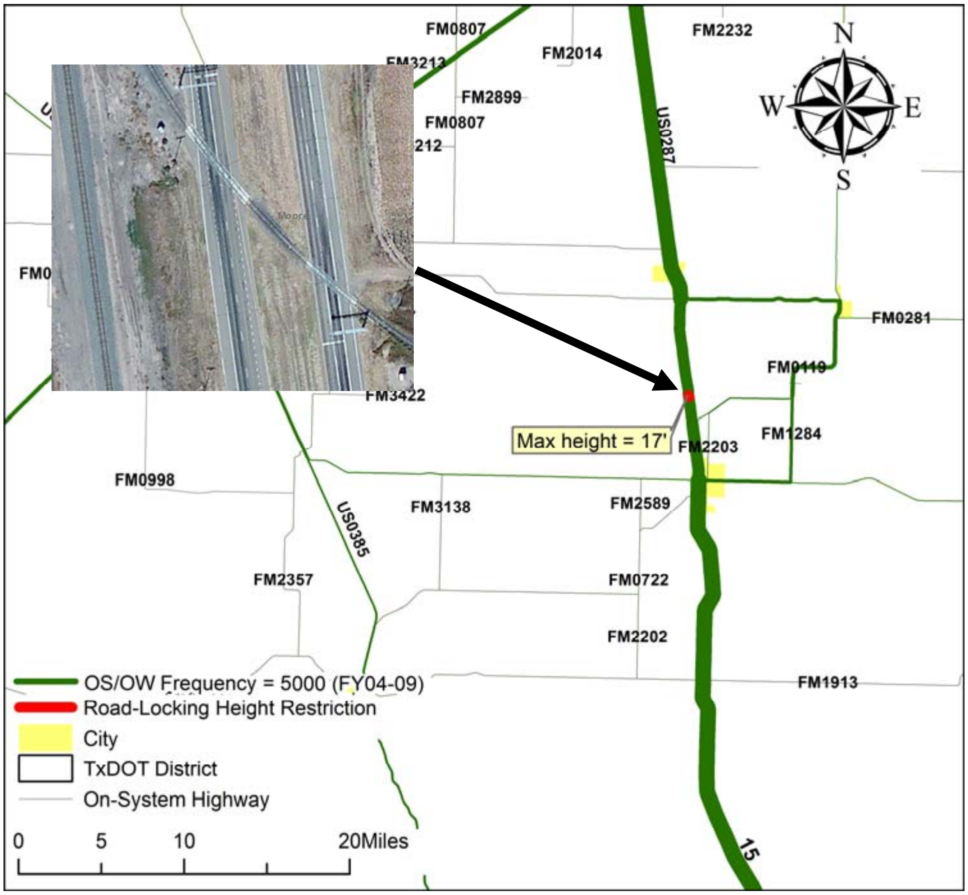


Figure 71. Height Restriction on US 287 in Dumas Area.

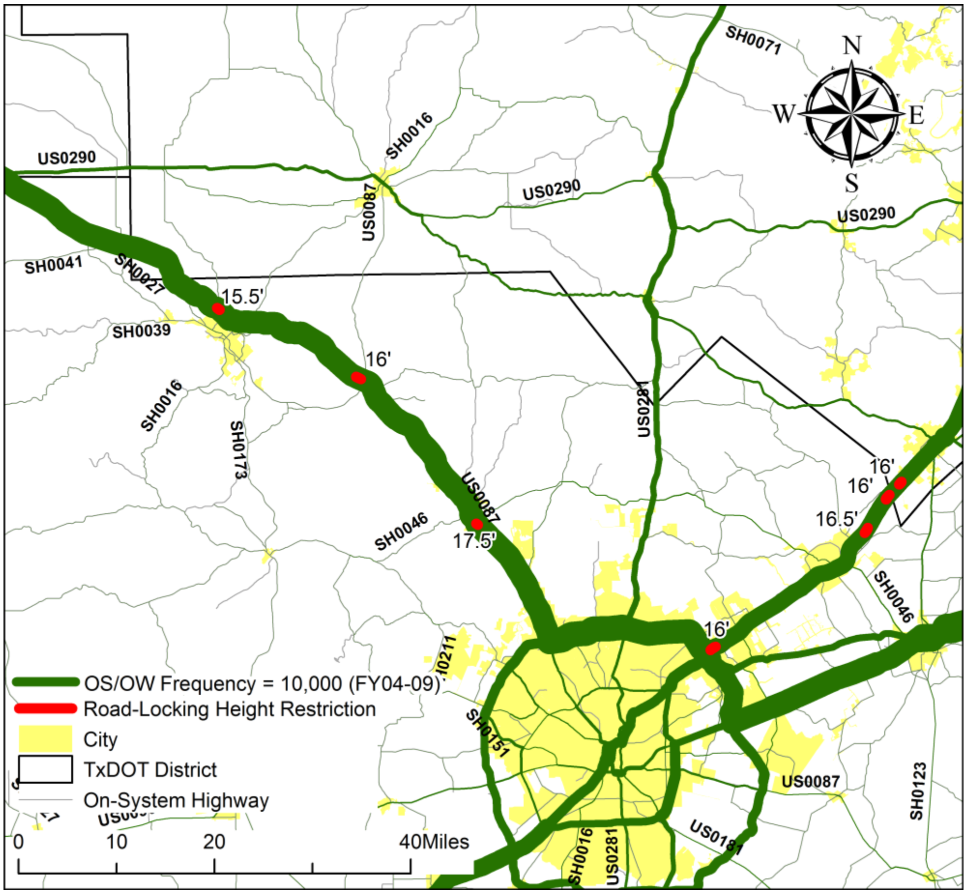


Figure 72. Height Restrictions on IH 10 North of San Antonio.

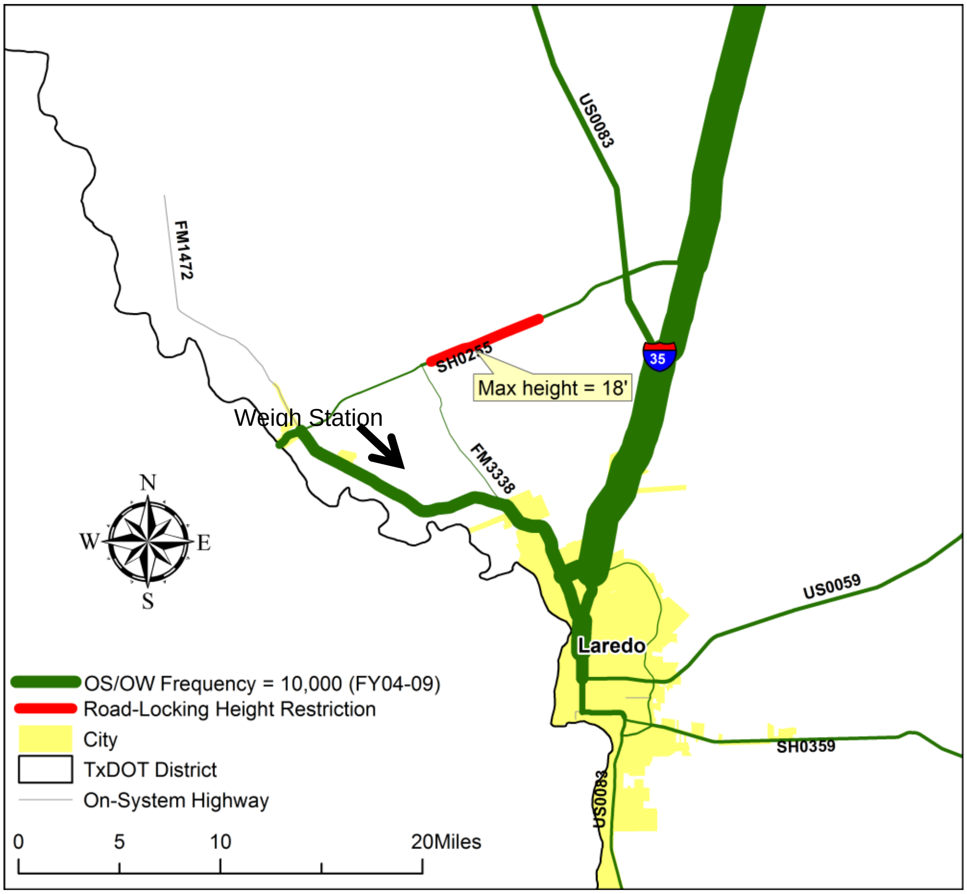


Figure 73. OS/OW Routing to Avoid a Height Restriction.

Optimal Route Analysis

The previous restriction analysis provides information about how road-locking restrictions, especially height restrictions, have impacted the routes of OS/OW loads locally. However, the analysis does not provide sufficient information for the assessment of the global impact of OS/OW routing. For example, to avoid a restriction on a major highway, some loads may be routed on an alternate roadway to completely bypass the highway instead of finding a local detour. To understand the global impact of the road-locking restrictions, the research team further conducted two types of optimal route analyses.

Optimal Route Analysis for Frequent ODs

During this analysis, the research team compared the permitted routes of the OS/OW loads between the most frequent origins and destinations, with the optimal routes generated assuming an ideal transportation network where there are no OS/OW restrictions. When generating optimal routes, the research team used city centroids as the actual starting/ending points for those permits with routes starting and/or ending in a city. OD pairs that started and ended at the same cities were not included in the analysis.

For accuracy, researchers visually inspected all permit routes for each OD pair and discarded those that appeared to be incorrectly processed during the route mapping. Because this process primarily used visual inspections using a map, some correctly processed routes may have been wrongly selected and discarded. As the purpose of this analysis was to obtain a reasonable estimate of the general difference between the actual permit routes and the optimal routes, in theory, it was not necessary and would be extremely time-consuming to identify each of the correct routes. There were two primary types of routes discarded during this screening:

- Routes with problematic intersections due to mapping errors: It was unrealistic to identify all routes involving incorrect intersections that were not in the original route descriptions. However, a non-trivial number of routes had unreasonably long lengths because incorrect intersections were used during the mapping process. It is generally straightforward to identify such routes on a map by comparing the OD locations and the mapped routes.
- Routes with missing intersections: For routes that involved a small number of intersections, missing an intersection during the mapping process (e.g., the intersection was not recognized by the mapping program) could result in significantly different routes. If the missing intersection was the first or last intersection on a route, the resulting routes could be much shorter than the intended routes in the original permits. Such routes are typically identifiable on a map as well by comparing them with the OD locations.

By the end of this process, analysts had evaluated a total of 95 of the most frequent OD pairs representing 114,200 OS/OW permits. Among the most frequent OD pairs, there were 26 instances where OD pairs involved the same pairs of locations but opposite directions (e.g., El Paso to NM State Line at IH0010 and NM State Line at IH0010 to El Paso). Table 26 summarizes the numbers of permits that were selected for this analysis and the mileage difference between the permitted routes and optimal routes. Figure 74 illustrates the road-locking height restrictions on the optimal routes of the 500 most frequent OD pairs.

Table 26. OS/OW Permits Used in the Optimal Route Analysis by Year.

Fiscal Year	Number of Permits	Average Permit Route Length (Mile)	Average Optimal Route Length (Mile)	Average Length Difference		Median Difference (Mile)	
				Miles	Percent	Miles	Percent
2004	19,084	298.5	274.6	23.9	8.0%	13.7	5.0%
2005	14,469	302.0	277.9	24.1	8.0%	13.1	4.7%
2006	16,936	320.9	295.8	25.1	7.8%	11.9	4.0%
2007	16,592	318.7	291.8	26.9	8.4%	18.9	6.5%
2008	23,838	300.7	279.7	21.0	7.0%	11.5	4.1%
2009	23,281	313.1	289.7	23.4	7.5%	13.9	4.8%
Total	114,200	308.6	284.8	23.8	7.7%	13.7	4.8%

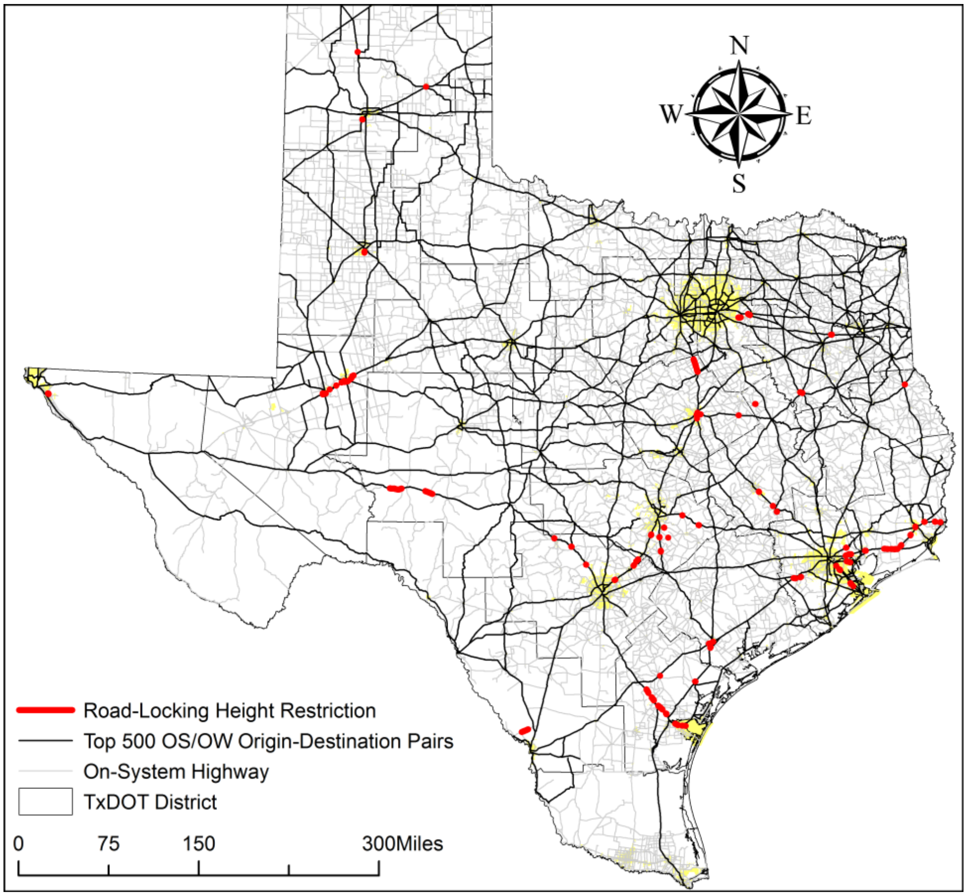


Figure 74. Optimal Routes of Top 500 Origin-Destination Pairs.

Based on the average route difference and median difference of the studied OS/OW routes, the research team further estimated the ton-miles associated with the additional miles traveled. Potentially, such additional ton-miles might be avoided by infrastructure improvements that allow the OS/OW loads to be shipped via shortest routes on the state highway network. Table 27 lists the estimated potential savings for OS/OW shippers in ton-miles for the analyzed OS/OW permits and all route-specific permits between FY04–09 in the original OS/OW permit databases if the optimal routes could be used. The table includes the following estimates:

- Additional ton-miles for the selected routes: These estimates were calculated as $\sum_1^n (GVW \times RD)$, where GVW is gross vehicle weight (in tons) of each loaded vehicle as specified in the original OS/OW permit data and RD is route difference in miles between the permitted route and optimal route for each load. In the original OS/OW permit databases, many route-specific permits involved legal-weight loads, for which the analysis assumed a GVW of 80,000 lb.
- Total additional ton-miles based on average route difference: These values were estimated for all route-specific OS/OW loads permitted between FY04–09. For each fiscal year, this value was calculated as$(\sum_1^n GVW) \times RD_a$, where RD_a is the average route

difference in miles between the permitted routes and optimal routes for the selected permits (see Table 26).

- Total additional ton-miles based on median difference: These values were estimated for all route-specific OS/OW loads permitted between FY04–09. For each fiscal year, this value was calculated as $(\sum_1^n GVW) \times RD_m$, where RD_m is the median route difference in miles between the permitted routes and optimal routes for the selected permits (see Table 26).

Table 27. OS/OW Permits Used in the Optimal Route Analysis by Year.

Fiscal Year	Additional Ton-Miles (Selected)	Total Additional Ton-Miles based on	
		Average Difference	Median Difference
2004	21,334,582	438,892,449	252,639,771
2005	16,973,851	441,237,511	253,989,660
2006	19,047,574	513,329,491	295,487,984
2007	20,380,460	545,914,142	314,244,695
2008	23,974,935	572,333,733	329,452,611
2009	25,604,793	515,144,062	296,532,507
FY04-09	127,316,195	3,026,851,387	1,742,347,227
Average	—	504,475,231	290,391,205

Based on the analysis, using non-optimal OS/OW routes resulted in a conservative estimate of more than 290 million ton-miles of shipments on the state highway network due to physical restrictions and possibly other factors. During the entire six-year study period and based on a conservative estimate, the accumulated ton-miles totaled more than 1.7 billion. When using the average route difference, these two values become 504 million and 3 billion ton-miles, respectively.

During this analysis, the research team quantified the additional ton-miles into dollar values to provide a general idea of the associated extra costs. For this purpose, researchers used the per-ton-mile cost estimates reflecting external and private operating costs as published in the study of Forkenbrock (Table 28) (*80*). External costs, as estimated in the referenced study, are costs due to crashes, emissions, noise, and unrecovered costs associated with provision, operation, and maintenance of public facilities. Private operating costs are direct expenses incurred by providers for freight transportation, such as fuel, wages, maintenance, user charges, and insurance. The referenced study was based on general freight trucks and intercity freight trips in primarily rural areas. Therefore, the per-ton-mile costs estimated from that study are undoubtedly conservative, considering that OS/OW loads are subject to more costs when compared to regular trucks, such as those associated with escort services, special fees, and more significant environmental and traffic impacts.

Table 28. External and Private Costs Associated with Intercity Freight Trucks.

Dollar Year	Private Operating Cost	External Cost	Total Cost
1994 Dollar/Ton-Mile	0.0842	0.0111	0.0953
2011 Dollar/Ton-Mile*	0.127799	0.016848	0.144647

*2011 dollars were converted based on Consumer Price Index (*81*).

Table 29 lists the estimated extra costs incurred by transportation providers and the public due to the additional miles that the OS/OW vehicles traveled. As shown in the table, each year, the additional ton-miles OS/OW vehicles had to travel resulted in about $42 to $73 million of additional costs for the shippers and the public. These numbers translate to a total of a $252 to $438 million loss between the six-year study period. Assuming each ton-mile produces 134.4 g (4.74 oz) (*82*) of CO_2, the additional ton-miles associated with the studied OS/OW vehicles contributed about 43 to 75 thousand tons of CO_2 every year (Table 29).

Table 29. Extra Costs Due to Additional Ton-Miles for Statewide OS/OW Vehicles.

Fiscal Year	Additional Costs (2011 dollars) based on		Additional CO_2 Emission (Ton) based on	
	Average Route Difference	**Median Route Difference**	**Average Route Difference**	**Median Route Difference**
2004	$63,484,480	$36,543,587	65,022	37,429
2005	$63,823,686	$36,738,845	65,370	37,629
2006	$74,251,575	$42,741,453	76,050	43,777
2007	$78,964,848	$45,454,555	80,878	46,556
2008	$82,786,362	$47,654,335	84,792	48,809
2009	$74,514,048	$42,892,540	76,319	43,932
FY04–09	$437,824,999	$252,025,315	448,430	258,130
Average	$72,970,833	$42,004,219	74,738	43,022

Note: These estimates are made with the assumptions of regular trucks and intercity freight trips.

To better understand how OS/OW loads would travel in an ideal world with no restrictions, the research team generated the optimal routes (i.e., shortest routes between origins and destinations) for the 500 most frequent OD pairs used by OS/OW routes in FY 2009. Those OD pairs represented 88,444 permits in FY 2009, which was equivalent to 34.6 percent of the total permits with mapped ODs, or 16.8 percent of the total OS/OW permits in the same year. Figure 75 shows the popular roadways on the optimal routes of the top 500 ODs in FY 2009. As illustrated, sections of US 59, IH 35E, and IH 35 were on the optimal routes of a large number of OS/OW permits. This map, along with other relevant information, provides information to help transportation officials to better plan improvements on OS/OW corridors that will potentially benefit the most users.

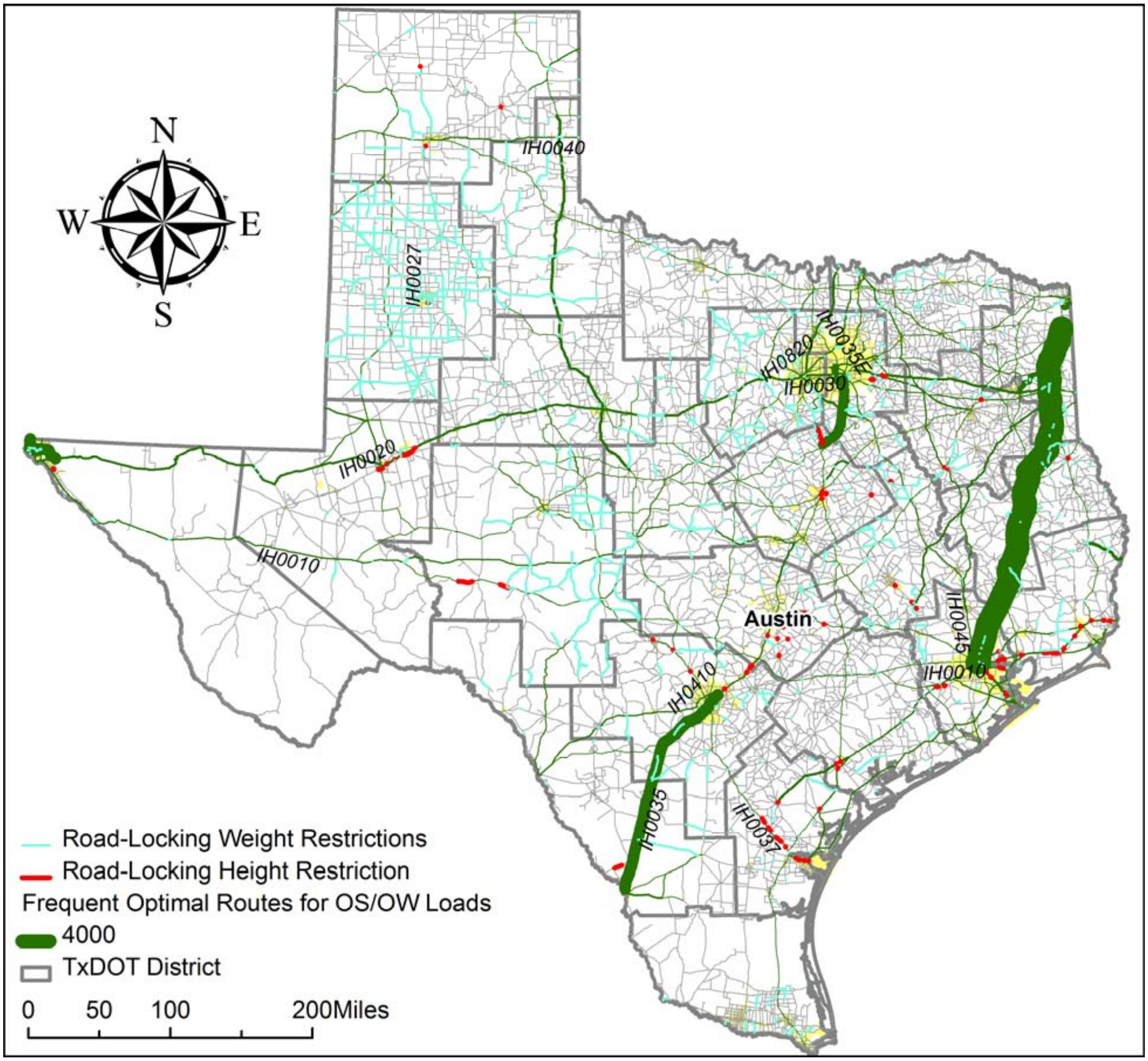


Figure 75. Most Frequent Routes Based on Optimal Routes of Top 500 OD Pairs.

Optimal Route Analysis for Top 5 Percent of OS Loads

The research team generated optimal routes for the top 5 percent of OS loads as if there were no infrastructure restrictions and compared them with their actual routes in an effort to understand the impact of restrictions on some of the largest loads. During this analysis, the research team only focused on those permits of which the route descriptions were successfully standardized and generated into a GIS format. This comparison used a total of 6787 permits between FY04–09, as listed in Table 30.

Table 30. Analyzed OS/OW Permits That Were Higher and Wider Than 16 Ft.

Fiscal Year	Number of Permits
2004	962
2005	632
2006	1105
2007	1061
2008	1347
2009	1680
Total	6787

Figure 76 shows the road-locking height restrictions on the optimal routes of the top 5 percent of OS loads, and Figure 77 illustrates the frequent routes taken by those large loads compared with the height restrictions. As shown by the figures, many of the road-locking height restrictions were located on the optimal routes. In practice, however, most loads used detours to bypass the restrictions.

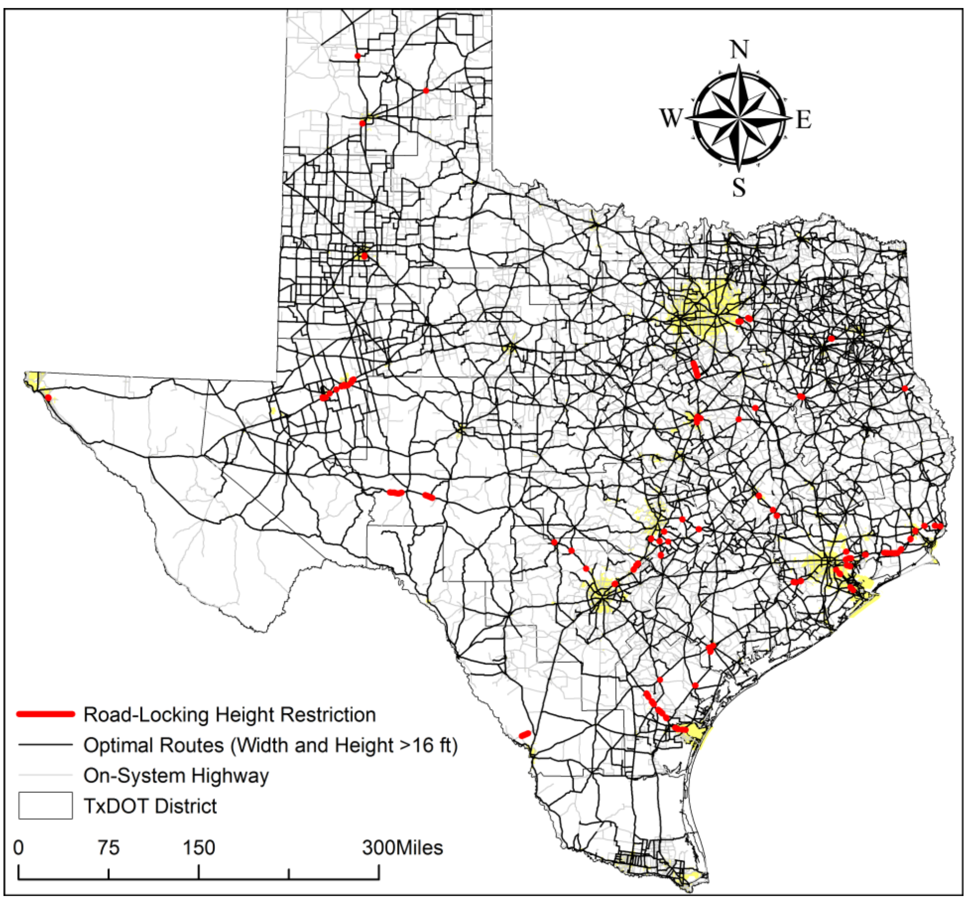


Figure 76. Optimal Routes of Loads Wider and Higher than 16 ft.

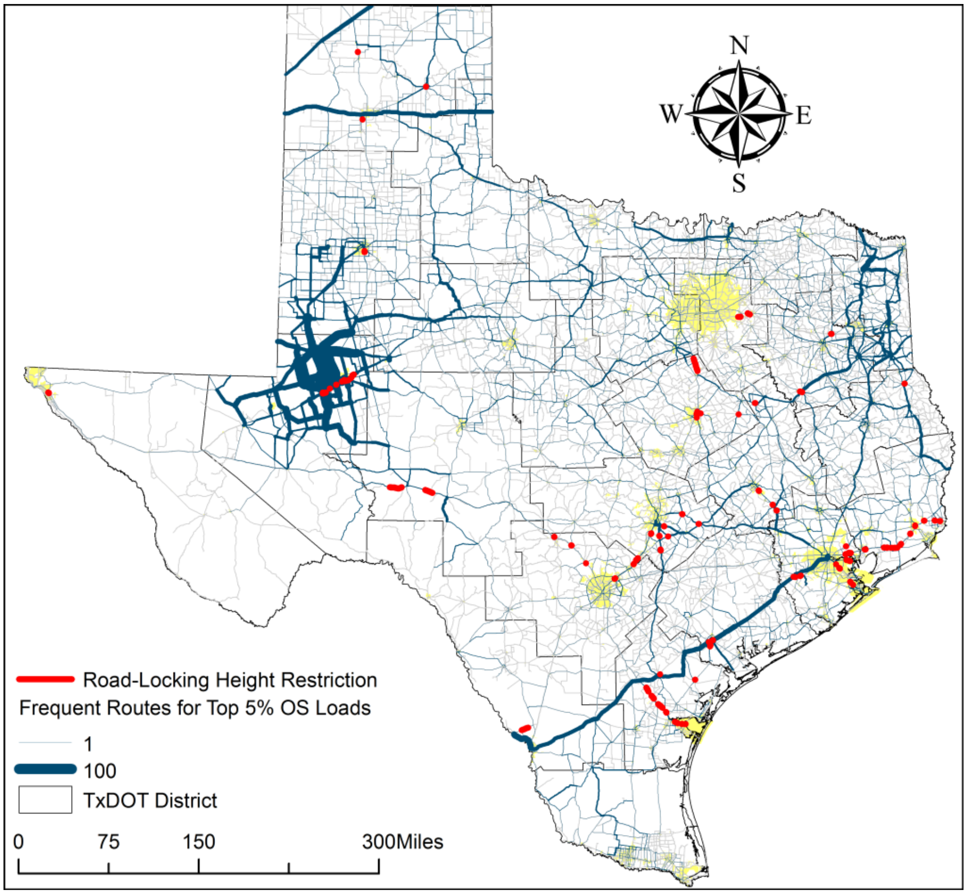


Figure 77. Height Restrictions and Frequent Routes for Top 5 Percent of OS Loads.

Table 31 lists the average differences in miles between the permitted and optimal routes of the top 5 percent of OS loads. Based on the routes that were successfully digitized, these loads in reality traveled about 20 extra miles per trip compared with the optimal distances using the shortest paths. In general, about 50 percent of such shipments were longer than the optimal routes on the map by more than 8 mi.

Table 31. Differences in Miles between Permitted and Optimal Routes.

Fiscal Year	Average Actual Route Distance (Miles)	Average Optimal Route Distance (Miles)	Average Difference		Median Difference	
			Miles	Percent	Miles	Percent
2004	58.8	41.5	17.2	29.3%	5.7	9.7%
2005	84.3	60.0	24.3	28.8%	8.8	10.4%
2006	82.1	61.7	20.5	25.0%	9.3	11.3%
2007	80.3	53.5	26.8	33.4%	10.5	13.1%
2008	73.1	49.9	23.2	31.7%	11.3	15.5%
2009	70.3	50.1	20.2	28.7%	9.2	13.1%
Total	74.0	52.2	21.8	29.5%	8.5	11.5%

Table 32 shows the numbers of permits involving loads that were taller and/or wider than 16 ft between FY04–09. Assuming the average difference (i.e., 21.8 mi; see Table 31) between the permitted routes and optimal routes for all loads wider and taller than 16 ft, the additional ton-miles that could potentially be avoided by improving the infrastructure totaled 622,652 for the six fiscal years, or 103,775 per year. Based on the median difference, the corresponding numbers are 242,777 ton-miles for six years, or an average of 40,463 ton-miles per year. These estimates would quadruple if the same additional miles were assumed for all permitted loads with heights greater than 16 ft.

Table 32. Numbers of Large OS Loads between FY04–09.

Fiscal Year	Height > 16 ft	Width > 16 ft	Height and Width > 16 ft
2004	13,830	12,402	3619
2005	15,486	13,584	4081
2006	19,622	15,043	5517
2007	22,496	15,327	5240
2008	25,572	15,633	5077
2009	23,010	14,575	5028
Total	120,016	86,564	28,562

CHAPTER 9: CASE STUDY—BRYAN DISTRICT

INTRODUCTION

This chapter provides an overview of the workshop that was held at the Bryan District offices on February 15, 2012. The purpose of this workshop was to discuss project findings with district personnel and solicit their input on movements of permit loads in their district. Researchers used a PowerPoint slide presentation to describe project objectives and findings and then asked TxDOT personnel for input based specifically on Bryan District experience with movement of permit loads. The instructor's guide, included as the Appendix, includes the slides used for the workshop.

THE BRYAN DISTRICT

TxDOT's Bryan District (BRY) encompasses a 10-county area and is located in central Texas between Houston and Dallas. In terms of land area, the district covers 7710 sq mi. The district serves over 14 million daily vehicle miles traveled by all vehicles with 3142 centerline miles of roadway. The population of the Brazos District is about 432,000 persons, and there are almost 389,000 registered vehicles within the district boundaries. Figure 78 shows the district and the major highways passing through it (*83*).

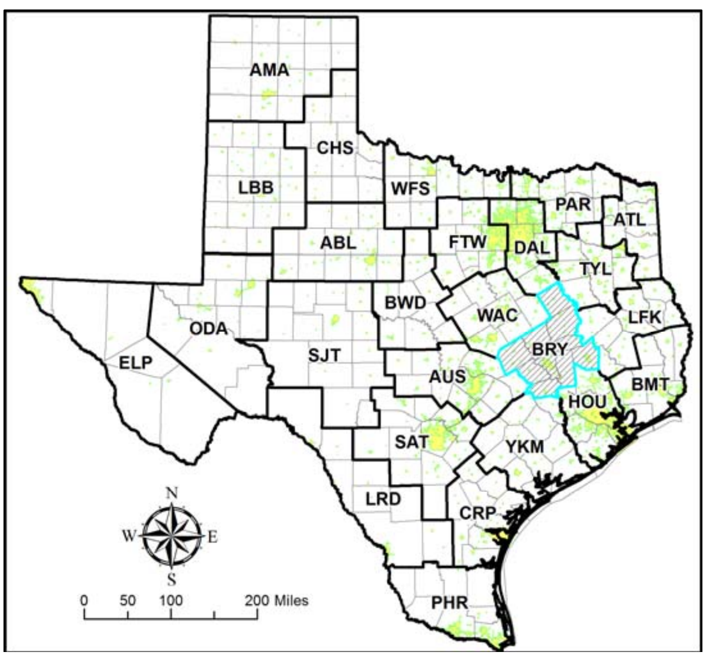


Figure 78. Bryan District.

WORKSHOP FINDINGS

Workshop findings are shown as bullets below under the following headings:

- Potential use of research results.
- Public-private coordination.
- Recommendations to the research team.
- TxPROS.
- Suggestions for high-level meeting.
- Miscellaneous.

Potential Use of Research Results

- Major OS/OW Corridors: The research enables the identification of major OS/OW corridors. Such major corridors need to be kept open to accommodate OS/OW loads. Construction or maintenance projects on these corridors require that bypasses be made available to mitigate their impact on OS/OW loads.
- Construction Zones: When planning construction zones, districts need to know if the roadway is a major route for OS/OW loads so that traffic plans can be developed accordingly to accommodate the loads. In this regard, it is important to know the dominant types of loads traveling on a particular highway section, taking into account both dimensions and weight.
- Permit Statistics: The statistics of permit loads on each roadway section provide information on the types of loads traveling on the section. This information can help district officials to better design the infrastructure (e.g., signal and traffic sign installations) to accommodate the loads. For example, slide number 40 (see Appendix) shows a list of values that are available to the user just by clicking on the route segment. The example shown is FM 50 in the Bryan District. It shows the number of permit loads of a certain description that used that segment. For example, SUMTTI_H_14_15 is the number of loads between 14 ft and 15 ft in height.
- Data for Design: The route statistics could be useful for design and could have provided critical information prior to the current upgrade of FM 50. Many wide loads use FM 50, causing significant impact for traffic in the other direction. The February 24, 2012, 0-6404 meeting in Austin with TxDOT leadership will allow the research team to share this information with the Bridge Division, the Design Division, and others.

Public-Private Coordination

- Coordination: Knowing the current OS/OW routes can improve coordination between TxDOT and the OS/OW carriers and shippers so that the industry can use more logical routes. In addition, TxDOT should work with major shippers/carriers in selection of ports and/or freight hubs to enable more efficient deliveries. This would probably require earlier coordination.
- Partnership Potential: Through public-private partnerships, the affected industries might be interested in improving major optimal corridors (e.g., shortest paths between major ODs) to enable savings in transportation costs. In addition, they might be willing to help improve some of the major corridors they currently use most. For example, if a sign

bridge south of Navasota creates a 40 mi detour, how much would it cost to raise that sign bridge to remove the obstruction, and would industries participate due to their savings? Also, if TxDOT has plans to replace an overpass and standards require a 15 ft clearance, how much additional cost would there be to raise it to 17 ft clearance? Another option might be to construct a short bypass or detour right at the sign bridge.

Recommendations to the Research Team

- Top 5 Percent of Loads: Another analysis that might be useful is a top 50 corridor analysis for the top 5 percent of loads.
- Local Knowledge: Most of the major corridors currently used by OS/OW loads are known to the districts. It was evident from the meeting that this local knowledge is critical to understanding which routes need to be designated as major OS/OW corridors. Researchers identified existing high-use corridors between major OD pairs but did not have time to evaluate some of the optimum corridors for full comparison with existing corridors.
- Route Restrictions: The analysis began with a broad view that extended beyond district boundaries, and then it narrowed its focus to the district level because a restriction on a certain roadway often results in carriers using an entirely different route. For example, many loads going north/south on IH 45 could also use SH 6 or SH 36. The research team might need to look along those routes to determine what is keeping them from being used more (such as height/width restrictions on railroad underpasses in Benchley and Milano or the ability to turn a large load in Hearne from SH 6 northbound to FM 79 westbound). Is there something TxDOT can do to fix one or two restrictions that may open up those paths?
- Texas Trunk System: When recommending top corridors, the Texas trunk system roadways need to be considered. Trunk system roadways can be found on the TPP website. However, truckers do not care if they are on the interstate or trunk system—they just want the shortest and quickest path. It does not matter if TxDOT puts higher standards for the trunk system if that trunk road is not a truck route.
- Potential Benefits of Improvements: The analysis results should provide districts with information on the potential benefits of a project for OS/OW loads. For example, if a bridge is further elevated by a certain height, the district should be able to show how many more loads will be able to go through and what the potential savings are. This will help districts to do cost analysis in relation to proposed projects and provide justification for such projects.
- Route Analysis: One purpose for the research project was to determine the reason why some permitted trucks went off route. A complete analysis will require looking at lower volume routes to find some of the answers. The route analysis could be improved by involving persons more familiar with them such as district personnel.
- District Guidance Essential: TTI observations indicated that US 79 and SH 21 might be viable options for routing of OS/OW loads in a general southwest/northeast direction. However, district personnel pointed out that there is very little demand for loads on those routes. Again, district input is critical in determining which routes need to serve this need. Currently, loads wider than 12 ft use portions of FM 50, US 79, and FM 1644.

- Design Vehicle: There should be a certain design envelope vehicle selected for the corridors chosen to serve OS/OW loads. This vehicle might be bigger than the 95th percentile vehicle, which is currently 16 ft wide and 16 ft tall. The Design Division would have to be involved in such decisions since it would represent significant costs and design changes. In changing design standards to encourage OS/OW corridors, TxDOT should focus initially on interstate and trunk system routes but, within those, concentrate on the primary corridors of the OD pairs to create more direct routes that would be utilized.

TxPROS

- Ongoing Updates: Beyond this research project, TxDOT needs to continue using updated GIS route data from TxPROS to keep the research results up to date.
- District Level Statistics: TxPROS will have reporting capacity to provide information on routes by load groups and statistics at the district level.

Suggestions for Upcoming Meeting with TxDOT Leadership

- Emphasis for Largest Loads: The research team needs to point out during the presentation to TxDOT leadership, scheduled for February 24, 2012, that the top 5 percent of loads are still a lot of loads.
- Numbers versus Percentages: In presenting information to others, the research team should emphasize the numbers of loads rather than percentages, as it is a more descriptive metric. For example, the research team can show that a route currently has 20,000 loads per year, but removing a particular obstruction could increase that number to 60,000 loads per year, diverting 40,000 loads from other routes.

Miscellaneous

- Monitoring Super-Heavy Loads: There was discussion about the impact of super-heavy loads on pavement. TxDOT requires that such loads be very carefully engineered and monitored to control their damage to the infrastructure. It is the not-so-heavy loads that cause more pavement damage due to their larger volume.
- Specific Restrictions: The overhead railroad bridge on SH 6 near Benchley is a major restriction along the corridor (clearance is 14 ft 6 inches). This restriction needs to be added to the research results. Another railroad overpass on SH 36 near Milano also caused many reroutes, and the SH 6 reconstruction project caused diversions between March 2006 and September 2010 as well.
- Fees for Permits: There was discussion on the current permit processing fee schedule. The consensus was that the current fees are not sufficient compared to the damage of OS/OW loads. The current fees are primarily determined based on weight, and the most expensive single permit is about $475. A significant portion of this revenue goes to the general fund and is not available for transportation projects. There is an ongoing project to evaluate what the cost should be (Research Project 0-6736), which is the Rider 36 project. It is likely that some of the permit costs need to increase. However, the amount

of change (if any) needs to reflect one of the overarching goals of maintaining a commerce-friendly atmosphere.

- Rail Shipments of OS/OW Loads: A comment received on the TTI survey of permit coordinators suggested that more oversize loads should be shipped by rail. However, rail systems are old, and they cannot accommodate some dimensions of these loads.
- Permit Trend: The 2012 permit issuance numbers will probably indicate continued growth in the annual totals since 2011 showed an increase over 2009 and 2010. This increase might represent a difference of 50 percent to 60 percent compared to the first year in the MCD dataset, 2004. There had been a downturn in permit applications, perhaps due to the sluggish economy.
- District Investment Decisions: The district needs to know the heights of all major obstructions along a route to make the best decisions. For example, if TxDOT decides that the railroad bridge clearance at Benchley should be increased, there should also be information on other structures to make sure improving this one would make a difference. If another low clearance exists along the route, fixing this one might not matter. To determine the return on the investment, the district would also need to know how many oversize loads could travel that route with and without the improvement. Also, rebuilding the Benchley overpass might cost $30 million to get its clearance to 17 ft, but should future clearances along OS/OW corridors be 18 ft, or even more?

CHAPTER 10: SUMMARY AND RECOMMENDATIONS

INTRODUCTION

This chapter provides a summary of findings based on stakeholder interviews and results of a spatial analysis using ArcGIS. Beyond the summary, the chapter provides recommendations related to primary oversize/overweight corridors throughout the state. The recommended corridors are based on historical usage of routes given a large number of restrictions such as overpasses and load-zoned bridges. Looking to the future, there will also need to be other recommendations pertaining to primary and alternate OS/OW routes based on workshops with districts similar to the one conducted in the Bryan District. The recommended statewide routes in this chapter acknowledge that some routes will serve as primary routes during some intervals of time and alternates during others.

Assumptions

There are a few assumptions and caveats that the analysis of routes needs to consider. The analysis in this report assumed that carriers used the same routes assigned by the MCD. There were likely some that did not follow the permit routing exactly, but the research team had no way to verify the routes.

Only certain loads (permit types) have routes assigned. The MCD offers a total of 26 permit types (including one for temporary operating authority). This research is based only on the permits that had routes assigned. Of the approximately 3.1 million records, the research team did not clean *all the routes* in any of the six years from 2004 through 2009. An early meeting with statisticians led to the conclusion that any results based on this process would probably be as valid as if routes were randomly selected. Besides, by selecting a sample randomly, the research team would probably not have as large a sample with which to work since some of the randomly selected routes would take more time to process than the ones actually selected.

Recent trends indicate that the economy is improving (following the downturn in 2009). This improvement is reflected in the increasing numbers of permits per year (e.g., 2011 totals indicate issuance of about 580,000 permits).

SUMMARY

The following summary includes these topics:

- TxPROS.
- District permit coordinator comments.
- Motor carrier industry comments.

- TMTA comments.
- Escort service comments.
- Enforcement comments.
- Spatial analysis.

TxPROS

MCD anticipates that full implementation of TxPROS will provide the following benefits specifically to TxDOT:

- Improve TxDOT's tracking of structures and restrictions that affect OS/OW routing.
- Allow tracking and reporting of the movement of OS/OW loads on Texas roadways.
- Provide the most customer-focused solution for meeting the needs of OS/OW carriers.
- Optimize use of current TxDOT technical architecture and available roadway data.
- Improve management of the transportation infrastructure.

To facilitate TxDOT's full utilization of the capabilities of TxPROS and the results of Research Project 0-6404, there must be a designated organizational component within TxDOT that becomes the liaison between MCD and TxDOT. The Office of Primary Responsibility (OPR) in this case is the Maintenance Division, so it will most likely have responsibility over the longer term to ensure that TxDOT stays in the loop with MCD. It is anticipated that this requirement will involve periodic communication and formal meetings with MCD staff. Keeping TxPROS viable in coming years will require this dialog on an ongoing regular basis.

Availability of TxPROS and results from Research Project 0-6404 serve as a starting point in this process. The research team envisions that TxPROS will provide reporting capabilities for TxDOT divisions and districts to accomplish the following:

- Identify routes used to transport OS/OW loads.
- Determine how often these routes are being used and vehicle sizes and weights.
- Determine the effect of permit restrictions on other roadways.
- Identify the types of loads transported over which routes.

District Permit Coordinator Comments

The following information is based on the survey of district permit coordinators. Fifty percent of responders thought OS/OW destinations had changed, whereas only 17 percent thought origins had changed. More than 70 percent of responders indicated that the overall dimension and weight of OS/OW loads had increased. In addition, 86 percent of the permit coordinators suggested that the frequency of OS/OW permit applications had increased. Permit coordinators anticipate the following trends in the next five to 10 years:

- More loads that are bigger than in the past.
- Increased number of loads coming from Mexico and shipped to Mexico.

Permit coordinators believe that the current impediments to movement of these OS/OW loads on trucks within their respective districts are:

- Limited structure heights.
- Construction or maintenance work zones.
- Fixed traffic signal mast arms instead of cables.
- One-way frontage roads (contra flow) combined with confined turning radius.
- Load-zoned roads and/or narrow roadbeds.

Only about one-third (29 percent) of responders believe that intermodal facilities need to be made larger or otherwise changed due to the predicted trends. Specific responses were:

- More OS/OW loads could be transported by rail.
- Roads need to be built to higher standards to withstand the weight and turning (radius) of these loads. Roadways need to be made wider.

Responders believe that the trends in other modes of transport besides trucks are:

- Rail is limited in moving OS/OW due to the size restrictions.
- Marine: Ships are bringing in larger cargo more often.

Specific other comments from responders were:

- More companies are hauling OS/OW loads than in the past.
- Carriers seem unaware of the damage, and fewer routes are available.

Motor Carrier Industry Comments

A seasoned motor carrier industry spokesman who had spent a significant amount of time throughout his career defining risk in the context of oversize/overweight loads classified operations into the three following general areas:

- Legal loads.
- Anything over legal up to 15 ft wide, 16 ft tall, and under 254,300 lb gross weight.
- Anything over 254,300 lb gross vehicle weight.

His conclusion regarding legal loads was that they involve medium risk. Sources outside the motor carrier industry can determine safety ratings to determine things like insurance rates, and these ratings provide a good idea about the risk involved.

Vehicles that exceed 254,300 lb gross vehicle weight are low risk. These are super-heavy loads, and the routes are heavily scrutinized mile by mile. This process usually investigates comprehensively any challenges that might occur and has a reasonable action plan to mitigate any perceived delays and problems. These loads are usually moving under direct traffic control of private as well as governmental escorts. The loads are so high profile and so expensive that the carrier and shipper cannot afford to overlook anything.

Finally, he maintained that the loads that fall between the first and second categories above are the high-risk loads. These loads seem to be treated as business as usual by everyone. States tend to route these loads on all types of roads and oftentimes allow carriers to tell the states which routes they prefer. There are probably safer routes that offer greater clearance or have less traffic.

Texas Motor Transport Association Comments

A TMTA spokesman noted the trend in larger and heavier OS/OW loads (i.e., super-heavy loads) and commented that loads will probably continue to get even bigger unless the government steps in and somehow limits or discourages the maximum sizes and/or weights that can be shipped on highways.

In a recent situation, apparently an exception to normal practice, the shipper contacted the motor carrier *prior to* manufacturing the load to inquire about shipment. The carrier told the manufacturer that reducing the load width by 2 inches would reduce the transportation cost significantly and would remove the need for a permit. Another example that illustrated a lack of understanding on the part of a manufacturer was when the manufacturer began building components for generating wind energy that would require super-heavy permits for shipment. The manufacturer apparently thought the Motor Carrier Division could issue super-heavy permits immediately, but that was not true.

The TMTA representative has heard complaints from carriers about traffic signal mast arms more than any other single obstruction. Since the mast arms are rigid, the load might have to pass to one side or the other to clear the arm. In other cases where the load is extremely large, mobile cranes might be used to lift the mast arms upward just enough to let the load pass, or field personnel might have to unbolt the mast arm to provide the required clearance. There is a risk of damage to the traffic signal equipment or vehicle detection equipment when this happens. One remedy is more widespread use of span wire to support the signal heads instead of the more rigid mast arms. The vertical clearance would be about the same, but the supporting cable would be easier to displace while causing little or no damage as the load passes.

The motor carrier community is anxious to see TxPROS released into full service. The carriers believe that TxPROS will make routing more efficient, with fewer unanticipated problems en route.

Escort Service Comments

A representative from Trailblazer Pilot Car said the real challenge in moving oversize loads is height. Some of the super-heavy loads he escorts are over 20 ft wide and up to 300 ft long. He has poled loads up to 26 ft high and loads weighing up to 800,000 lb.

This escort service has been lobbying to get a certification law passed to make it a requirement for all escorts to be certified. He maintains that escorts should have the authority to keep a load from moving if it is actually bigger than the permit says it is. Some carriers request a permit for a smaller load that does not require an escort so they can save money. According to this escort service, enforcement personnel rarely stop oversize loads. He commented that in his 16 years of operating the escort service, enforcement has only stopped two or three oversize/overweight loads. Even then, officers gave the permit a cursory glance and sent the driver on his way. One load trend he noted was that loads are getting larger and heavier.

This escort service is involved in four big upcoming loads, one of which is 22 ft wide and 34 ft tall. He offered comments in favor of developing designated routes for OS/OW loads across Texas. He emphasized that there should be high routes where loads could be as much as 25 ft tall. He added that some routes in Canada have no overhead lines to restrict the movement of tall loads.

Enforcement Comments

Enforcement of OS/OW loads to verify that the weights are the same as claimed on the permit is time-consuming, especially for super-heavy loads. Checking the weights of the bigger loads requires using scales from several roving troopers. Bringing in several troopers is disruptive to normal schedules and might take a few hours for all the troopers to arrive at the enforcement site and then conduct the weight check.

The second challenge to weighing these OS/OW loads is in getting the portable scales in position to accurately check the weight. Once positioned, the truck driver must carefully move forward until the axles are directly over the scales. Also, due to the trailers being so low to the ground, crawling underneath to position the scales is difficult, even with a smaller person.

Due to the challenges associated with weighing these large loads, DPS usually relies on visual observation or on WIM, although WIM alone is not sufficiently accurate for direct enforcement. DPS is receiving more requests from TxDOT to check the weights on the heaviest vehicles than it did a few years ago.

Spatial Analysis of OS/OW Routes

According to the analysis, the busiest IH corridors for permit loads included many sections of IH 10, IH 20, IH 30, and IH 35. The major US corridors used by OS/OW loads included many sections of US 59, US 90, and US 287. The busiest SH/SL and FM corridors used by OS/OW loads were generally detours or shortcuts along the major IH and US corridors or short corridors impacted by local activities.

The analysis evaluated major routes taken by permitted loads where width and height were both greater than 16 ft. Such loads became known as the top 5 percent of loads for convenience. Panel members suggested that due to their large dimensions, these big loads need special attention and frequently cause problems such as damage to roadside/overhead structures on FM roadways. Such loads frequently traveled in the Odessa, Pharr, and Atlanta Districts. A known factor contributing to frequent large loads in those areas was concentrated oil/gas and/or wind energy activities. Odessa and Pharr, in particular, had proportionally many more loads that were taller than 14 ft compared to other districts.

The analysis also included the distribution of OS/OW trips in various TxDOT districts by load width. The majority of the OS/OW permit-miles involved widths in the range between 8.5 ft and 16 ft. Loads wider than 12 ft were the dominant OS group for several districts, such as Pharr, Odessa, Bryan, and Fort Worth.

The distribution of OW trips on FM roadways by gross vehicle weight indicated that Atlanta and Pharr were the two districts where FM highways carried the most overweight permit loads. Districts such as Odessa, Atlanta, and Pharr had a significant number of trips involving heavy vehicles weighing between 120,000 lb and 150,000 lb. In addition, the Atlanta, Pharr, and Bryan Districts had a large number of overweight permits involving vehicles weighing more than 175,000 lb. Among all districts, Abilene FM highways carried the most loads weighing more than 200,000 lb. This finding probably results from local wind farm development activities. FM roads in Odessa, Pharr, and Atlanta carried most loads related to oil/gas development, while Abilene had the largest proportion of permits involving loads associated with wind farm development.

The major OD analysis indicated that Houston, Dallas-Fort Worth, and El Paso were major hubs generating/attracting OS/OW loads. Among those major hubs, Houston further stood out with highly frequent OS/OW trips originating or destined for the Houston area. This finding is undoubtedly due, at least in part, to activities at the Port of Houston. Based on the top OD pairs, there were a significant number of OS/OW permits from Louisiana and Arkansas destined for Houston. In addition, many OS/OW loads traveled between Oklahoma and New Mexico via the Texas panhandle. A significant number of trans-state OS/OW trips occurred between El Paso, Laredo, or Houston and the surrounding states.

Based on the analysis of restrictions and based on the average route difference and median difference of the studied OS/OW routes, the research team estimated the ton-miles associated with the additional miles traveled (optimal vs. actual). Potentially, such additional ton-miles might be avoided by infrastructure improvements that allow the OS/OW loads to be shipped via shortest routes on the state highway network.

Using non-optimal OS/OW routes resulted in a conservative estimate of more than 290 million ton-miles of shipments on the state highway network due to physical restrictions and possibly other factors. During the entire six-year study period and based on a conservative estimate, the accumulated ton-miles totaled more than 1.7 billion. When using the average route difference, these two values become 504 million and 3 billion ton-miles, respectively.

The research team also evaluated the extra costs incurred by transportation providers and the public due to the additional miles that the OS/OW vehicles traveled. On an annual basis, the additional ton-miles OS/OW vehicles had to travel resulted in about \$42 to \$73 million of additional costs for shippers and the public. These numbers translate to a total of about \$252 to \$438 million loss during the six-year study period.

RECOMMENDATIONS

Trends in OS/OW Vehicle Sizes and Weights

A critical component of this research was determining the appropriate size and weight factors for vehicles currently using and expected to use TxDOT roadways. The research team in conjunction with the Project Monitoring Committee stratified vehicles of primary interest as the 95th percentile vehicles and the top 5 percent of vehicles. The top 5 percent of vehicles generally fall into the category of super-heavy vehicles, although they are specifically defined as those weighing at least 254,000 lb (*64*). Table 33 compares the 95th percentile vehicle based on data from the MCD from 2009 with the largest and heaviest super-heavy vehicle in 2009.

Table 33. Comparison of Historical 95th Percentile and Super-Heavy Vehicles (2009).

Size/Weight Component	95th Percentile Vehicle	Largest Super-Heavy Vehicle
Height	16 ft	33.5 ft
Width	16 ft	45 ft
Length	120 ft	256 ft
Weight	168,000 lb	1.8 million lb

Consideration must also be given to current trends in vehicle sizes and weights to predict future clearance and structural needs around the state. Vehicle characteristics in the six-year database from MCD as well as stakeholder input indicates that permit vehicles are getting heavier and larger. The MCD data indicate that the 95th percentile vehicle beyond 2012 should be at least 18 ft high and 17 ft wide. The length is also increasing and will be greater than 120 ft, necessitating adjustments in the design of intersections and turning roadways.

With the increase in demand for super-heavy permits over the six-year database, the MCD will also need to carefully consider the impact of super-heavy vehicles over the longer term. Given their smaller numbers and the close scrutiny paid to them on every route, they are less likely to become a problem than the 95th percentile vehicles. The research team recommends that TxDOT and MCD continue to monitor the activities of super-heavy vehicles to determine if change is needed in the way they are handled. As time goes on, there might need to be a limited number of special routes along the highest demand corridors to meet their specific needs.

Spatial Analysis for Statewide Network of Routes

The Bryan District workshop left a clear and lasting impression on the research team that developing recommended primary and alternate routes requires local knowledge of permit needs. In other words, future activities related to permit load routing must involve the local rich knowledge base that is available in each district office. That knowledge will be essential in selecting primary and alternate routes. For that reason, the research team developed a statewide map that primarily reflects historical routes and does not fully develop recommended primary and alternate routes as originally intended. Researchers propose that the final primary and alternate route network be developed in an implementation project that will begin in FY 2013.

Figure 79 shows the routes corresponding to the top 500 origins and destinations, without distinction to vehicle sizes and weights (i.e., it includes both 95th percentile vehicles and top 5 percent vehicles). This map represents the research team's initial proposed primary/alternate route network for the entire state.

Improve Public-Private Coordination

As shown in the study, infrastructure restrictions impose significant restrictions on OS/OW routing and cause non-trivial additional costs for the associated industries. This research provides an opportunity for the initiation of cooperation between public transportation agencies and the affected industries to collaboratively improve critical corridors between major ODs to reduce the route mileage required for delivering OS/OW loads. Research results can serve the needs of both transportation agencies and shippers to select and coordinate the optimum transportation modes and routes to mitigate traffic impacts while minimizing transportation costs. In other words, the results can facilitate potential coordination on the most rational freight hubs and/or ports (i.e., origins and/or destinations) so that the best modes and routes can be utilized.

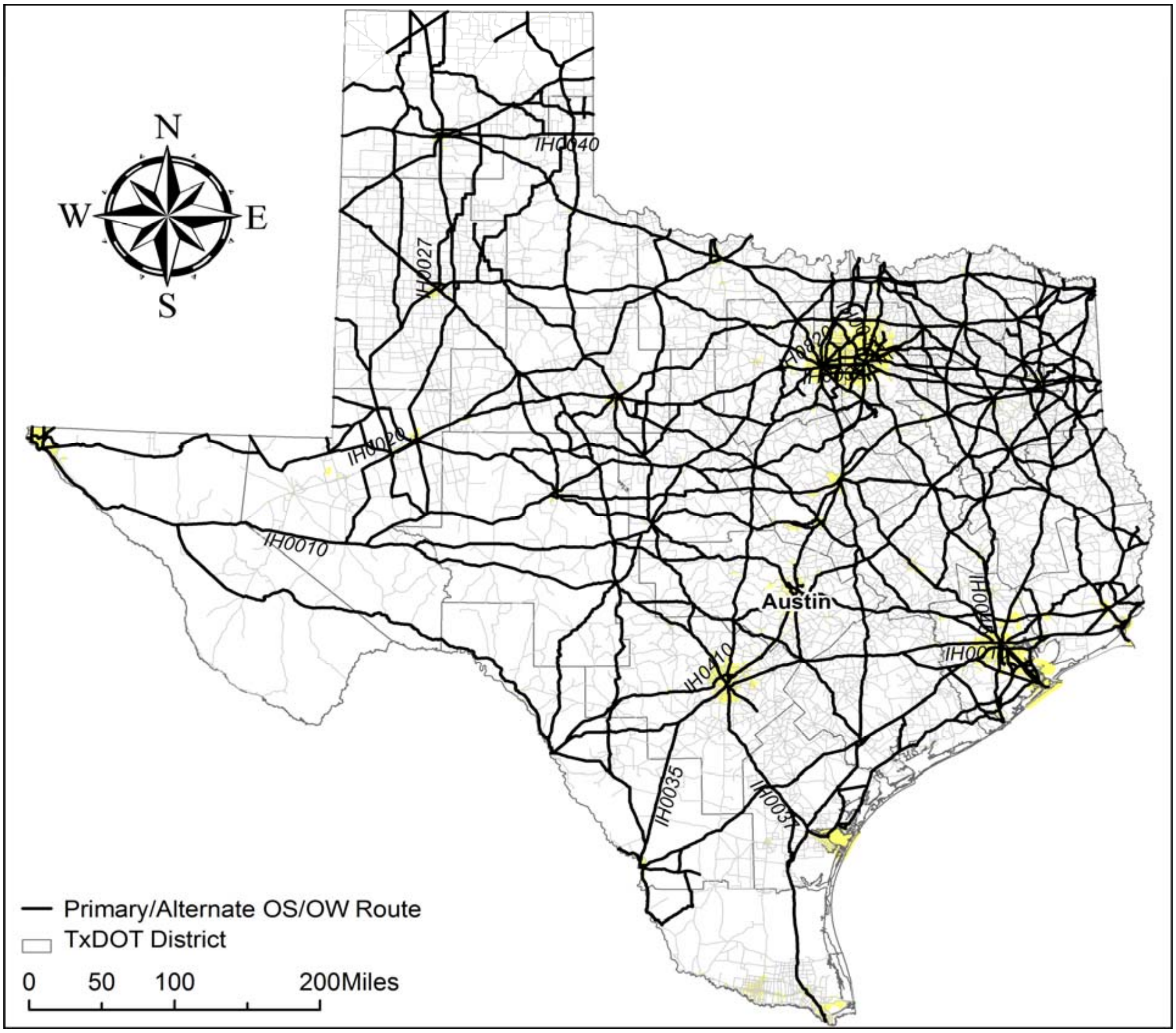


Figure 79. Primary/Alternate OS/OW Routes.

Implementation of Research Results

By linking OS/OW permits with specific roadway segments, this research helps TxDOT officials to determine the magnitude and characteristics of OS/OW loads on any roadway section. Such information is critical for assigning suitable corridors for OS/OW loads and planning detours during road construction and maintenance activities. It also allows for controlling such loads on unsuitable corridors. The research results also provide critical information for roadway designers to better accommodate OS/OW loads. The results are also valuable for public information and justification of important highway projects that would yield significant benefits to users with moderate changes in current design standards.

Given the value of the research results, the research team recommends that workshops like the one conducted in the Bryan District be carried out in other districts. Without the input from local knowledgeable district personnel, the final selection of primary and alternate routes will be much less valuable. Researchers propose that other districts be contacted through an implementation project that begins in FY 2013. The project length would likely be one year.

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APPENDIX A

ACCOMMODATING OVERSIZE AND OVERWEIGHT LOADS:

INSTRUCTOR GUIDE

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1. INTRODUCTION

INTRODUCTION

This instructor and student guide is designed to guide the instructor in conveying information at the district level concerning Research Project 0-6404, “Accommodating Oversize and Overweight Loads.” The specific information focuses on the Bryan District but could be adapted to other districts.

BACKGROUND

Effective and sufficient support to domestic and international freight movements is a key to a vibrant economy. In 2007, the U.S. transportation system moved 51 million tons of commodities each day worth $45 billion (*1*). Although temporarily decreasing between 2008 and 2009, the total tonnage started to rebound in 2010, and it is forecasted that annual tons per capita will increase 27 percent from 55 tons in 2010 to 70 tons in 2040. A significant proportion of this tonnage translates to oversize and/or overweight (OS/OW) truck loads that have to be routed to avoid permanent or temporary physical constraints of the transportation infrastructure.

Texas, along with many other states, has been making significant strides in developing the state transportation system to accommodate OS/OW loads. Available information based on research experience and interviews with the Texas Department of Transportation (TxDOT) indicate that many state permit offices experienced increased numbers of OS/OW permit requests and super-heavy load requests prior to the economic downturn. For example, TxDOT’s Motor Carrier Division (MCD) experienced an increase in permit requests of 33 percent from 2003 to 2007 (*2*). Super-heavy requests increased 667 percent from 2004 to 2007, partly due to the statewide boom in wind energy and oil/gas development. Since 2007, TxDOT has issued more than 500,000 OS/OW permits every year. Although decreasing in 2009, there is little doubt that OS/OW activities will bounce back and continue to grow nationwide.

To prompt safe and efficient routing for OS/OW loads, improve safety, and minimize deterioration to state highways, Texas formed an OS/OW working group consisting of engineers from the north and east Texas (NETx) district and division representatives. In 2007, TxDOT further organized a Super-Heavy and Overweight Load/Seal Coat Damage Prevention Work Group consisting of staff from NETx districts, MCD, the Construction Division, and the Maintenance Division. In addition, TxDOT is currently in the process of developing geographical information system (GIS)-integrated software, called Texas Permit Routing Optimization System (TxPROS), to automatically route OS/OW loads online (*3*).

As part of Research Project 0-6404, the research team processed and mapped a massive dataset of OS/OW permit routes into a GIS format. This instructor and student guide presents the objectives of the project along with some of the findings in tabular and graphical formats. It also briefly covers the methodology used to gather and process the information gathered from the Motor Carrier Division and industry stakeholders.

OBJECTIVES

The primary objectives of this research included:

- Development of criteria for assigning current and projected OS/OW groups to future network.
- Identification of strategic infrastructure improvements to accommodate such loads.
- Development of optimal routes for priority load groups between the most common origins and destinations.

ORGANIZATION OF THE GUIDE

This guide consists of three chapters organized as follows. Chapter 2 presents the methodology used to gather and process the information. Chapter 3 is a series of slides for use at the district level to inform district decision-makers and solicit district-specific information regarding oversize/overweight permitting activities in that district. In its current form, it applies to the Bryan District and was used in a district workshop held on February 15, 2012.

CHAPTER 2. METHODOLOGY

INTRODUCTION

The research team acquired information along two separate tracks. The primary data for analysis came from six years of historical data provided by the Motor Carrier Division. The bulk of this chapter deals with the methodology for analyzing that data. The other track for gathering information from stakeholders used telephone calls to contact key individuals and organizations to ask questions about permit load movements.

For the purpose of this project, the research team requested OS/OW permit data from TxDOT MCD for the period fiscal year (FY) 2004 through FY 2009. The original data contained more than 3 million permits over the six-year period. For most of the permits, the data included information such as load dimensions, weights, axle configurations, and load description. For a majority of the permits, the original database also included manually entered descriptions of permit routes, route origins, and route destinations.

To enable GIS-based analysis of OS/OW loads and their routes, the research team mapped a large number of the permit routes including their origins and destinations as described in the original permit data into a GIS format. Based on the mapped routes, the research team conducted a spatial analysis to understand how different groups of OS/OW loads historically traveled on the state highway network and how permanent restrictions impacted the route choices of such loads.

STAKEHOLDER INTERVIEWS

The Texas Transportation Institute (TTI) team solicited information from a comprehensive and broad-based list of agencies to gather information and data. TTI conducted phone and/or office interviews with knowledgeable personnel from each of the identified agencies. The "other stakeholders" included:

- Enforcement agencies.
- Escort companies.
- Metropolitan planning organizations.
- TxDOT:
    - Bridge Division.
    - District Permit Coordinators.
    - Maintenance Division.
    - Traffic Operations Division.
    - Transportation Planning and Programming.

GIS ROUTE AND ORIGIN-DESTINATION (OD) MAPPING

Historically, the MCD manually assigns permit routes when processing OS/OW permit applications based on the load dimensions and weights. As a result, the manually entered route information in the original permit database was not immediately ready for use within a GIS. The syntax used for route starts, route ends, and route descriptions was not standardized and contained many spelling errors, inconsistent abbreviations, and unknown entries. A large number of records contained multiline text in the route description field where only one line corresponded to the route information. In addition, many records contained different special characters that cluttered the data and made it more difficult to use.

The research team developed a multi-step process to map the permit routes into feature classes. The mapping process used the Route Analyst function available in ESRI ArcGIS® Desktop to convert text route descriptions into ESRI line features. In addition, the superior data storage and query capabilities of Oracle® database management software were utilized during the mapping process to improve processing speed. The entire route mapping process included the follow general steps:

- Clean and standardize original route descriptions.
- Prepare a navigable route network based on a TxDOT on-system roadway layer.
- Create a route intersection layer (referred to as the junction layer hereafter) that contained all intersections, origins, and destinations involved in the original route descriptions.
- Map route descriptions into separate ESRI Shapefiles based on the route layer and junction layer.
- Further process the resulting Shapefiles for future GIS route analysis.

The research team used a similar approach as for permit route description to standardize the route origin and destination descriptions. For those that could not be standardized using scripts, the researchers identified meaningful records and manually processed the common entries among them. Because the future analysis required association between OD pairs and the actual mapped routes, the OD description cleansing was primarily focused on those records that contained valid route descriptions. The research team developed VBA scripts on the ArcGIS Desktop platform to map the unique OD pairs into line features. OD analysis results based on the original permit data were then appended to the corresponding OD pairs for further analysis and presentation.

OS/OW ROUTE ANALYSIS

Based on the GIS routes that were successfully mapped, the research team conducted several types of analysis to understand how OS/OW loads travel on the state highway network and how infrastructure restrictions affected the route choices. The analysis results constituted the foundation for the materials used in the pilot workshop in the Bryan District. Major analyses included:

- Frequent route analysis. During this analysis, the research team estimated the frequencies of OS, OW, and all permits on each individual roadway segment during each study year. In addition, the total weight of the OW loads on each roadway segment was also determined for the corresponding roadway segment. Focusing on FY 2009 data, the research team also determined the numbers of loads of different categories grouped by load dimension and weight information for each individual roadway segment.

- OD analysis. For each OD pair, the research team determined the numbers of associated OS/OW loads of different load categories grouped based on load dimension and weight.
- Restriction analysis. Based on the permanent restriction data received, the research team identified road-locking height and weight restrictions on major OS/OW routes and compared them against the current OS/OW routes. For simplicity, the research team focused on the most frequent OS/OW routes during the height restriction identification. Doing so allowed researchers to identify those that impacted a significant number of loads yet allow them to finish within the time constraints. The analysis helps readers to understand how such restrictions affected the route selection of OS/OW loads both globally and locally. In addition, it provides critical information to help identify the critical restrictions that impact significant numbers of OS/OW loads.
- Optimal route analysis. The research team generated optimal routes based on the top 500 OD pairs and OD pairs associated with loads that were higher and wider than 16 ft. This analysis helps readers to understand how the loads would travel in an ideal world without any restrictions. In addition, the research team also quantified the additional travel into both ton-miles and dollars based on a comparison study between the current routes and optimal routes.

CHAPTER 3. PRESENTATION SLIDES

INTRODUCTION

TxDOT's Bryan District encompasses a 10-county area and is located in central Texas between Houston and Dallas. In terms of land area, the district covers 7710 sq mi. The district serves over 14 million daily vehicle miles traveled by all vehicles with 3142 centerline miles of roadway. The population of the Brazos District is about 432,000 persons, and there are almost 389,000 registered vehicles within the district boundaries. Figure A-1 shows the district and the major highways passing through it (*4*).

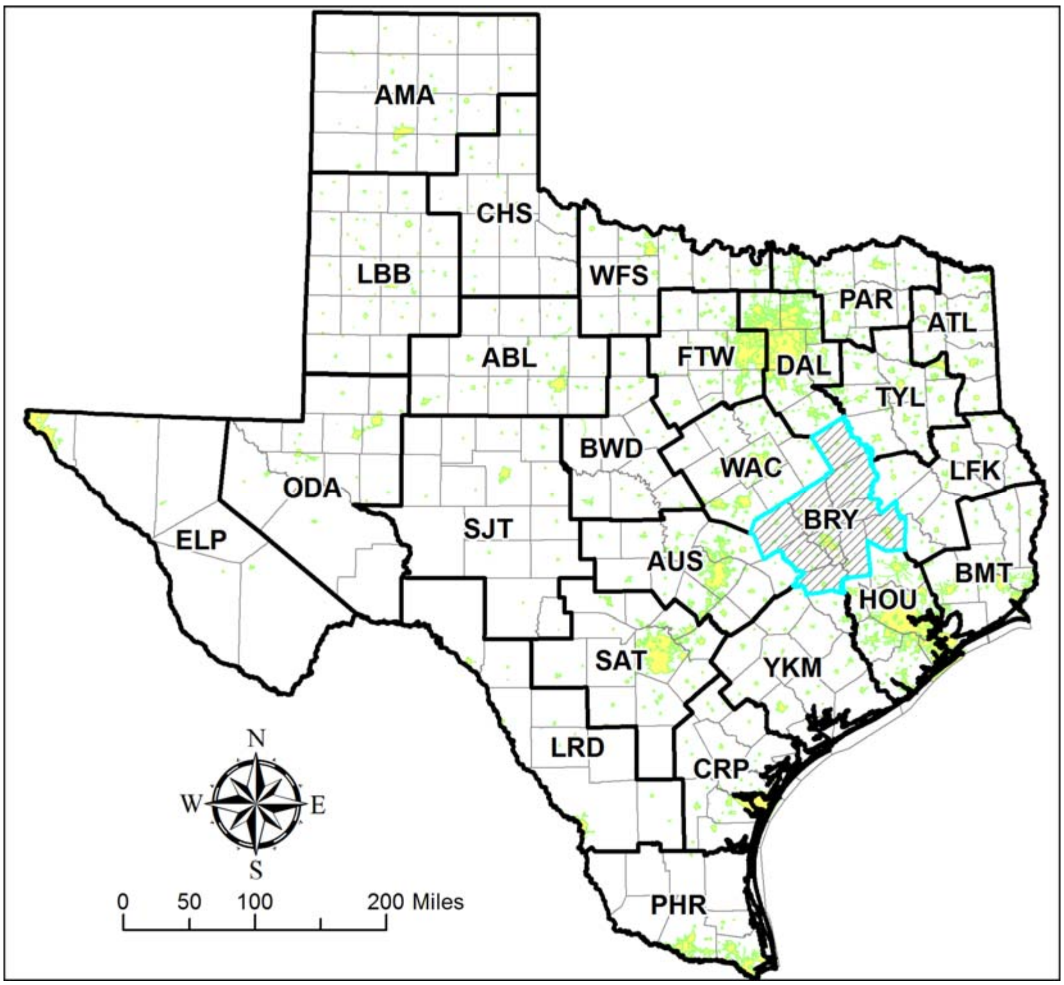


Figure A-1. Bryan District.

PRESENTATION SLIDES

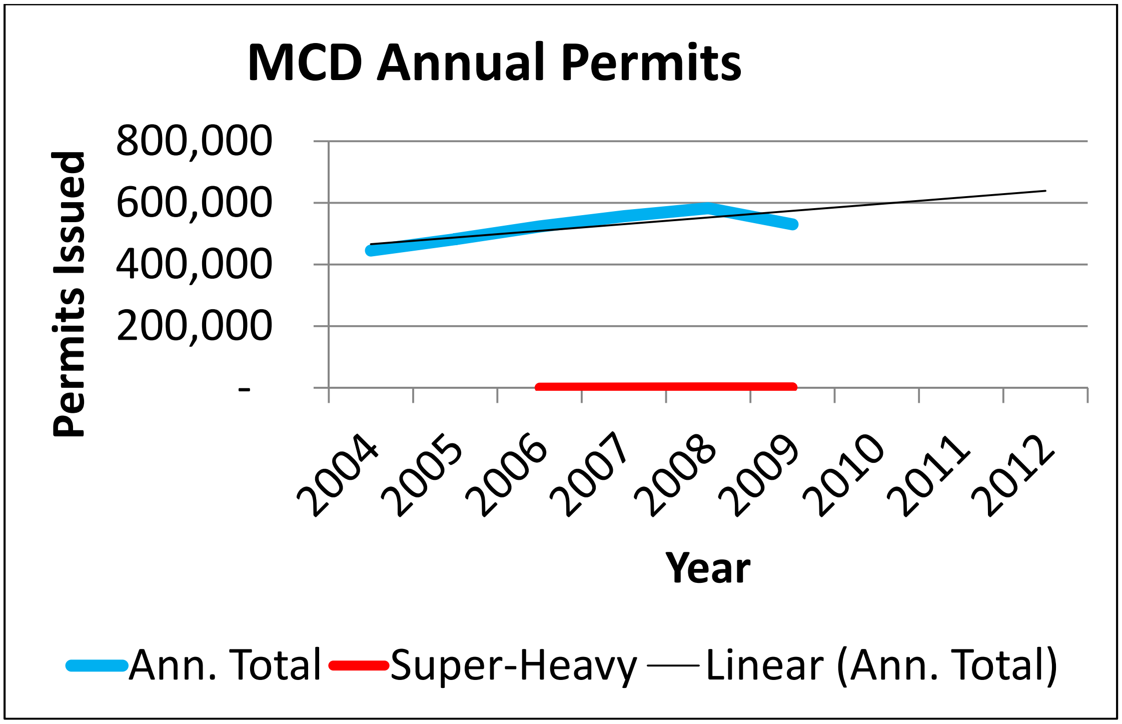
Slide #1 Title Slide

Slide #2 TxDOT and TTI Team Members

TxDOT	TTI
Connie Flickinger (PD)	Dan Middleton (RS)
Darlene Goehl	Eric Li
Ray Hutchinson (retired)	Jerry Le
Vincent Lewis	Jodi Carson
Janet Manley	Nick Koncz
Justin Obinna	Chi-Leung Chu
Andrew Wanees	Cesar Quiroga
Dean Wilkerson	
Duncan Stewart	
Frank Espinosa	
Brian Merrill	
John Holt	

Slide #3 Project Motivation

- NETx Working Group Recommendations
    - Improve communications
    - Improve route options for OS/OW loads
    - Reduce seal coat damage
- MCD permit trends
    - Weights and sizes are increasing
- Promote commerce
    - Keep routes open



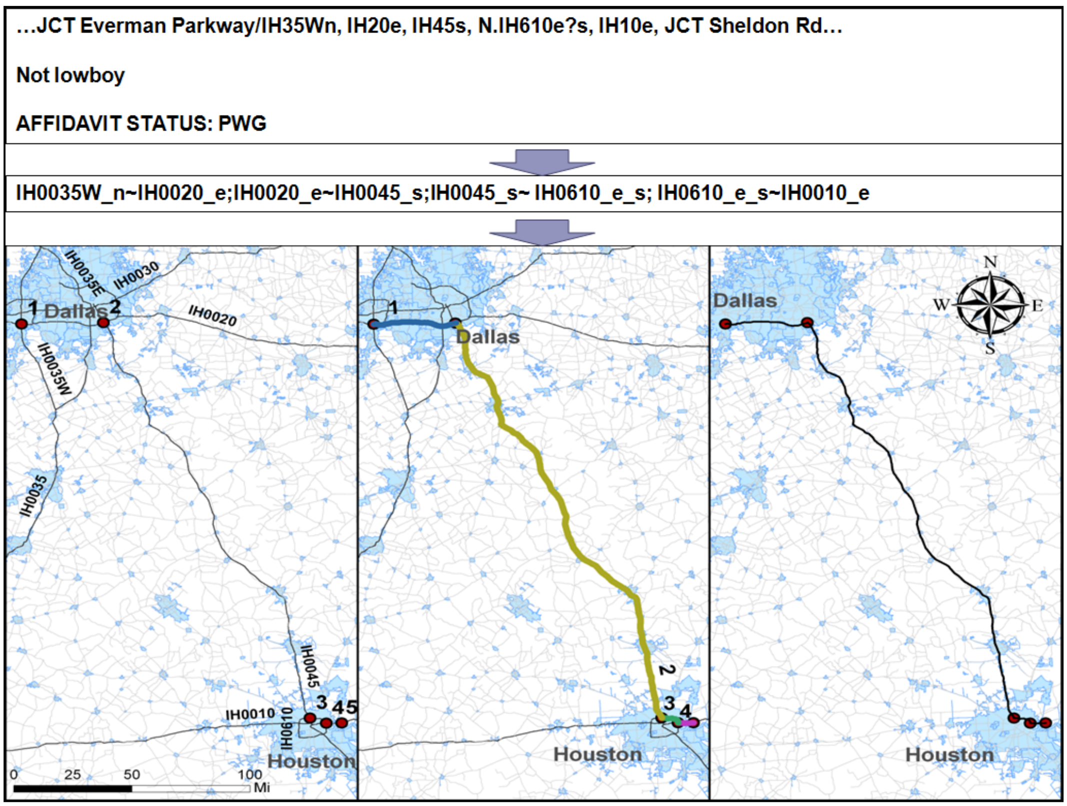
Slide #4 Research Objectives

- Identify a set of OS/OW <u>dimension and weight groups</u> and O-D routing needs
- Identify criteria for assigning these OS/OW groups to road networks <u>as they currently exist</u>
- Identify criteria for assigning these OS/OW groups to road networks <u>upgraded to meet projected OS/OW freight demand</u>

Slide #5 Work Plan

- Task 1. Conduct literature and Internet review
- Task 2. Evaluate MCD Data & Stakeholder input
- Task 3. Review TxPROS
- Task 4. Criteria for OS/OW loads—existing network
- Task 5. Criteria for OS/OW loads—future network
- Task 6. Develop statewide map
- Task 7. Develop deliverables

Slide #6 Example of Route-Building Process



Slide #7 Research Findings

Slide #8 Major Permit Types (2009)

Permit Type	Percent
General (single trip permits)	62.3%
Manufactured housing	12.5%
Over-axle weight tolerance (1547)	5.8%
Portable buildings	3.9%
30/60/90-day width	3.6%
HUB	3.5%
Temporary registration	2.9%
30/60/90-day length	1.5%
Concrete beam/girder (HB 2093)	1.1%
All others	<1% each

Slide #9 Historical MCD Data Processing

Year	Original Tabular Permit Data			Processed GIS Permit Routes		
	Total Permits	Permits with Valid Route Descriptions	Permits with Processed Routes	No. of Complete Routes	No. of Permits for these Routes	Percent of Total Permits
2004	444,326	385,912	225,083	99,739	225,077	50.7%
2005	447,876	417,263	238,772	79,723	170,464	38.1%
2006	522,696	445,976	240,399	83,440	181,152	34.7%
2007	554,198	463,621	233,653	86,123	186,024	33.6%
2008	580,410	483,136	268,240	109,051	210,776	36.3%
2009	527,447	428,920	255,490	134,011	254,452	48.2%

Slide #10 Description of Loads—Heights

FY	Truck Height (ft.)				
	<12	≥12 but <14	≥14 but <16	≥16 but <18	>18
2004	358(0.2%)	64,326(39.7%)	91,672(56.6%)	5,051(3.1%)	697(0.4%)
2005	418(0.2%)	67,704(39.9%)	95,352(56.2%)	5,463(3.2%)	647(0.4%)
2006	373(0.2%)	76,940(41.2%)	100,252(53.7%)	8,407(4.5%)	713(0.4%)
2007	282(0.1%)	71,310(36.7%)	111,778(57.5%)	**10,220(5.3%)**	646(0.3%)
2008	427(0.2%)	71,772(35.7%)	115,929(57.7%)	**12,114(6.0%)**	821(0.4%)
2009	537(0.3%)	66,482(37.7%)	97,412(55.3%)	**10,976(6.2%)**	792(0.4%)

Slide #11 Description of Loads—Widths

FY	Truck Width (ft.)					
	<9	≥9 but <11	≥11 but <13	≥13 but <15	≥15 but <17	>17
2004	3,173 (2.0%)	12,498 (7.7%)	36,369 (22.4%)	64,962 (40.1%)	39,091 (24.1%)	6,011 (3.7%)
2005	2,878 (1.7%)	12,368 (7.3%)	40,039 (23.6%)	66,798 (39.4%)	41,122 (24.2%)	6,379 (3.8%)
2006	4,374 (2.3%)	14,376 (7.7%)	42,456 (22.7%)	76,361 (40.9%)	42,135 (22.6%)	6,983 (3.7%)
2007	4,523 (2.3%)	16,768 (8.6%)	46,622 (24.0%)	78,193 (40.3%)	41,066 (21.1%)	7,064 (3.6%)
2008	5,733 (2.9%)	17,860 (8.9%)	47,926 (23.8%)	78,114 (38.9%)	43,851 (21.8%)	7,579 (3.8%)
2009	7,573 (4.3%)	16,714 (9.5%)	41,097 (23.3%)	66,021 (37.5%)	37,771 (21.4%)	7,023 (4.0%)

Slide #12 Description of Loads—Lengths

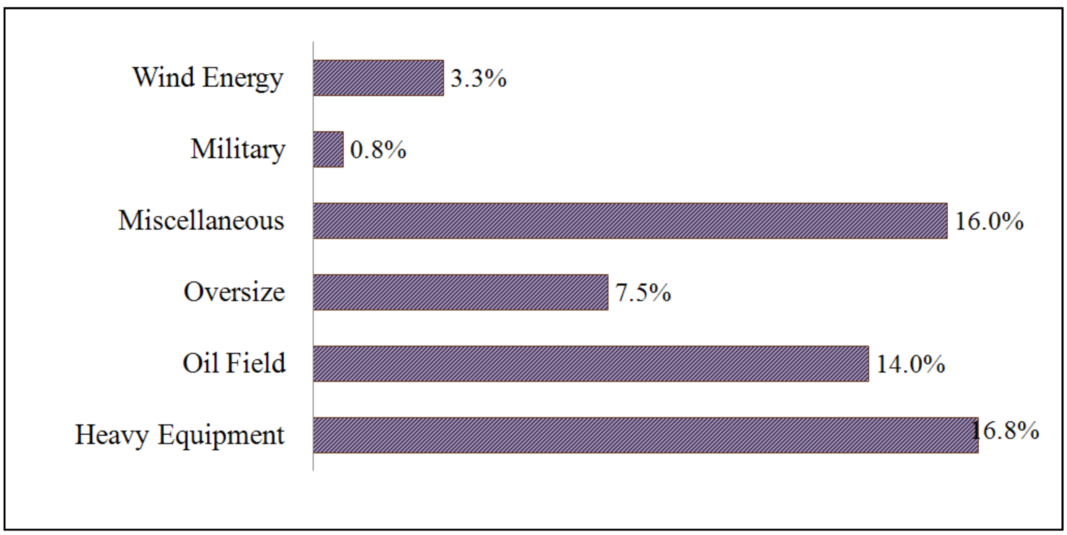
FY	Truck Length (ft.)				
	<80	≥80 but <100	≥100 but <120	≥120 but <140	>140
2004	20,105 (12.4%)	99,463 (61.4%)	39,659 (24.5%)	2,151 (1.3%)	726 (0.4%)
2005	21,068 (12.4%)	105,157 (62.0%)	39,500 (23.3%)	2,881 (1.7%)	978 (0.6%)
2006	21,693 (11.6%)	109,899 (58.9%)	48,896 (26.2%)	3,879 (2.1%)	2,318 (1.2%)
2007	20,896 (10.8%)	109,271 (56.3%)	56,076 (28.9%)	3,944 (2.0%)	4,049 (2.1%)
2008	20,723 (10.3%)	108,464 (53.9%)	61,036 (30.4%)	4,976 (2.5%)	5,864 (2.9%)
2009	19,029 (10.8%)	94,503 (53.6%)	52,055 (29.5%)	4,269 (2.4%)	6,343 (3.6%)

Slide #13 Identify OS/OW Groups

Category	Height (ft)	Width (ft)	Length (ft)	Gross Wt. (lb)
1	14.1 to 15	8.1 to 10	60 to 90	80k to 120k
2	15.1 to (16)	10.1 to 12	90.1 to (120)	120,001 to 150k
3	16.1 to 17	12.1 to 14	120.1 to 150	150,001 to 175k (168K)
4	17.1 to 18	14.1 to (16)	150.1 to 180	175,001 to 200k
5	18.1 to 19	16.1 to 18	>180	200,001 to 254k
6	19.1 to 20	18.1 to 20	N/A	>254k
7	N/A	>20	N/A	N/A

Shaded cells reach maximum at 95th percentile (indicated in red).

Slide #14 Load Categories



Slide #15 Internet Survey of District Permit Coordinators

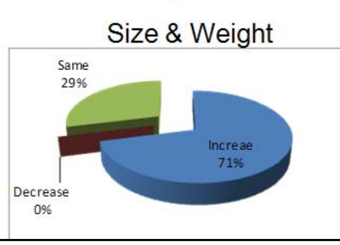
Internet Survey of District Permit Coordinators

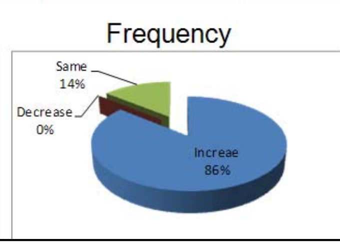
Slide #16 Survey Question #4

Survey Question #4

- Is trend in OS/OW loads increasing or decreasing in:

	Increasing	Decreasing	Same/Similar
Size	71%	0%	29%
Weight	71%	0%	29%
Frequency	86%	0%	14%





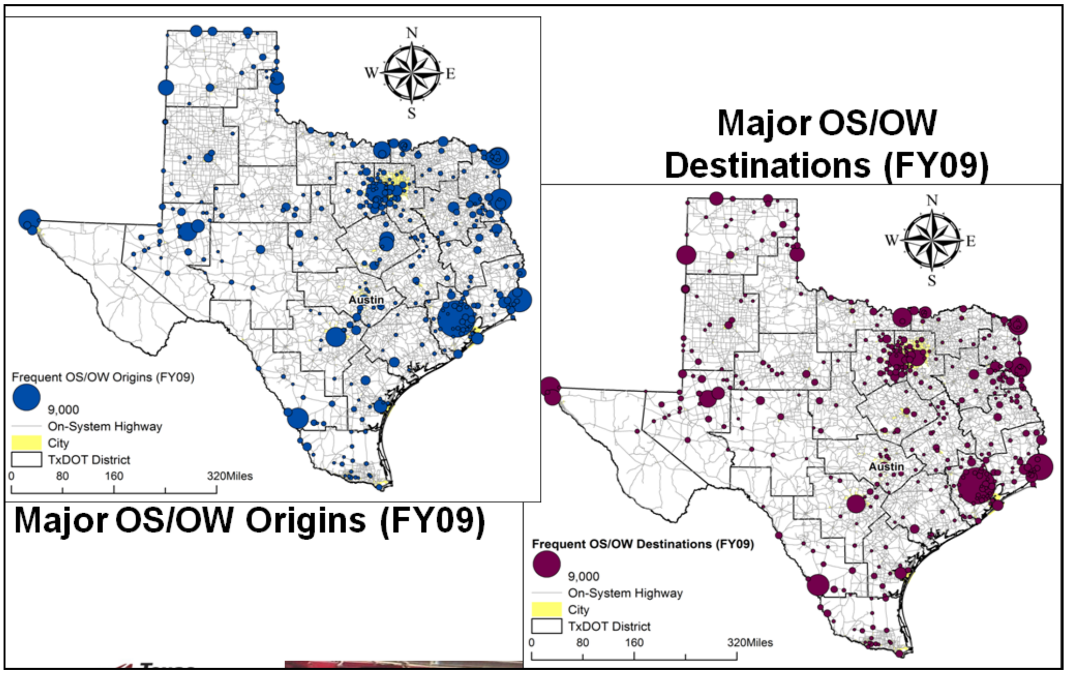
Slide #17 Survey Question #6

Survey Question #6

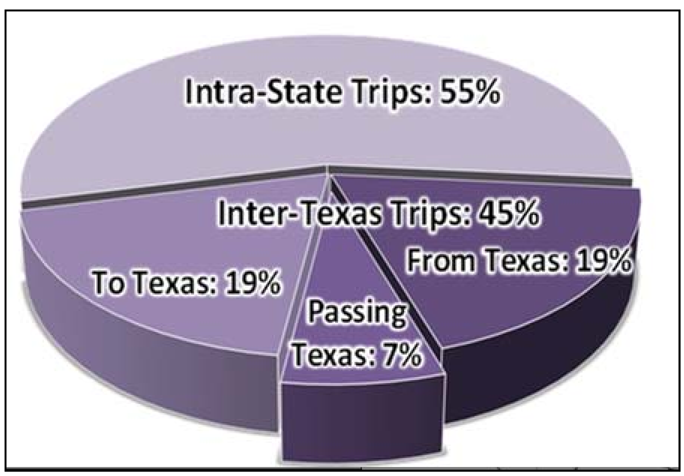
- a.What are the current impediments to movement of these OS/OW loads on trucks in your area?
  - Construction zones
  - Traffic signal mast arms instead of cables
  - Low bridges and underpasses, low hanging lines
- b. Do intermodal facilities need to be made larger or otherwise changed due to the predicted trends (yes)?
  - More OS/OW loads could be transported by rail
  - Roads need to be built wider and to higher structural standard to withstand the weight and turning (radius) of these loads.

Slide #18 Spatial Analysis Using ArcGIS

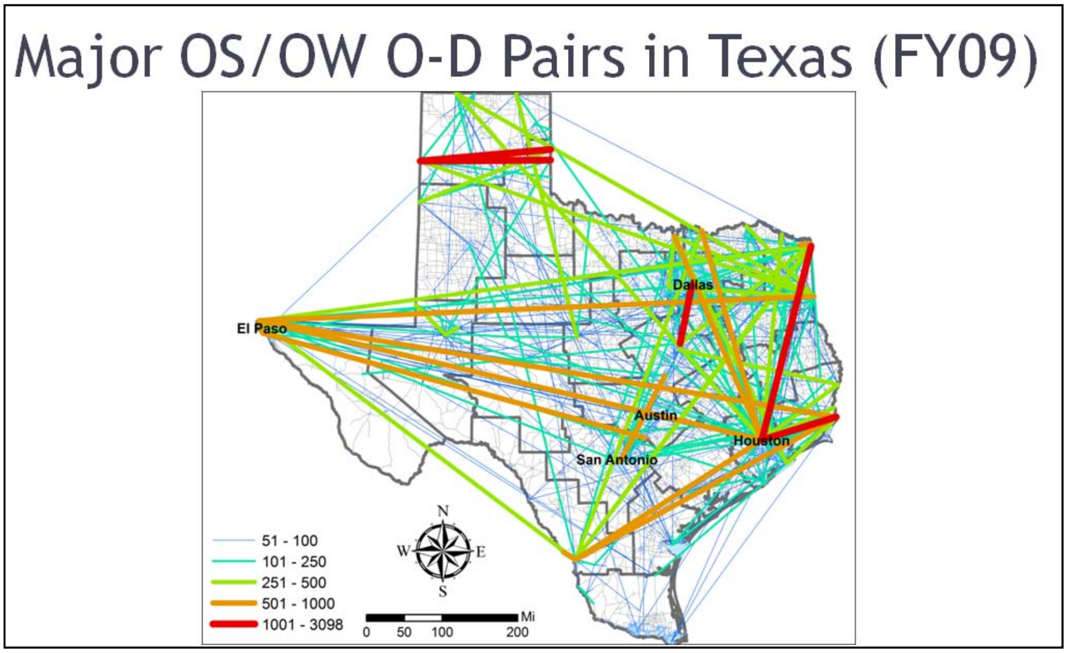
Slide #19a Major Origins and Destinations for 95th Percentile Loads (2009)



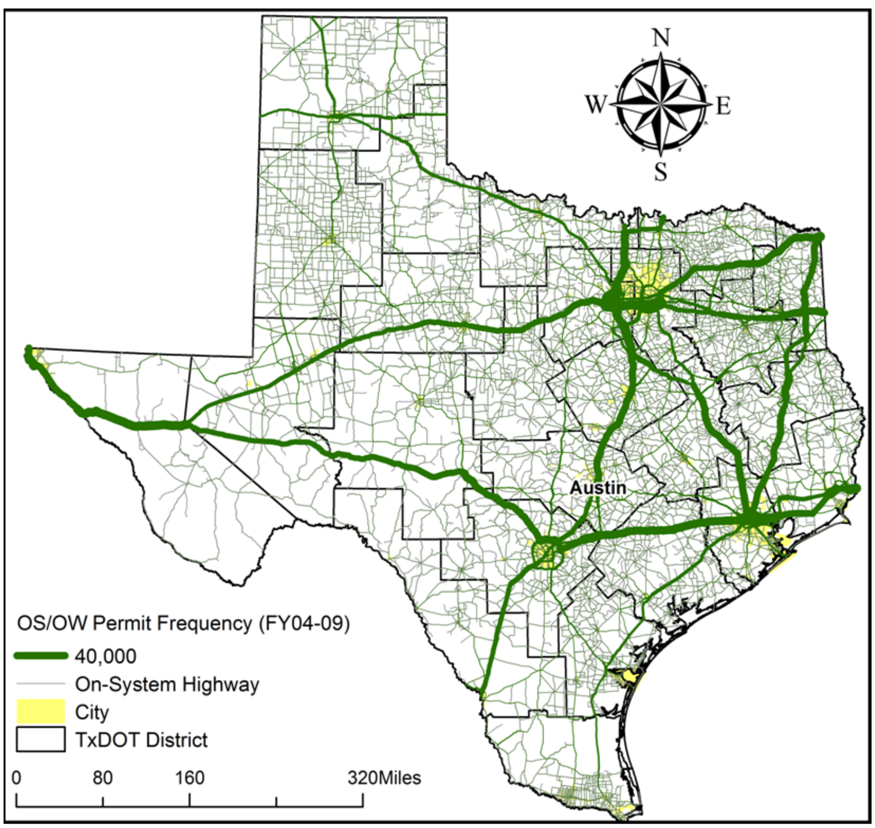
Slide #19b Animation Showing Trip Categories



Slide #20 Major OS/OW O-D Pairs in Texas (FY09)



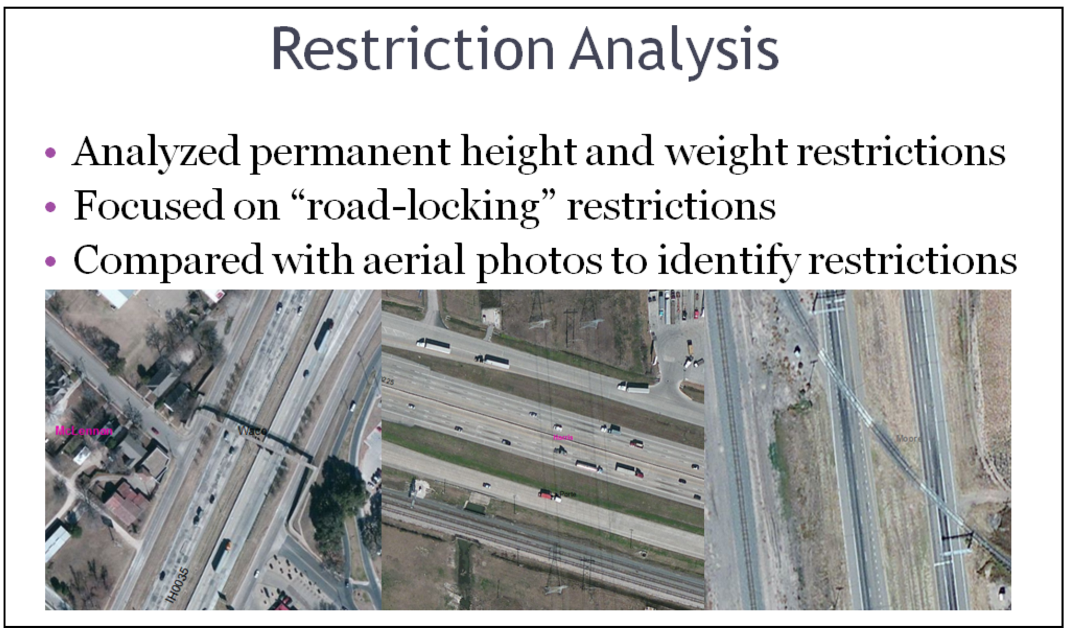
Slide #21 OS/OW Permit Frequency (FY04-09)



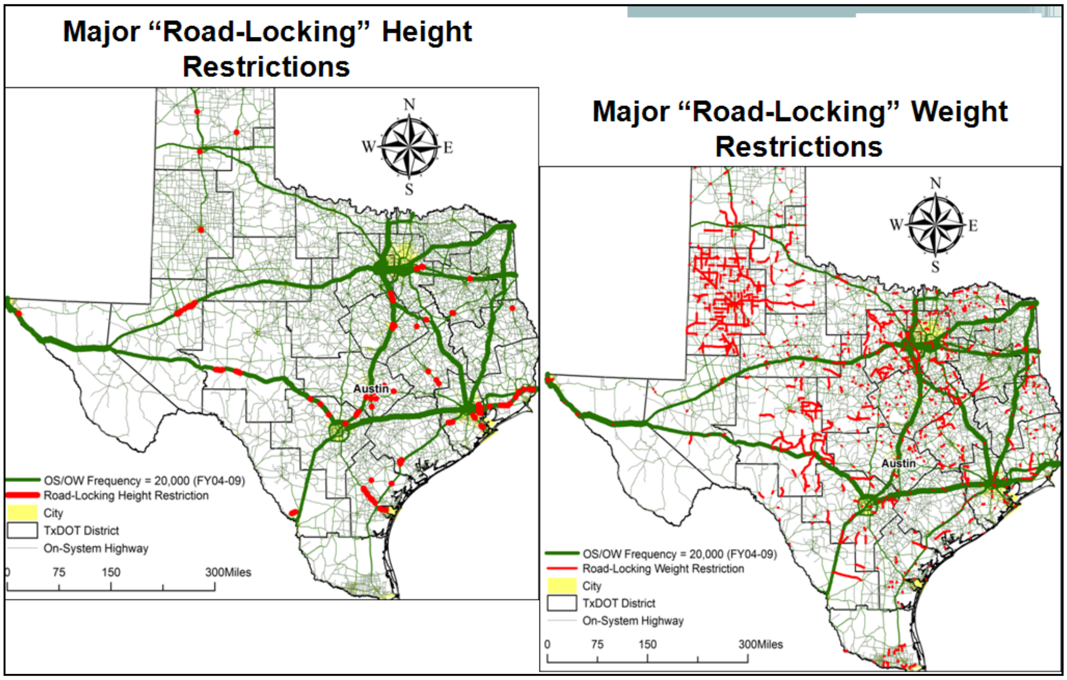
Slide #22 Restriction Analysis

- Apply "restrictions" from ProMiles
  - o Compare actual vs. optimum routes
- Criteria for determining improvements
  - o Number of loads bypassing per unit time
  - o Difference in optimal routes and actual routes
  - o Cost to motor carriers for extra mileage

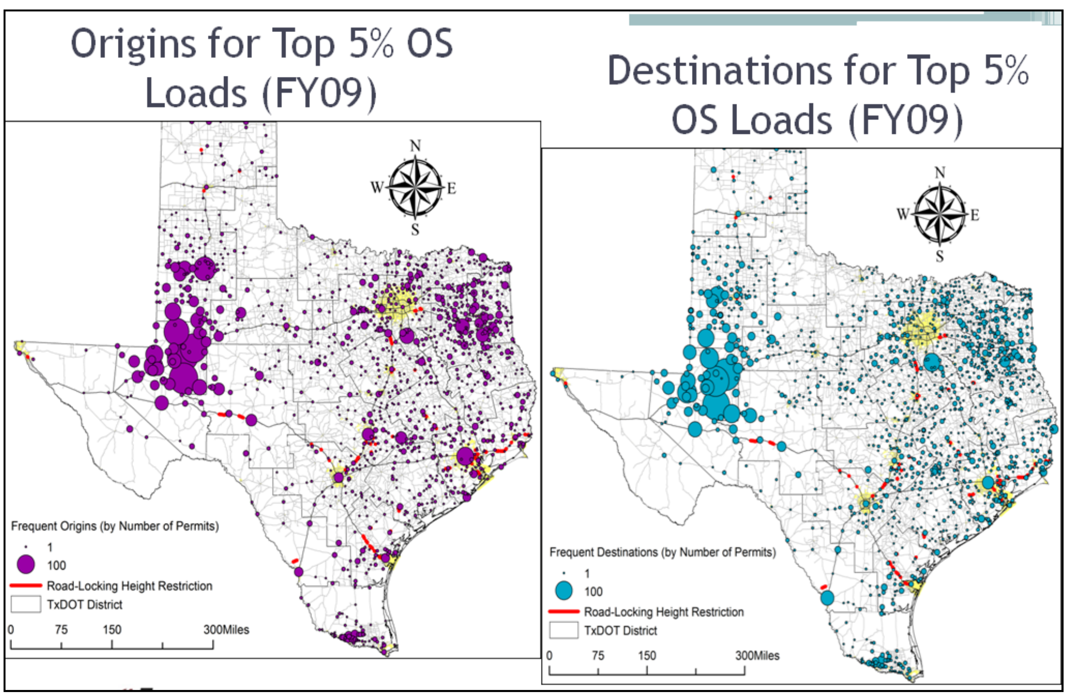
Slide #23 Restriction Analysis



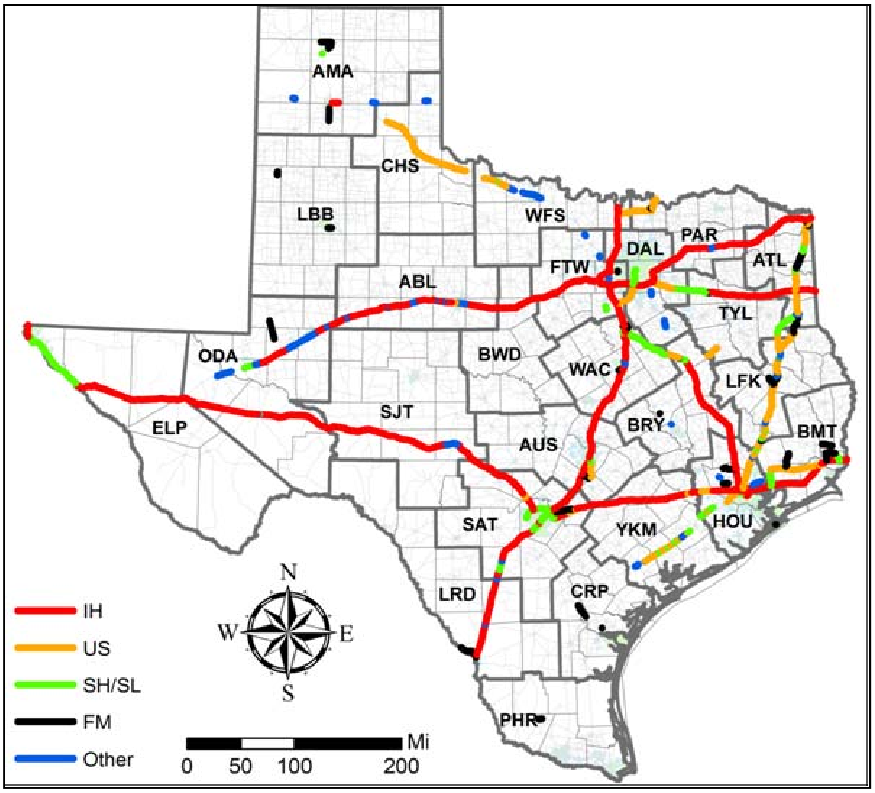
Slide #24 Height and Weight Restrictions



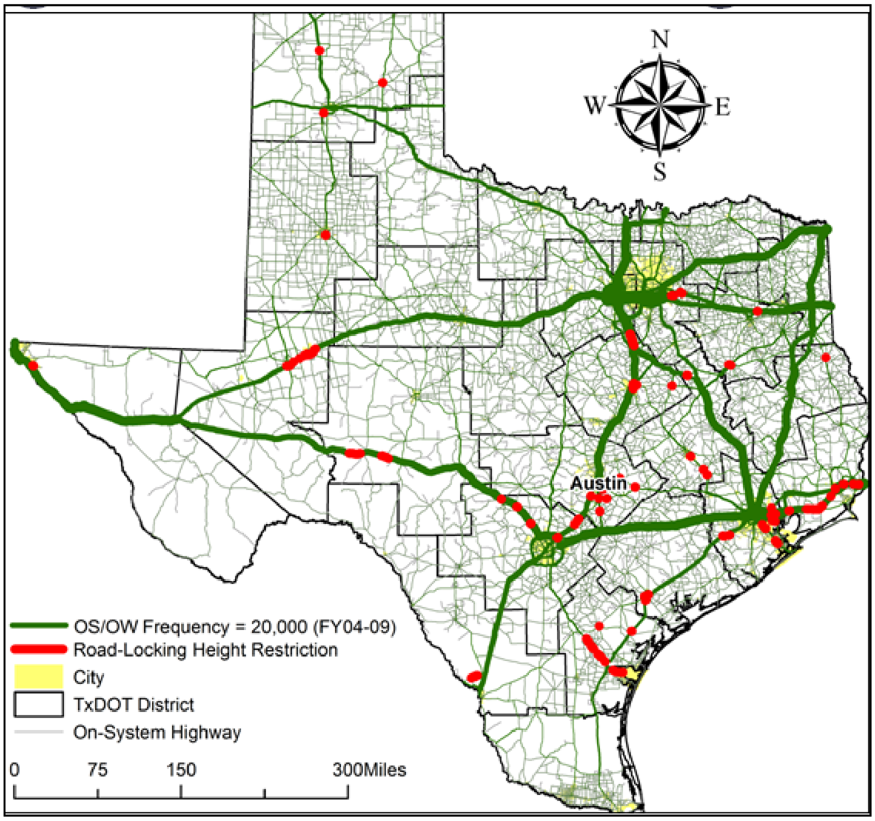
Slide #25 Origins and Destinations for Top 5 Percent Loads (FY09)



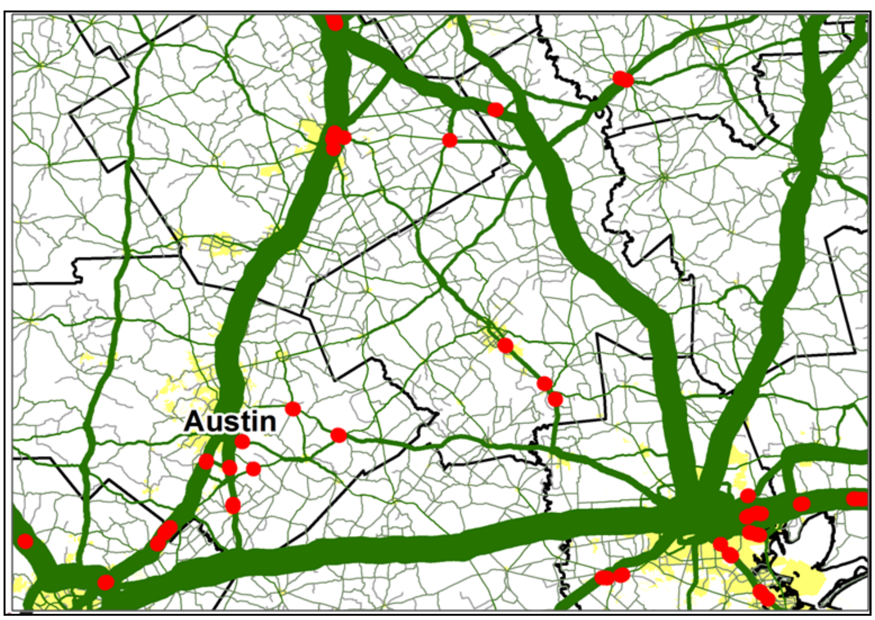
Slide #26 Top 50 OS/OW Corridors by Highway Type



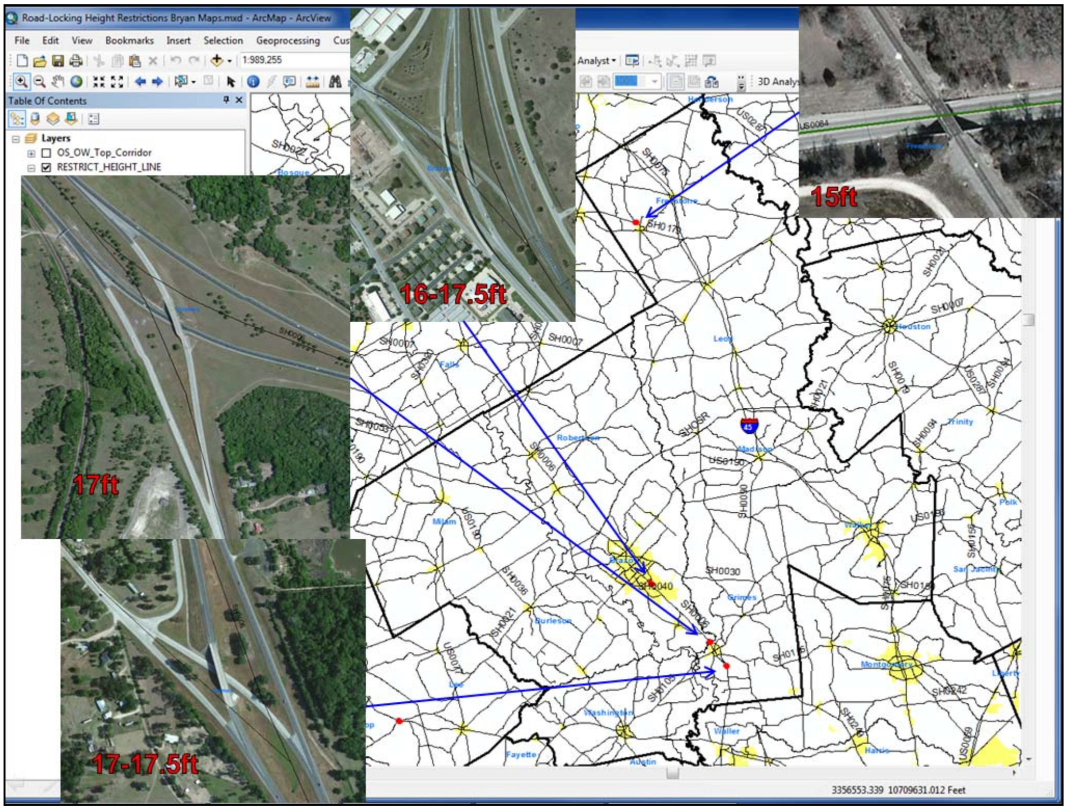
Slide #27 Height Restriction Segments



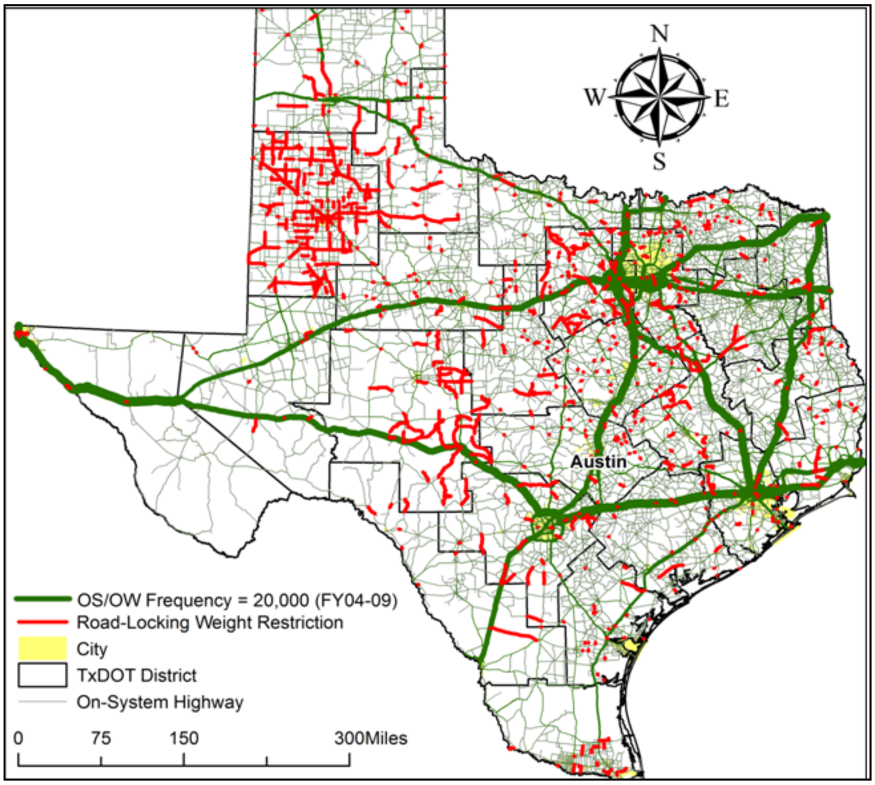
Slide #28 Height Restrictions Bryan District



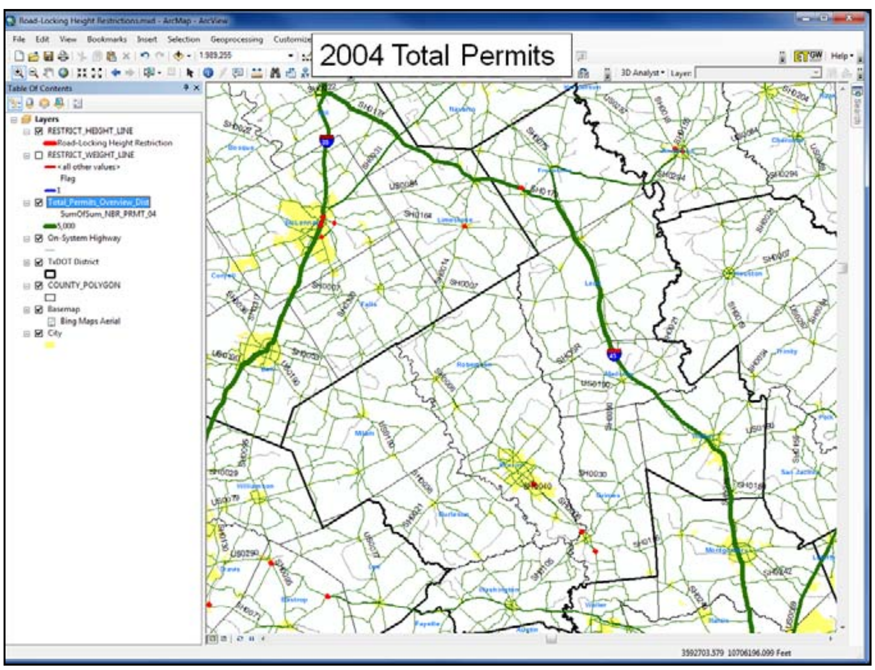
Slide #29 Map Showing Vertical Clearances in Bryan District



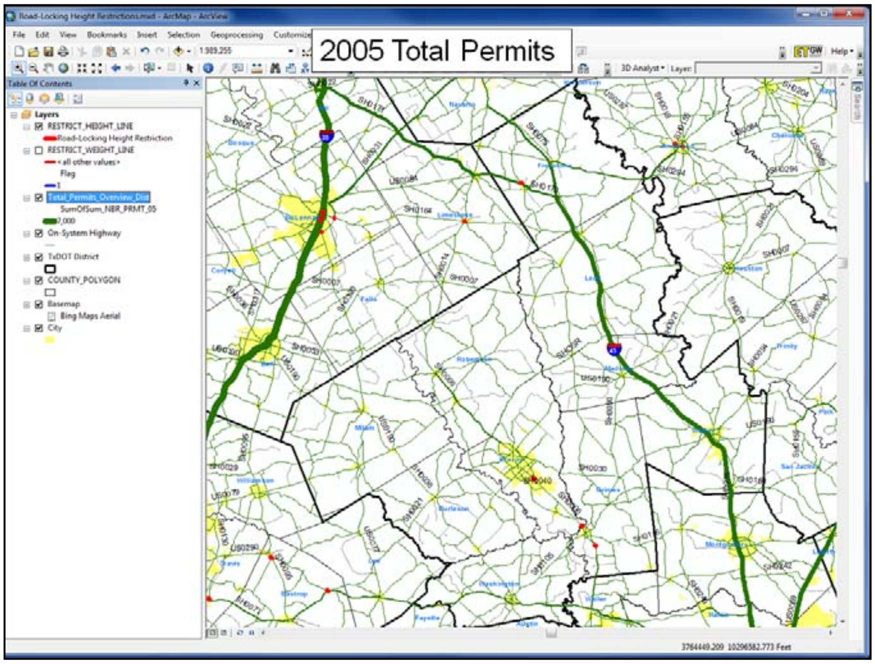
Slide #30 Weight Restriction Segments



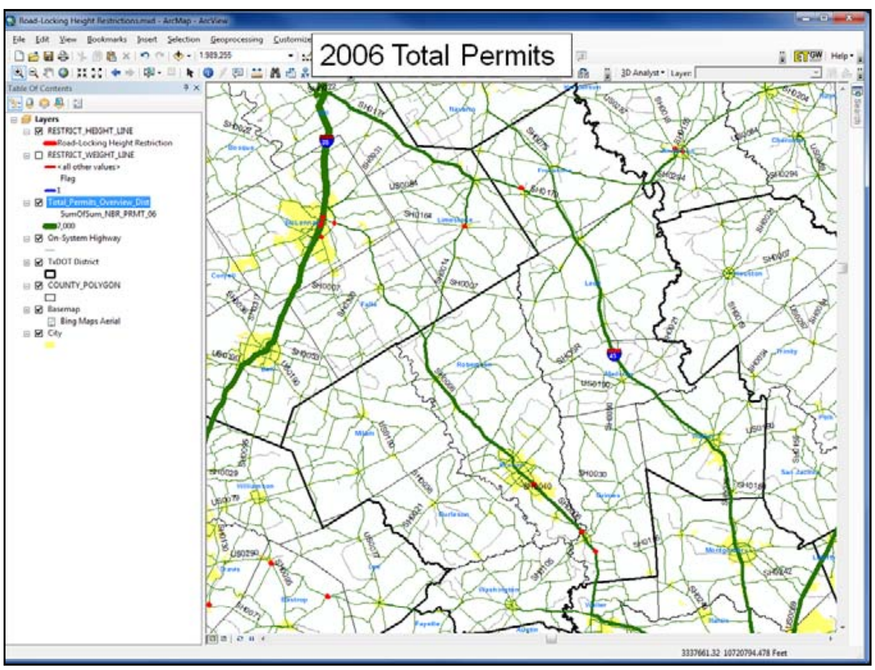
Slide #31 2004 Total Permits



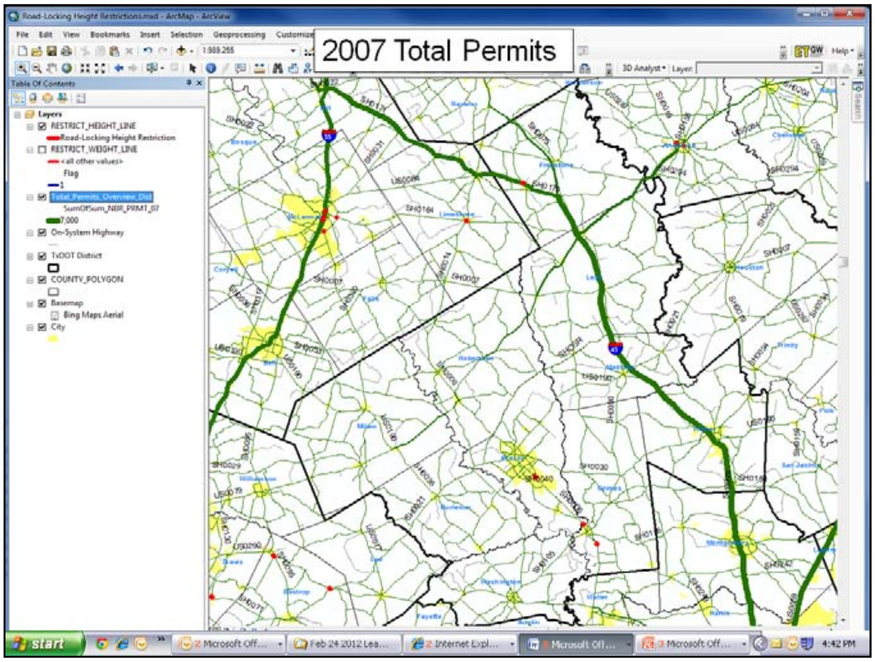
Slide #32 2005 Total Permits



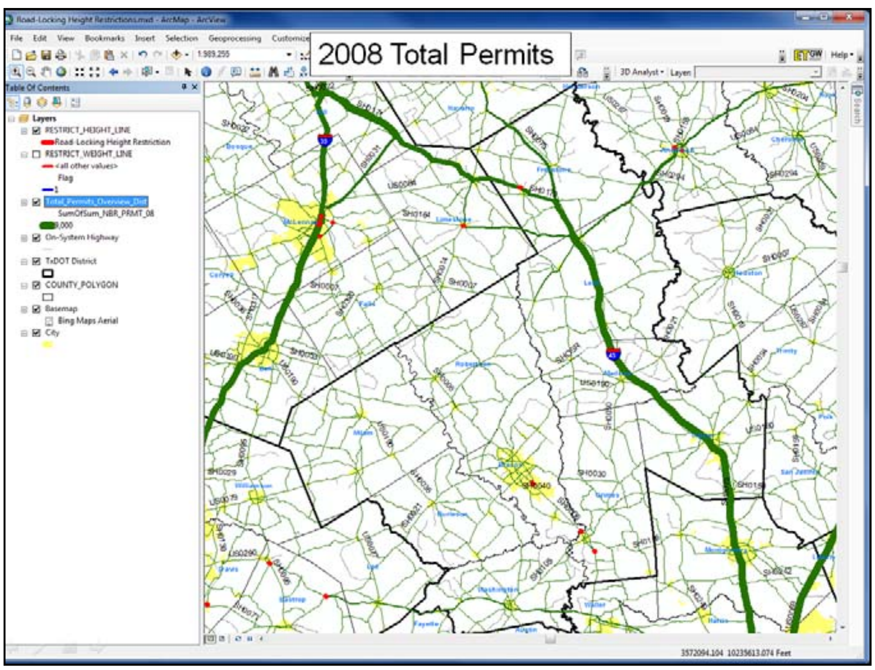
Slide #33 2006 Total Permits



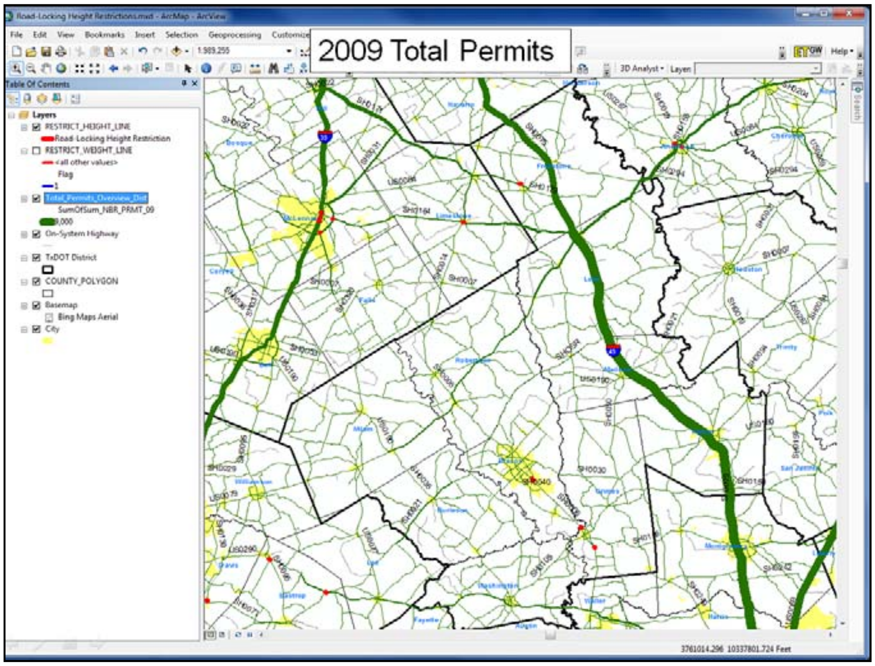
Slide #34 2007 Total Permits



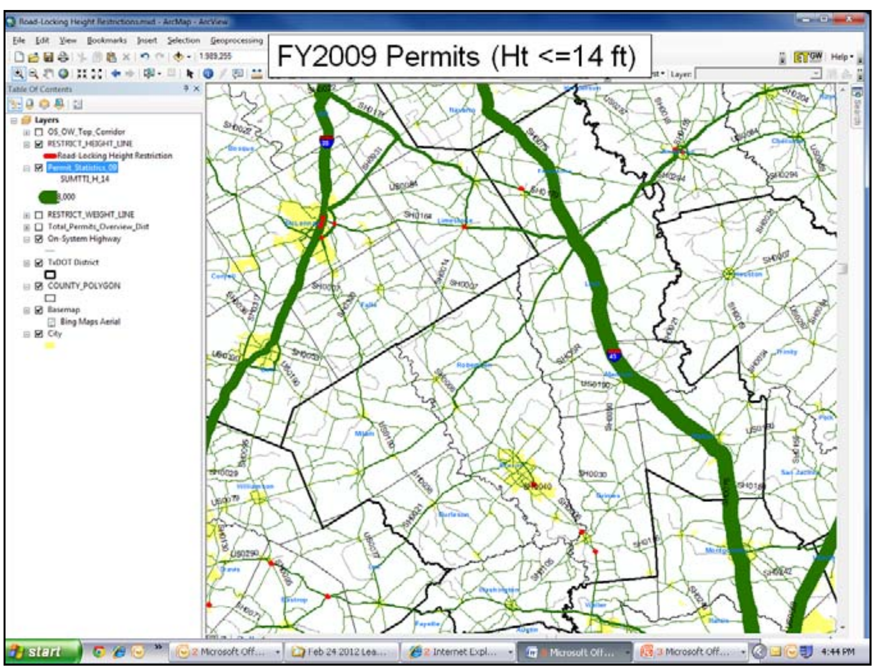
Slide #35 2008 Total Permits



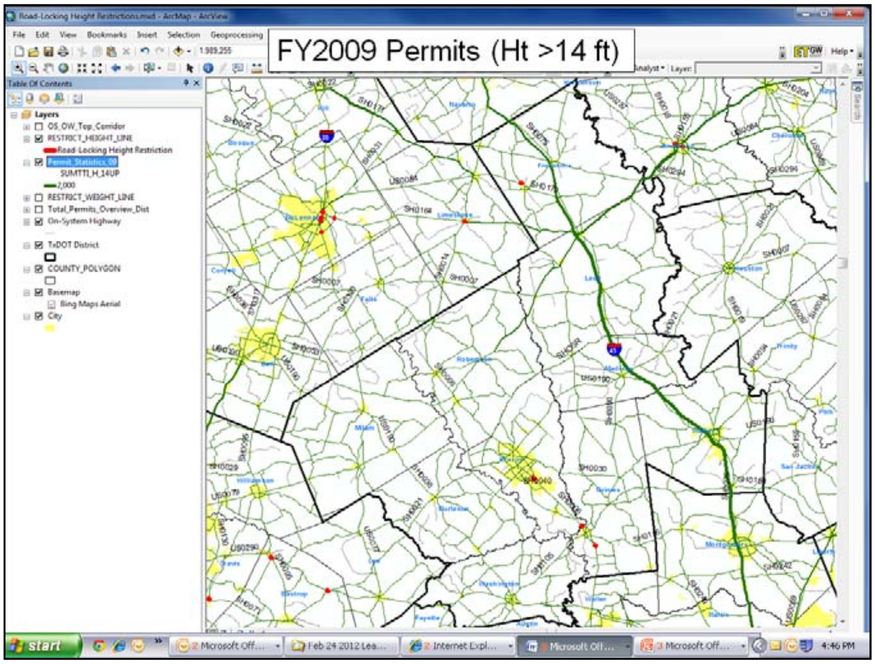
Slide #36 2009 Total Permits



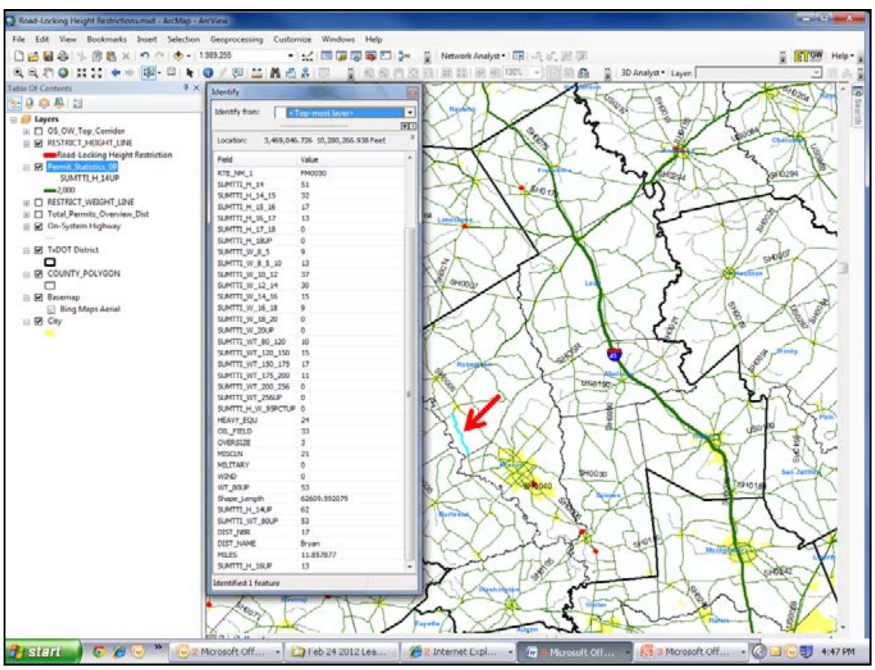
Slide #37 FY 2009 Permits (Ht <=14 ft)



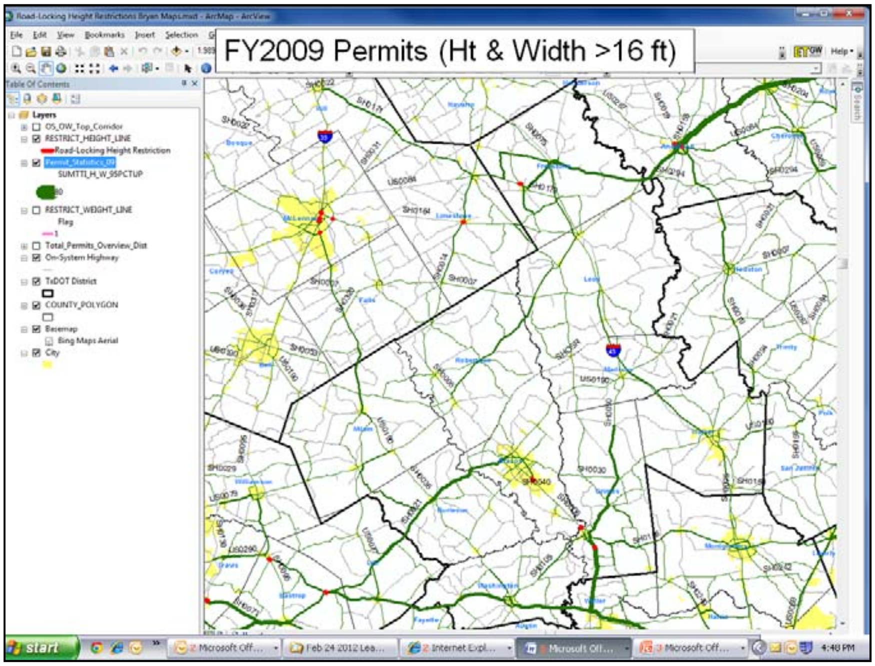
Slide #38 FY 2009 Permits (Ht >14 ft)



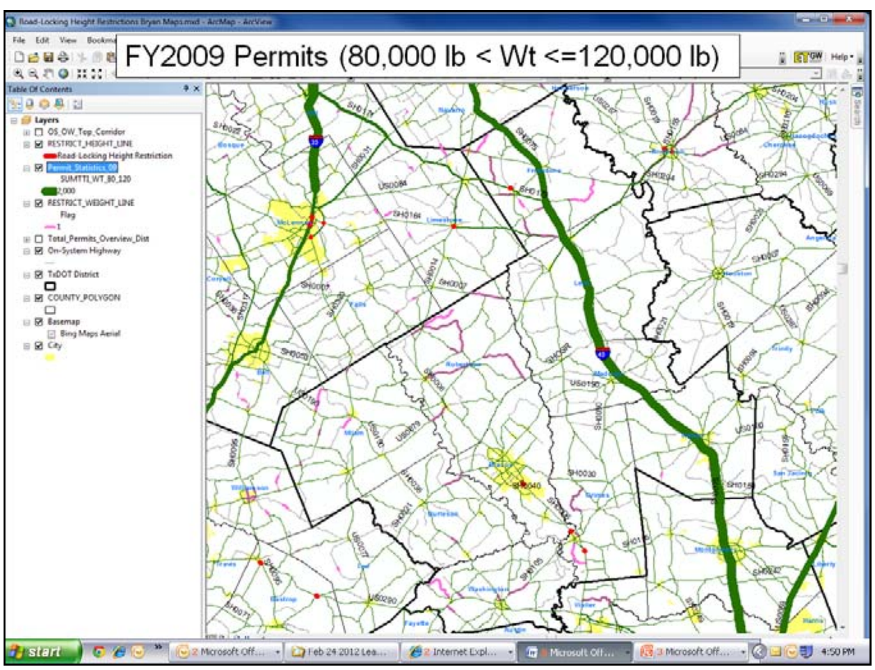
Slide #39 Route Information Showing Permit Loads



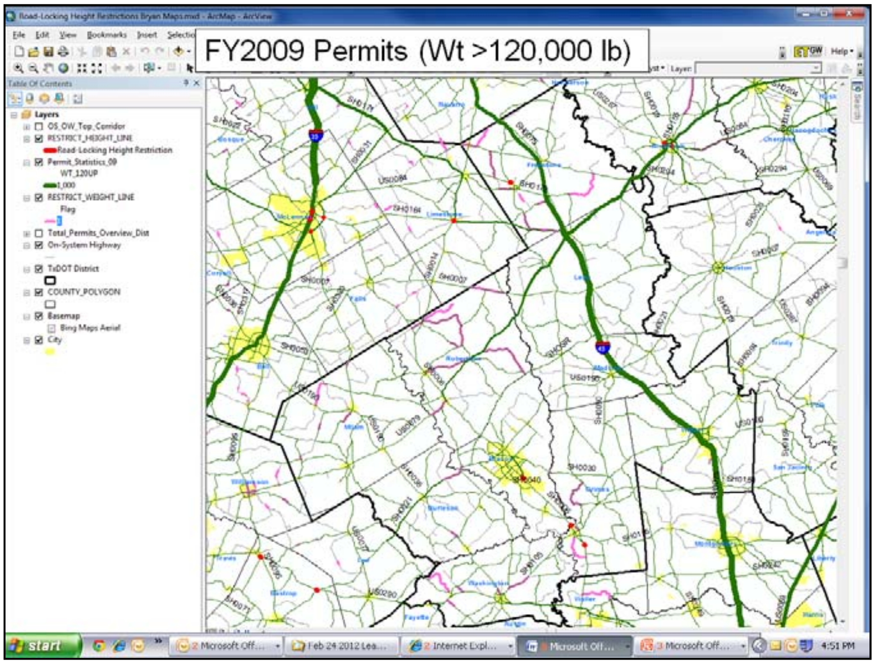
Slide #40 FY 2009 Permits (Ht & Width >16 ft)



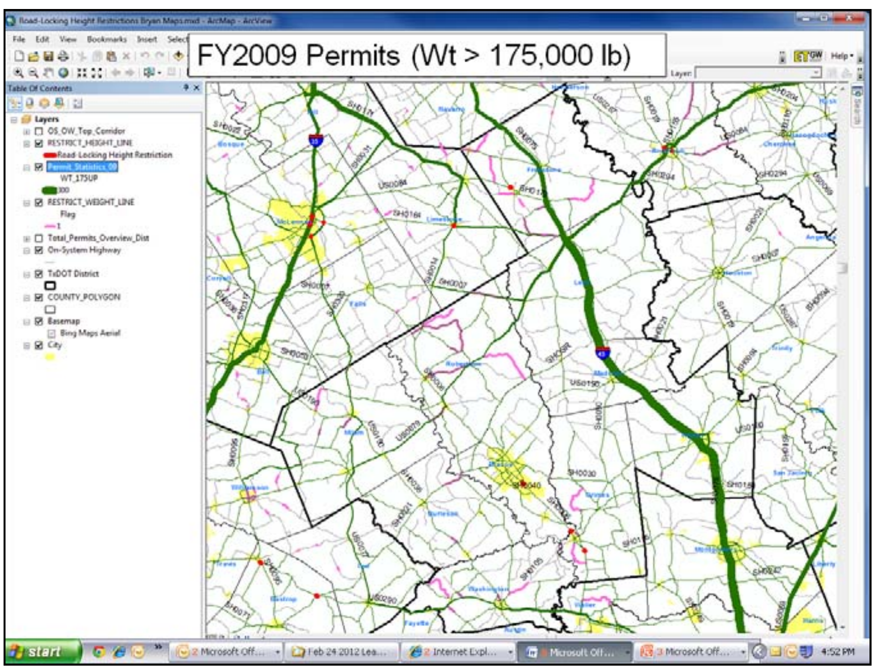
Slide #41 FY 2009 Permits (80,000 lb < Wt <= 120,000 lb)



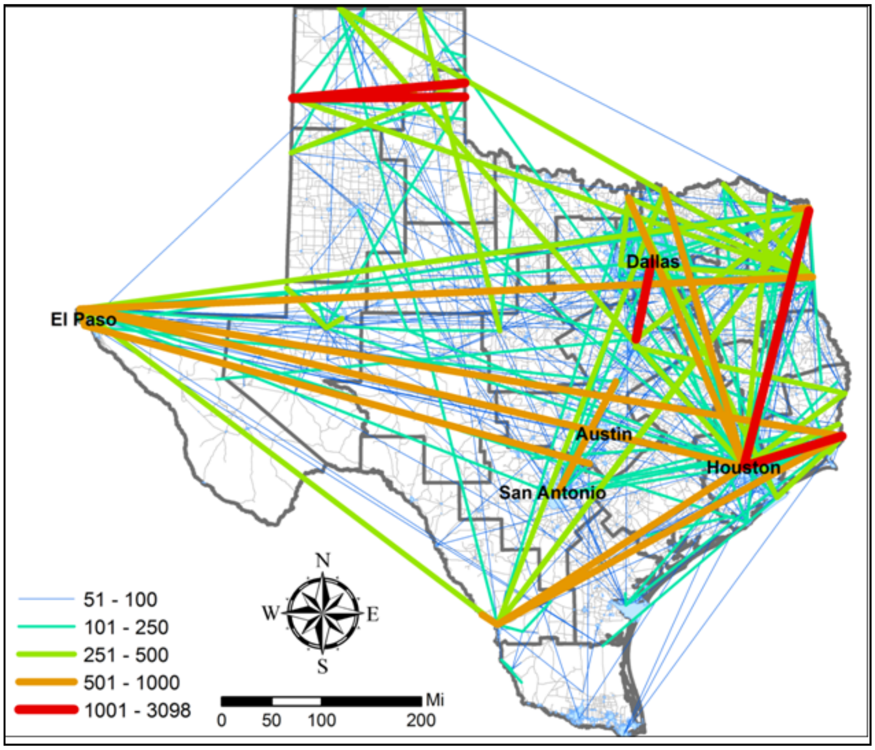
Slide #42 FY 2009 Permits (Wt > 120,000 lb)



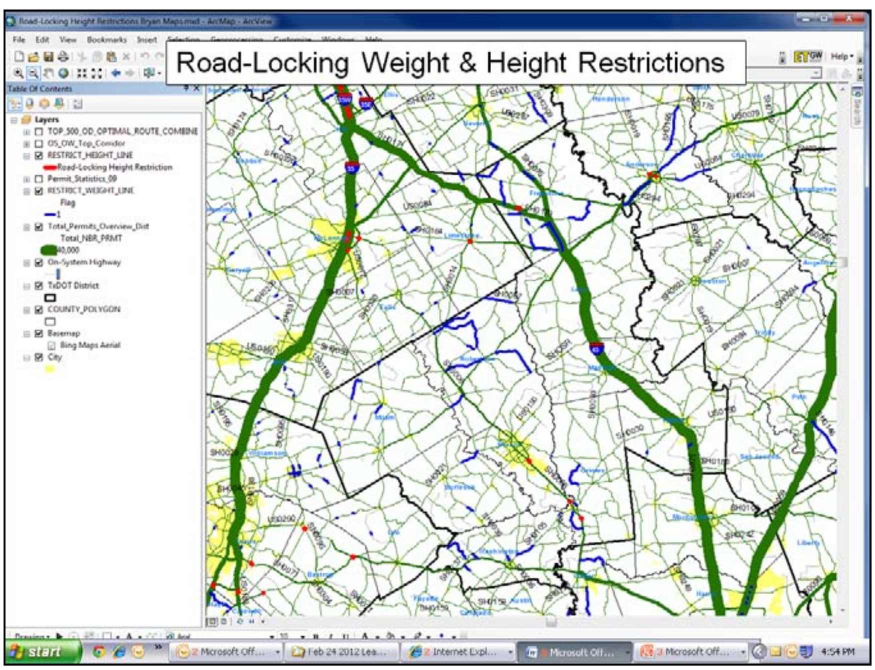
Slide #43 FY 2009 Permits (Wt > 175,000 lb)



Slide #44 Major OS/OW O-D Pairs in Texas (FY09)



Slide #45 Road-Locking Weight and Height Restrictions



Slide #46 Actual vs. Optimal Routes

Fiscal Year	Additional Ton-Miles (Selected)	Total Additional Ton-Miles Based on	
		Average Difference	Median Difference
2004	21,334,582	438,892,449	252,639,771
2005	16,973,851	441,237,511	253,989,660
2006	19,047,574	513,329,491	295,487,984
2007	20,380,460	545,914,142	314,244,695
2008	23,974,935	572,333,733	329,452,611
2009	25,604,793	515,144,062	296,532,507
FY04-09	127,316,195	3,026,851,387	1,742,347,227
Average	--	504,475,231	290,391,205

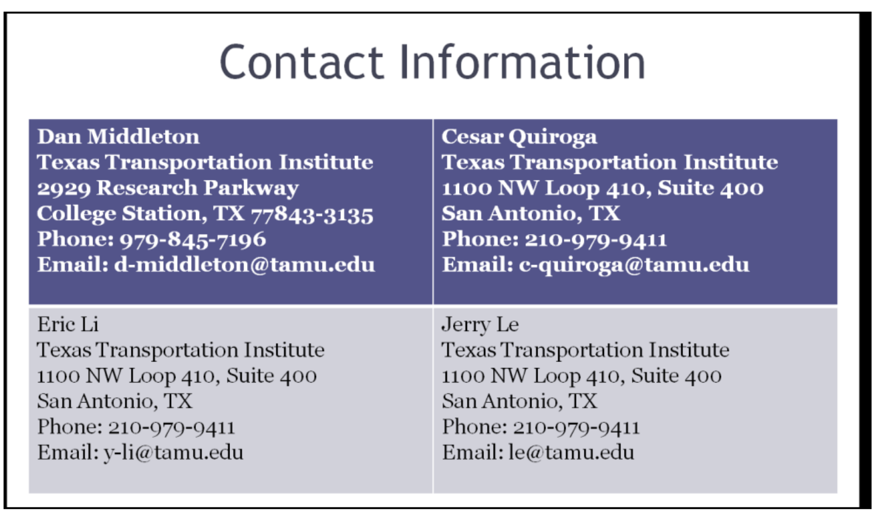
Slide #47 Summary: Actual vs. Optimal Routes

- Average difference of about 24 miles per trip
- OS/OW loads traveled about 504 million ton-miles more per year
- Additional cost of about $73 million per year
- Additional CO_2 emission of about 75,000 tons

Slide #48 Conclusions and Recommendations

- Logical parallel OS/OW routes
  - IH-45 Houston to Dallas
  - SH 6/US 290 to IH-35 in Waco
  - Others as needed
- Height restrictions are minimal in Bryan District
- Weight restrictions mostly on minor connectors

Slide #49 Contact Information



APPENDIX B

SUPPLEMENT TO THE

TXDOT ROADWAY DESIGN MANUAL

INTRODUCTION

The major corridors identified through this research project, supplemented by the proposed upcoming IPR (if approved), need to meet certain minimum dimensional (e.g., height and width) requirements throughout. Weight is also a factor, but the carrier can reduce the effects of an OS/OW load by adding axles and by spreading the load over a longer distance as well as by increased width. The weight reduction is typically sufficient to bring the loads applied to pavements and bridges within acceptable limits. However, as TxDOT refurbishes corridor segments along OS/OW corridors, it should upgrade the design criteria to increase the strength and geometrics to accommodate heavier and larger loads.

In the selection of a design vehicle for a heavy-haul corridor, TxDOT would likely consider the following parameters:

- The roadway functional class (e.g., arterial, collector).
- The roadway route category (e.g., IH, U.S., FM).
- The frequency of a certain size truck using the facility.
- Cost to users of taking a bypass route (e.g., additional length and travel time).

This proposed supplement to the *Roadway Design Manual* (TRDM) (*5*) contains design criteria for dimensional clearance at structures. This supplement includes height and width criteria for structures located along identified major OS/OW corridors. These criteria in the AASHTO *Green Book* (*6*) and in the TRDM are designated as cross-section elements. Other design elements besides cross-section elements that might occasionally be considered for OS/OW corridors are sight distance, and horizontal and vertical alignment of the roadway. However, typical design practice that uses designated design vehicles from the *Green Book* provides adequate design elements for the larger OS/OW vehicles. Therefore, this supplement focuses on the vertical clearance and widths necessary for movement of these larger loads.

DESIGN VEHICLE

The AASHTO *Green Book* states that roadway design is based on "the physical characteristics and the proportions of vehicles of various sizes using the highway" (*6*). The weight, dimensions, and operating characteristics of the vehicles using a facility are used to establish highway design controls, but the selected design vehicle establishes the envelope for the designer to follow.

The *Green Book* presents the following general guidance when selecting a large truck as the design vehicle (*6*):

- The WB-67 truck (5-axle tractor with 53-ft semi-trailer) should be the minimum size design vehicle in areas with high traffic volumes or areas that provide local access for large trucks.
- The WB-62 design vehicle (5-axle tractor with 48-ft semi-trailer) may be used for designing turning maneuvers where rear axles of 53-ft semi-trailers are often moved

forward for maneuvering and/or where the law requires a kingpin to rear axle limit of 41 ft.

- Design vehicles larger than the WB-67 are grandfathered for operation on some freeways but their width and height limits are the same as for other combination vehicles. Their allowable lengths go up to 129.3 ft and articulation points differ, so turning performance varies considerably from the more typical WB-67.
- To state the obvious, the *Green Book* does not offer a design vehicle for OS/OW applications. Therefore, it is necessary to use vehicle descriptions provided by OS/OW permit applicants.

The desirability of using a particular vehicle as the design vehicle is a function of cost weighed against how often a more demanding vehicle type uses a facility. In a general sense, the likelihood of choosing an oversize permit vehicle as the design vehicle would be relatively low due to the incremental cost involved and the relative low numbers of such vehicles. However, designating certain corridors as heavy haul corridors would help make the case for increased geometric and weight limits for a select few corridors while keeping more normal limits on all other corridors. The marginal cost of increased vertical clearance, for example, could be more easily justified by minimizing the number of such improvements through designated corridors. The research team believes that, for designated heavy haul corridors, TxDOT should adopt vehicle dimensions from this research when rehabilitating existing infrastructure as it reaches its design life or when designing new construction.

Based on information that permit applicants from 2004 through 2009 provided, the 95th percentile vehicle today is 16 ft wide, 16 ft tall, and 120 ft long. However, trends in the data suggest that TxDOT should consider an increase in at least the width and height to 17 ft and 18 ft, respectively. The length of the design vehicle is also increasing, so an increase in length to 140 ft appears to be appropriate. The research team recommends that TxDOT use these dimensions along selected corridors across the state.

APPLICATION OF DESIGN VEHICLES

Vertical Clearance

The *Green Book* criteria for vertical clearance are generally 16 ft on arterials and freeways. However, design vehicles in the *Green Book* have a maximum height of 13.5 ft. Even though Texas allows a height of up to 14.0 ft, almost all trucks are 13.5 ft in order to operate in other states and because the cost of the more common 13.5-ft equipment is more reasonable. Obviously, the vertical clearances in the *Green Book* are not based on OS/OW loads (*6*).

The TRDM stipulates that all controlled access facilities should provide 16.5 ft minimum vertical clearance over the usable roadway. It provides exceptions for controlled access roadways within urban areas where a bypass exists with the full 16.5 ft clearance. Exceptions for rural interstates and single priority defense interstate routes require approvals. Again, the TRDM clearances are not based on OS/OW loads (*5*).

Applying the dimensions of the 95th percentile trucks to OS/OW corridors, the designer must consider both the vehicle and the operator. An 18-ft high load would require a clearance of more than 18 ft. Considerations include:

- Continuing upward trends in 95th percentile OS/OW vehicle sizes.
- Vehicles taller than the 95th percentile vehicles.
- Allowing for future resurfacing operations that might reduce the existing clearance.
- Dynamics in the vehicle suspension while the vehicle is moving.
- Inaccurate measurements or reporting of the load height by the operator.
- Differences in clearance from one side of the paved surface to the other (e.g., cross-slope).
- Occasional debris on the pavement surface under the overpassing structure.

These considerations suggest that the designer add a safety factor to ensure that loads do not hit and damage the overhead structure. As a minimum, the designer should include an additional 6 inches of clearance to allow for these factors.

Horizontal Clearance to Obstructions

Vehicle operator skill is critical for safely negotiating narrow segments of roadway with an overwide load. There must be some latitude horizontally to maneuver an overwide load past obstructions. In low to moderate traffic volumes, the vehicle operator has the option of using additional lanes in the same travel direction or even opposing lanes. Motor carriers are required to use escort services for some larger loads, and one responsibility of an escort is to provide traffic control to ensure safe passage of the load. At a minimum, the escort warns other motorists through the use of high-visibility markings and flashing lights in advance and/or trailing behind the load. In cases where the overwide load needs to take more lanes to get past an obstruction, the escort must make sure that other traffic vacates the needed lanes in a safe and efficient manner.

In the absence of known definitive guidance for how precise most commercial drivers can operate in close quarters, the authors suggest increasing the available width for an oversize load by at least 5 ft more than the load width. For the vehicle design width of 17 ft, the designer should provide 22 ft of available width.

In summary, TxDOT designers should provide the following horizontal and vertical clearances along heavy-haul corridors:

- Height: 18 ft, 6 in.
- Width: 22 ft.

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5. TxDOT *Roadway Design Manual*, http://onlinemanuals.txdot.gov/txdotmanuals/rdw/rdw.pdf Accessed April 19, 2012.

6. *A Policy on Geometric Design of Highways and Streets*, 6^{th} Edition. American Association of State Highway and Transportation Officials. Washington, D.C., 2011.