Technical Report Documentation Page

1. Report No. FHWA/TX-06/0-4169-2	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Defining and Measuring Rural Truck Traffic Needs in Texas		5. Report Date May 2005; Rev. June 2006 6. Performing Organization Code
7. Author(s) Jolanda Prozzi, Robert Harrison, Jorge A. Prozzi		8. Performing Organization Report No.
9. Performing Organization Name and Address Center for Transportation Research The University of Texas at Austin 3208 Red River, Suite 200 Austin, TX 78705-2650		10. Work Unit No. (TRAIS) 11. Contract or Grant No. 0-4169
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, TX 78763-5080		13. Type of Report and Period Covered Technical Report: 9/1/2003-8/31/2004 14. Sponsoring Agency Code

15. Supplementary Notes
Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.
Project title: Managing Rural Truck Traffic in Texas

16. Abstract
In 2002 the Texas Department of Transportation (TxDOT) contracted with the Center for Transportation Research (CTR) at The University of Texas at Austin and Texas Tech University to provide evidence of the truck volume and pavement damage associated with major rural truck traffic generators in Texas. It was felt that given increased funding shortfalls for the maintenance and modernization of rural infrastructure, TxDOT staff responsible for rural infrastructure will benefit from a better understanding of the rural truck trip generators in these areas that impact rural infrastructure. The objectives of the first year (2003) report were to highlight the factors that result in greater demands on rural roads, describe the condition of the existing rural road system in Texas, provide evidence of the impacts of increased demand for trucking on rural roads, and highlight the role of rail in rural areas before concluding the report. This report documents the research conducted in the second year of the study and provides information on major rural stakeholder views concerning the impacts of rural truck traffic, presents a methodology to estimate equivalent damage factors to allow for the calculation of truck pavement impacts, and finally presents a methodology to prioritize and policy options to address rural transportation concerns.

17. Key Words rural truck traffic, pavement impacts, big boxes, edge urbanization		18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161; www.ntis.gov.	
19. Security Classif. (of report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages 84	22. Price

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

Defining and Measuring Rural Truck Traffic Needs in Texas

Jolanda Prozzi
Robert Harrison
Jorge A. Prozzi

CTR Research Report:	0-4169-R2
Report Date:	May 2005; Revised June 2006
Research Project:	0-4169
Research Project Title:	Managing Rural Truck Traffic in Texas
Sponsoring Agency:	Texas Department of Transportation
Performing Agency:	Center for Transportation Research at The University of Texas at Austin

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

Center for Transportation Research
The University of Texas at Austin
3208 Red River
Austin, TX 78705

www.utexas.edu/research/ctr

Disclaimers

Author's Disclaimer: The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation.

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

Acknowledgements

The authors would like to acknowledge the guidance provided by Project Director Mike Battles, P.E. (Tyler district), and Program Coordinator Mary Owens, P.E. (D.E., Tyler district), in developing this document. Special thanks are due to Karan Kapoor for his drafting of the chapter on pavement impacts and Phil Nash (Texas Tech) for his detailed documentation of the transportation concerns in north and west Texas. Thanks are also due to Ka Yan Lo (CTR), who provided word processing and graphical assistance in the production of this document.

Products

This report contains Product 1 and Product 3.

Table of Contents

List of Figures

List of Tables

1. Introduction

Texas—the second largest state in the United States in terms of land area—has the largest highway system, the highest volume of truck traffic (Brian, 2001), and the highest percentage of truck traffic in the United States (Middleton and Crawford, 2001). Texas has more interstate miles than any other state in the United States, and more than half of the state's highway system consists of farm-to-market (FM) and ranch-to-market (RM) roads (Turnbull, Dresser, and Higgins, 1999). A critical underpinning of the state's economy is thus its transportation system, and on the highways it ranges from multi-lane interstates to rural farm-to-market roads.

Over the past two decades, the changing transportation demands of agriculture and rural industry as well as strategic rail decisions that resulted in the abandonment of many rural rail links have had severe impacts on rural road infrastructure. Also, with the state changing from its traditional agribusiness economy to more of a service-oriented economy, there is concern that rural interests are often overlooked to satisfy the demands of urban areas. In 2001 Prater reported that 28 percent of the system mileage in the federal aid highway program is rated below fair condition, and in many key agricultural states this rises to more than more 40 percent. Moreover, many of the current rural roads are beyond their design life. Prater (2001) argued that more funds are needed to invest in the rural road networks to keep up with the rising costs of maintenance for rural roads. The objective of this research was to provide evidence of the truck volumes and pavement damage associated with major rural traffic generators in Texas.

1.1 Background

During the first year of this two-year study, the research team undertook an in-depth analysis of the pavement condition data collected by TxDOT on an annual basis. This section highlights the salient findings of the first year's report 0-4169-1, "Rural Truck Traffic and Pavement Conditions in Texas."

1.1.1 Rural Truck Traffic

The TxDOT Research Report 4169-1 reported that many TxDOT districts have seen an increase in the volume of truck traffic on rural infrastructure (see Table 1.1). The increase is a result of a combination of factors, including:

- Agricultural industrialization resulting in fewer but larger farms and the trend toward moving products between specialized operations predominantly by truck;
- Increases in the physical sizes of agricultural equipment and the trend toward joint ownership or the lease of large and expensive pieces of farm equipment or outsourcing these services, resulting in increased movements on rural roads;
- Economic revival of the oil industry, resulting in relatively short but high-volume "heavy" movements;
- House Bill 2060 that allows the trucking industry to purchase permits at a nominal fee that allow 84,000-lb vehicles (gross vehicle weight) to traverse roads posted for 58,240 lb (gross vehicle weight);

- Location of large distribution centers of retail chains, such as Wal-Mart, HEB, and Target, in rural counties, where land is comparatively inexpensive and major highways provide access to major metropolitan markets;
- Location of landfill sites in western and northern Texas, which have raised concerns about pavement rutting caused by overloaded garbage trucks;
- Dramatic increases in truck traffic resulting from the North American Free Trade Agreement (NAFTA) that traverse a number of rural counties in Texas; and
- The abandonment of approximately 2,400 miles of rail track in Texas, following the Staggers Act, which has decreased the potential for large Class I railroads to service rural shippers, resulting in a large number of bulk commodities being moved on rural roads.

Table 1.1 Percent Growth in Average Annual Daily Truck Traffic Volumes in Rural Texas*

District	Average Annual Daily Growth in Truck Traffic (1997 to 2001)	District	Average Annual Daily Growth in Truck Traffic (1997 to 2001)
Paris	3.12	Austin	13.00
Fort Worth	7.34	San Antonio	4.72
Wichita Falls	7.85	Corpus Christi	4.91
Amarillo	3.04	Bryan	5.76
Lubbock	3.65	Dallas	5.91
Odessa	7.38	Atlanta	3.65
San Angelo	5.85	Beaumont	3.64
Abilene	6.23	Pharr	6.87
Waco	6.41	Laredo	6.06
Tyler	5.51	Brownwood	5.18
Lufkin	4.57	El Paso	10.38
Yoakum	3.99	Childress	4.96

Source: Texas Department of Transportation, 2003
*These figures relate to the rural areas in each of the districts.

When the broad categories of truck demand in rural counties needed for the study were considered, the following were found to be relevant to the project.

- The first includes centers of consumption which, given the diminishing population, are more associated with agricultural needs than human needs. The movement of feed stock to centers of production for cattle, hogs, and chickens are all examples of this category of freight demand.
- The second group serves centers of production which tend in Texas to be regionally based, such as timber in the east and oil in both the west and east. The centers of production can, and do, place a substantial demand on limited sections of the highway

network in rural districts and remain an important focus of the planning and maintenance work undertaken at TxDOT districts with large rural networks.

- Finally, there are freight corridors—typically interstate and US highway segments—that traverse rural areas and act as links between either (a) both an origin and destination outside the state or (b) an origin or a destination within the state linking an origin or a destination outside the state. The size of Texas and its strategic location both in relation to Mexico and along the Gulf of Mexico mean that there are several important transportation corridors carrying a variety of commodities moving into, out of, and across the state. Again, these corridors can be significant and at times dominate the work of district staff. As an example, in 2003, when unusually rapid pavement deterioration was noted on IH-20 in the Odessa district, funds were diverted from discretionary state highway maintenance to correct the problem and maintain the efficiency of this important Texas corridor (Personal Communication with Odessa District Engineer, 2003). But in so doing, other parts of the district network had to have programmed maintenance needs rescheduled to a later date.

A central problem associated with the growth of trucks in the state is that while the arterial systems (particularly the interstate elements) have been designed to carry increases in volumes and heavier axle loads, much of the rural system has not. Both on- and off-systems contain posted highways and posted bridges, which reflect the 58,200-lb load limit that was in existence when these roads were originally designed by the Texas Highway Department in the 1940s and 1950s.

1.1.2 Rural Road Network in Texas

Substantial investments in state highway infrastructure since the 1930s have created several categories of highways in the statewide network now managed by TxDOT. Chronologically, these comprise the extensive rural highways built between 1920 and 1950, the interstate highway system from 1958 to 1985, the metropolitan and freeway systems of the 1970s to the present, the toll roads from the 1980s to the present date, and finally the recognition that multi-county, multi–TxDOT district freight highway corridors now carry an increasing variety of state and national products.

Those TxDOT districts that can be regarded as rural generally have three of these categories—namely rural, interstate, and multi-county corridors—in their domain. The nature of rural truck demand in Texas has changed substantially in the last two decades, partly as a result of demographic changes which are characterized as a broad transfer of population from rural areas to a relatively small number of metropolitan areas. Information from the state demographer indicates that since 1990, around 100 counties have experienced a significant population loss and that this rate of loss has accelerated since 2000. Furthermore, Texas demographic data suggest that the population will undergo substantial growth in the next 20 years and will be diverse, younger, and metropolitan-based, further weakening the traditional role of rural counties in the state (Murdock, 2005).

TxDOT collects annual pavement condition data, which are entered into the Pavement Management Information System (PMIS) database on a county-by-county basis. TxDOT measures ride quality and rates pavement distress on all state-maintained roads to assist districts in identifying deficient highway segments (needs) and developing cost-effective design procedures. The collected data on ride quality and distress also provides the districts with necessary pavement information to aid in prioritizing and optimizing highway construction projects.

The first criteria TxDOT uses in its evaluation are pavement distress scores, which are calculated to reflect the condition of the roads. Based on the 2001–2003 data from the PMIS, the rural roadbed section-miles in Texas were in fairly good shape, with only 10 percent rated poor or very poor in terms of the distress score in 2003. Moreover, the overall condition and ride scores for rural Texas revealed that less than 5 percent of the roadbed section-miles were rated poor or very poor in 2003 in terms of both these scores.

However, the PMIS distress scores at the TxDOT district level revealed that ten districts—Paris, Amarillo, Lubbock, Tyler, Lufkin, Yoakum, Corpus Christi, Dallas, Beaumont, and Laredo—had more than 10 percent of their rural roadbed section miles rates poor or very poor in 2003. Most of these districts are located in northern and eastern Texas. This finding was consistent with the contention expressed by many rural stakeholders that increased agricultural industrialization and the use of larger and heavier trucks to move agricultural produce in northern Texas (see Report 4169-P2, "What is Moving in Rural Texas?"), and the impact of timber harvesting in eastern Texas is causing undue stress on rural roadways in these areas. Although PMIS data represent a surface measurement—not subsurface measurement—distress scores in Category D (poor) and F (very poor) are most likely an indication of structural problems (personal communication with Bryan Stampley, 2003).

In terms of the overall condition scores, which are a function of the distress score and the ride utility value,[1] only 4 percent of the rural roadbed section-miles in Texas were rated poor or very poor in 2003. The PMIS data for nine TxDOT districts[2] revealed that more than 5 percent of their rural roadbed section-miles were rated poor or very poor in terms of the overall condition scores in 2003. Six of the nine districts were located in northern and eastern Texas.

TxDOT measures the International Roughness Index and converts these values to a ride score to evaluate pavement condition. In laymen's terms, ride scores are simply an indication of the roughness of the pavement when traveling on a roadway. The PMIS data revealed that Texas only had four districts[3] with more than 5 percent of their rural roadbed section-miles rated poor or very poor in 2003.

Finally, the PMIS data were analyzed by highway type that showed that the condition of farm-to-market roads and U.S. highways are rated somewhat below that of interstate and state highways. Approximately 83 percent of U.S. highways and 87 percent of farm-to-market roadbed section-miles were rated good or very good in terms of the distress score in 2003, compared to 91 and 92 percent of interstate highways and state highways, respectively. In addition, an analysis of the ride scores in 2003 revealed that almost 44 percent of the farm-to-market rural roadbed section-miles were rated fair to very poor, which is substantially higher than interstate highways (18 percent), U.S. highways (6 percent), and state highways (13 percent). Poor ride scores can point to a possible maintenance need.

Nine districts had more than 10 percent of their farm-to-market rural roadbed section-miles rated poor or very poor in terms of the distress score in 2003. Of the nine, five were in

---

1 The ride utility value is a function of the ride quality lost, which is calculated considering both the traffic speed and the traffic volume. In other words, the overall condition score for a given section will be lower given higher traffic speed and volumes compares to low traffic speeds and volume sections, all else being constant.

2 Paris, Amarillo, Tyler, Corpus Christi, Bryan, Dallas, Beaumont, Laredo, and El Paso

3 Paris, Dallas, Laredo, and El Paso

eastern Texas, two were in northern Texas, and two were in southern Texas. Finally, almost half (12) of the TxDOT districts had more than 5 percent of their rural roadbed section-miles rated poor or very poor in terms of the overall condition score in 2003. Lubbock, Yoakum, and Tyler districts had the most rural farm-to-market roadbed section-miles rated poor or very poor in 2003 at 431, 292, and 253 miles, respectively. Detailed information on the rural pavement condition by highway type and for each district by highway type is summarized in TxDOT Research Report 4169-1, "Rural Truck Traffic and Pavement Conditions in Texas."

1.2 Concluding Remarks

Many TxDOT districts have seen an increase in the volume of truck traffic on their network and have found disequilibrium between rural demand and highway supply—often necessitating increased maintenance. In general it was found that TxDOT district staff is maintaining the state's rural roadbed section-miles very well, although certain districts are more impacted by larger and heavier trucks traversing their roadways, specifically farm-to-market roads. Since individual TxDOT Districts are responsible for balancing rural and metropolitan needs, priority is often given to higher volume roads in urban areas. Some districts are finding it increasingly challenging to maintain and repair all of their rural transportation system due to budget constraints. Accordingly, this research report considers innovative measures that could address rural maintenance and rehabilitation concerns.

The first year report highlighted the factors that result in greater demands on rural roads, described the condition of the existing rural road system in Texas, provided evidence of the impacts of increased demand for trucking on rural roads, and highlighted the role of rail in rural areas. This document provides information on major rural stakeholder views (Chapter 2), the TxDOT District perspective (Chapter 3), equivalent damage factors to allow for the calculation of truck pavement impacts (Chapter 4), and finally a methodology to prioritize and policy options to address rural transportation concerns (Chapter 5).

2. Characterization of Rural Traffic Generators

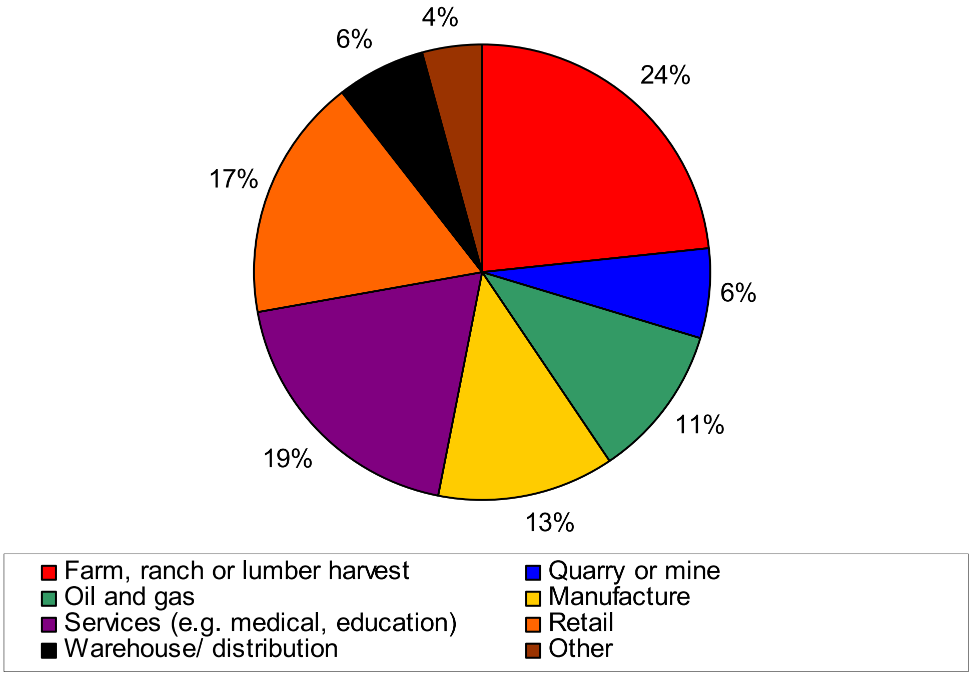
2.1 Introduction

Data from the Bureau of Economic Analysis revealed that employment/economic opportunities in rural Texas are largely tied to four sectors: government, service, farming, and mining. "Government and Government Services" was the primary revenue-earning sector for 79 rural counties in 2000. That was followed by the service sector (45 counties), farming (30), and finally mining (22 counties). These four sectors were the major revenue earners in 176 of the 196 rural counties in Texas, representing almost 90 percent of the rural counties in Texas. Also, it was found that employment/economic opportunities in rural communities are largely area-specific, tied to a community's natural resources or comparative advantage. For example, farming is the primary revenue generator in northern Texas; mining, and government and government services are the major revenue earners in western Texas; and government services and services are the primary economic driver in southern and eastern Texas.

During this research, surveys were undertaken of rural stakeholders, industry, and trucking companies to identify major rural truck traffic generators, to collect data on commodities transported and trip patterns, and to determine whether rural transportation is regarded as a concern in rural communities. This chapter of the report summarizes the major findings of these surveys.

2.2 Rural Stakeholder Perspectives

The rural stakeholder survey was sent to fifty-six rural Chambers of Commerce. Of these, fourteen rural Chambers of Commerce (25 percent) completed and returned the survey. Rural stakeholders were asked to identify the major sectors that generate income/economic activity in their county. As can be seen from Figure 2.1, farming, ranching, or lumber harvesting (24 percent); services, for example, medical and education (19 percent); and retail (17 percent) were identified as the three major income/economic generators in the responding counties.



Other includes tourism and a power plant.
Number of responses = 47

Figure 2.1 Major Income/Economic Generators

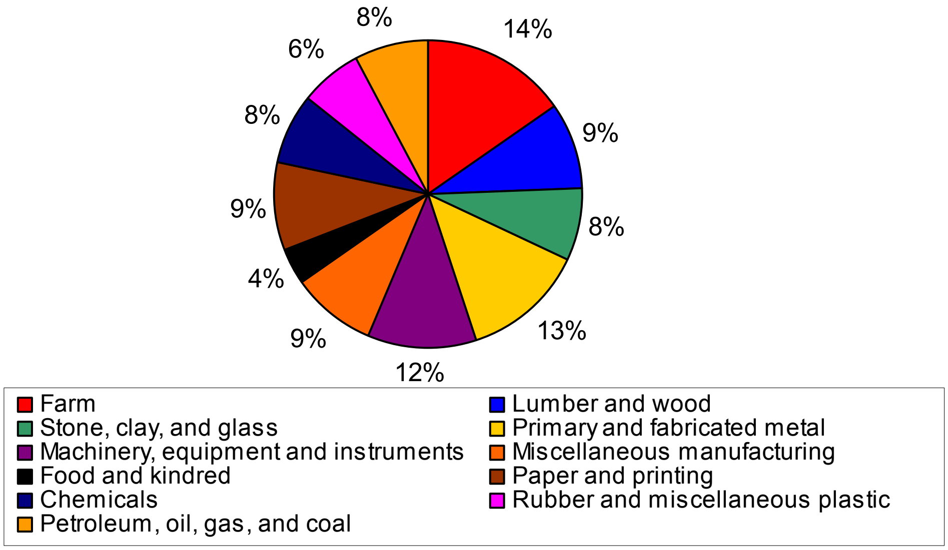
When asked to identify the top five facilities/businesses in the county, ten out of the fourteen respondents (more than 70 percent), reported the Independent School District to be one of the top five facilities in the county. Half of the respondents (seven) reported Wal-Mart to be one of the top five facilities in the county. Finally, seven of the respondents reported a medical facility to be one of the top five facilities in the county. The sizes, in terms of number of employees, of the top five facilities indicated by the respondents varied from 30 to 1,800.

Finally, rural stakeholders were asked whether rural transportation is a major issue or concern in their community. More than 90 percent of the respondents indicated that rural transportation is a major issue or concern. A myriad transportation concerns were expressed, ranging from the county having inadequate infrastructure to support shipping by rail to the general condition and deterioration of county roads. For additional information about the rural stakeholder responses the reader is referred to "What Is Moving in Rural Texas?" (Prozzi and Lo, 2003).

2.2.2 Rural Shipper Perspectives

Fifty-two rural shippers from 42 rural counties completed and returned the rural shipper questionnaire. The majority of the respondents were small shippers with 47 percent having a workforce of 5 or fewer, including the owner. Only 6 percent of the respondents employed more than 50 people. The largest rural shipper that participated in the survey employed 250 people.

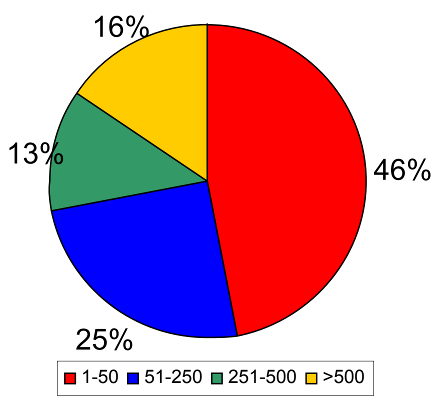
The respondents were asked to indicate the major commodities that were delivered to the shipper in a representative year. These are illustrated in Figure 2.2. As can be seen from this figure, rural agriculture and industry receive a variety of products in a representative year.



Number of Reponses = 78

Figure 2.2 Incoming Commodities

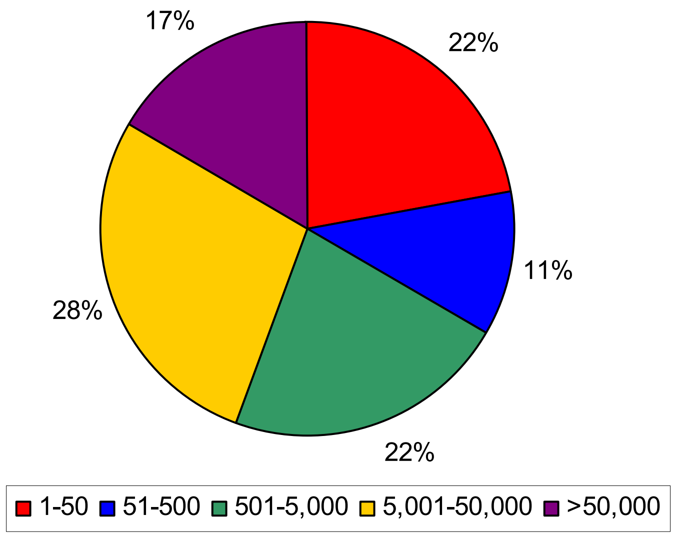
The respondents were asked to indicate how many loads (or tonnage) are received in a representative year. Almost half of the respondents (46 percent) indicated that they typically receive less than 1 load per week. Another 25 percent of the respondents receive approximately 51 to 250 loads per year. Only 16 percent of the respondents (5) received more than 500 loads per year—thus more than 2 loads per week day.



Number of Respondents = 32

Figure 2.3 Number of Loads Delivered/Year

In terms of tonnage, the responses varied considerably (See Figure 2.4). On the one extreme, 22 percent of the respondents received fewer than 50 tons per year, while on the other 17 percent of the respondents received more than 50,000 tons per year.

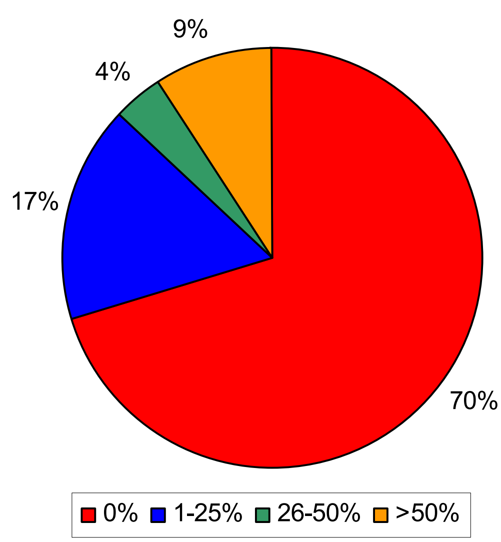


Number of Respondents = 18

Figure 2.4 Tonnage Delivered/Year

Important to the objectives of this study, however, was how many of these loads (or tonnage) are delivered to the shipper by truck. Ninety-two percent of the rural respondents indicated that 100 percent of their incoming shipments (tonnage or loads) are delivered by truck. Only four respondents indicated that less than 100 percent of their shipments are delivered by truck.

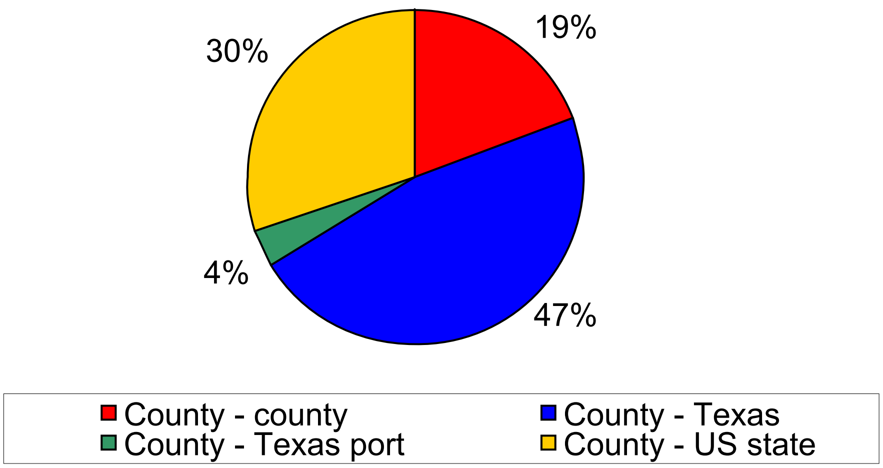
Most of the respondents (70 percent) indicated that their incoming shipments originate outside of the county that the shipper resides in. Nine (17 percent) respondents have 1 to 25 percent of their incoming shipments originate in the county, while only five respondents (9 percent) have more than 50 percent of their incoming shipments originate in the county the shipper resides in.



Number of Respondents = 54

Figure 2.5 Percentage of Incoming Shipments Originating in the County

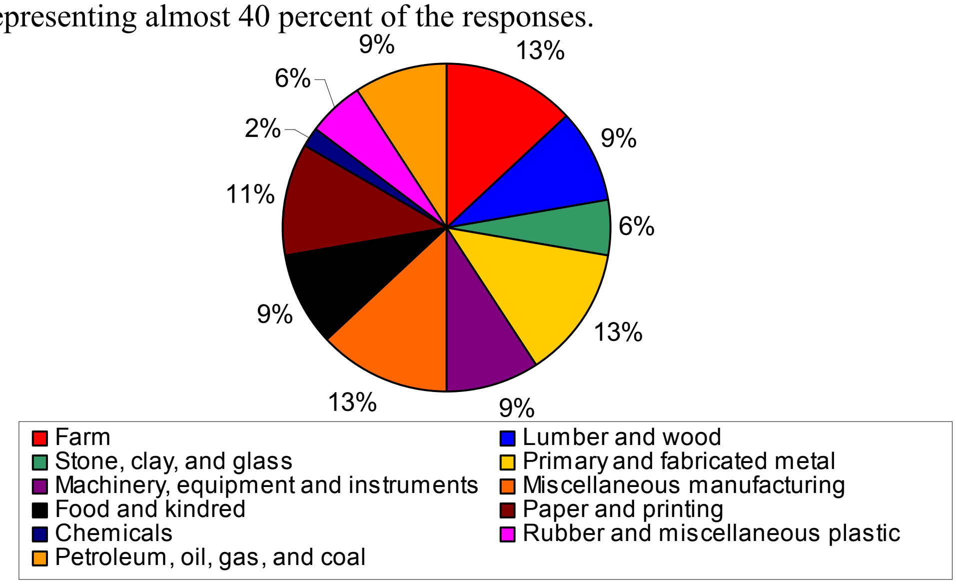
The major origin-destination pairs for the incoming shipments reported by the respondents are illustrated in Figure 2.6. As can be seen, 19 percent of the shipments involve an intra-county movement, 47 percent involve a movement between the county and another county in Texas (not considering a Texas port), and 30 percent involve a movement between the county the shipper resides in and another state. Only 4 percent of the shipments involve a movement between the county the shipper resides in and a Texas port.



Number of Responses = 32

Figure 2.6 Incoming Shipments: Major Origin/Destination Pairs

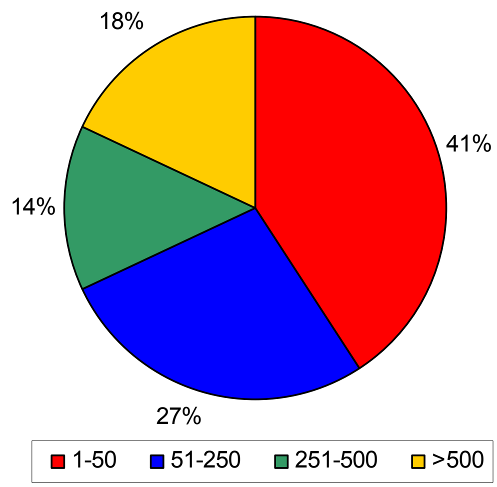
The respondents were also asked to indicate the major commodities that were shipped in a representative year (see Figure 2.7). As is the case with the incoming shipments, rural businesses ship a variety of commodities. The three major commodities reported were farm products, primary and fabricated metal products, and miscellaneous manufacturing products, together representing almost 40 percent of the responses.



Number of Responses = 54

Figure 2.7 Outgoing Commodities

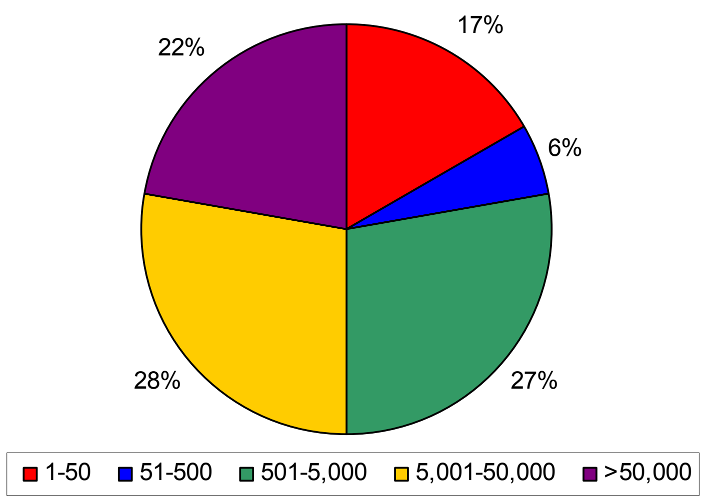
The respondents were also asked to indicate how many loads (or tonnage) were shipped in a representative year. As can be seen from Figure 2.8, 41 percent of the respondents that answered this question in terms of the number of loads shipped indicated that they typically ship less than one load per week. Another 27 percent of the respondents ship approximately 51 to 250 loads per year. Approximately 18 percent of the respondents (4) ship more than 500 loads per year—thus at a minimum more than two loads per week day.



Number of Respondents = 22

Figure 2.8 Number of Loads Shipped/Year

In terms of tonnage, the responses varied considerably (See Figure 2.9). On the one extreme, 17 percent of the respondents that answered this question in terms of tonnage shipped less than 50 tons per year. On the other hand, 22 percent of the respondents shipped more than 50,000 tons per year.

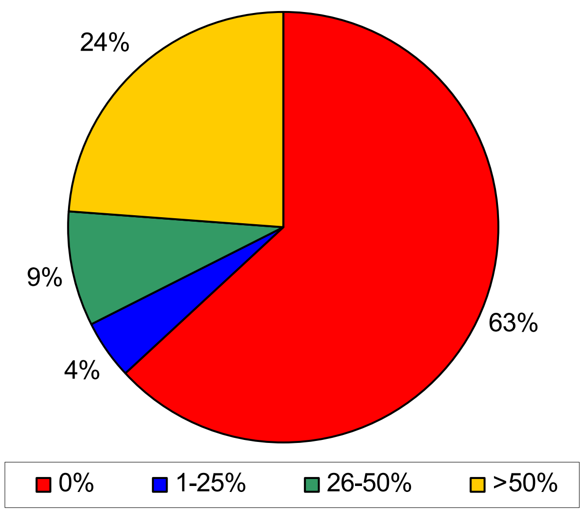


Number of Respondents = 18

Figure 2.9 Tonnage Shipped/Year

As was the case for the incoming shipments, it is evident from the survey data collected that rural shippers have come to rely on trucks for the shipment of their commodities. Ninety-four percent of the rural respondents indicated that 100 percent of their outgoing shipments (tonnage or loads) are moved by truck. Only three respondents indicated that less than 100 percent of their shipments are shipped by truck. These respondents use rail to deliver 10, 15, and 50 percent of their outgoing shipments, respectively.

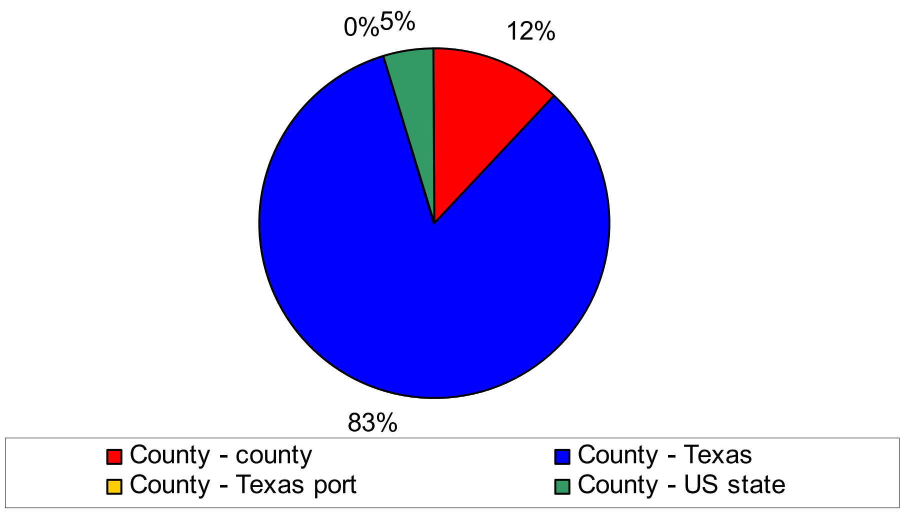
Most of the respondents (63 percent) indicated that all their outgoing shipments have a destination outside of the county in which their business is located. Eleven (24 percent) respondents have more than 50 percent of their outgoing shipments destined for the county in which the business resides.



Number of Respondents = 46

Figure 2.10 Percentage of Outgoing Shipments Destined for the County

The major origin-destination pairs for the outgoing shipments reported by the respondents are illustrated in Figure 2.11. As can be seen, 12 percent of the shipments involve an intra-county movement, 83 percent involves a movement between the county and another county in Texas (not considering a Texas port), and 5 percent involve a movement between the county the shipper resides in and another state.

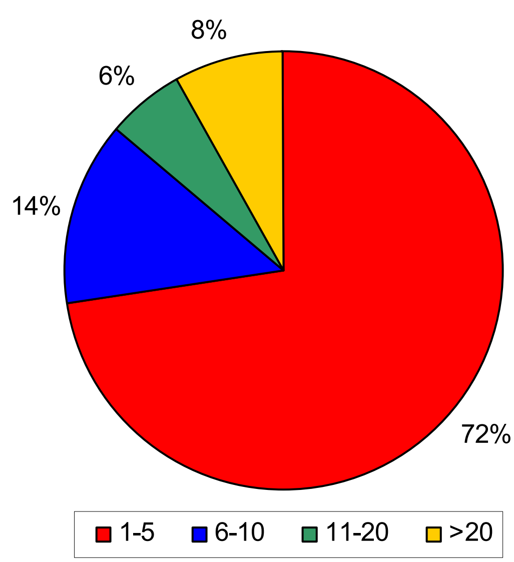


Number of Responses = 22

Figure 2.11 Outgoing Shipments: Major Origin/Destination Pairs

2.2.3 Rural Trucking Perspectives

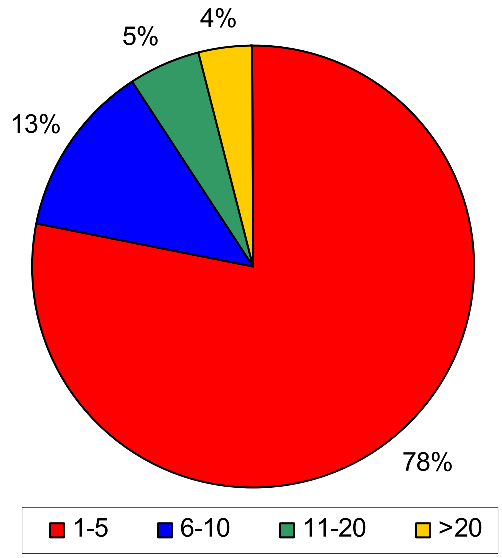
One hundred and fifty-two valid trucking responses were received. The respondents were asked to record the size of their operation by indicating the number of single-unit trucks, number of truck tractors, number of trailers, or the number of drivers employed. As is evident from Figure 2.12, 72 percent of the respondents owned between 1 and 5 single-unit trucks. Only 8 percent of the respondents owned more than 20 single-unit trucks, with the largest trucking company owning 190 single-unit trucks.



Number of Respondents = 87

Figure 2.12 Number of Single-Unit Trucks

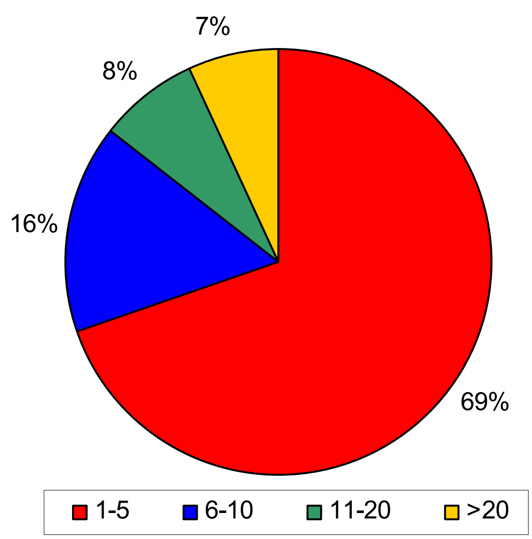
More than 90 percent of the rural trucking companies that responded owned 10 or fewer truck tractors. Only 4 percent (five respondents) owned more than 20 truck tractors. The largest owner operated 50 truck tractors.



Number of Respondents = 132

Figure 2.13 Number of Truck Tractors

In terms of the number of trailers, almost 85 percent of the respondents owned 10 or fewer trailers. Only 7 percent (nine respondents) owned more than 20 trailers and the largest owner had 100 trailers.

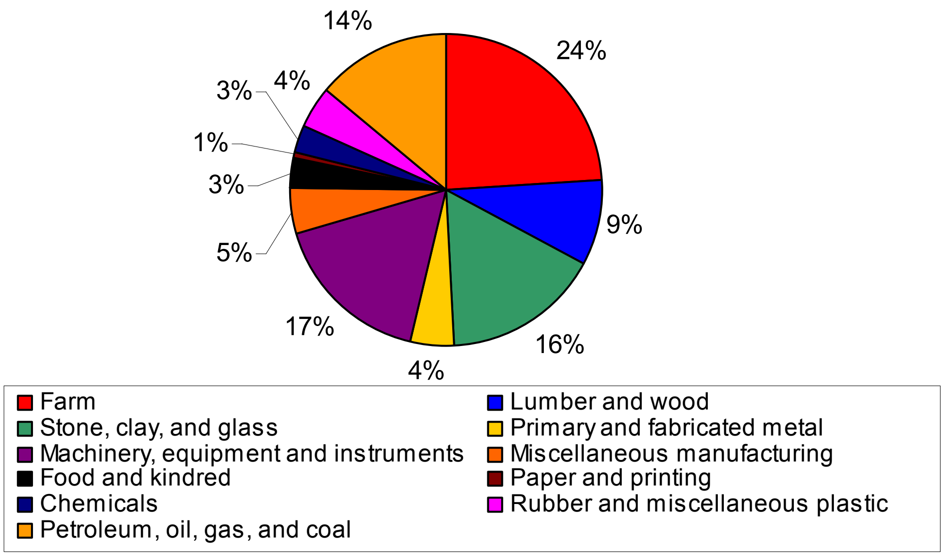


Number of Respondents = 132

Figure 2.14 Number of Trailers

Seventy-two percent of the respondents employed five or fewer drivers, including four cases in which the owner also drives the trucks. Less than 20 percent of the respondents employed more than ten drivers. Most of the respondents to the trucking questionnaire were thus smaller-sized companies.

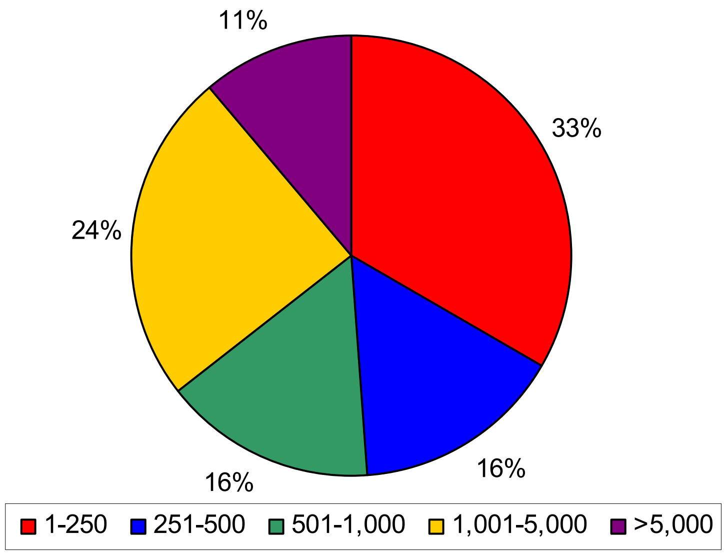
Rural trucking respondents were asked to reveal the three major commodities transported in a representative year, as well as the tonnage or number of loads transported. The responses are illustrated in Figure 2.15. As can be seen from Figure 2.15, the three major commodities reported were farm products (24 percent), machinery, equipment, and instruments (17 percent), and stone, clay, and glass products (16 percent). In addition, miscellaneous manufacturing (14 percent) was reported to be a major commodity transported by rural trucking. These four commodity groups represented more than 70 percent of the total responses.



Number of Reponses = 323

Figure 2.15 Major Commodities Transported

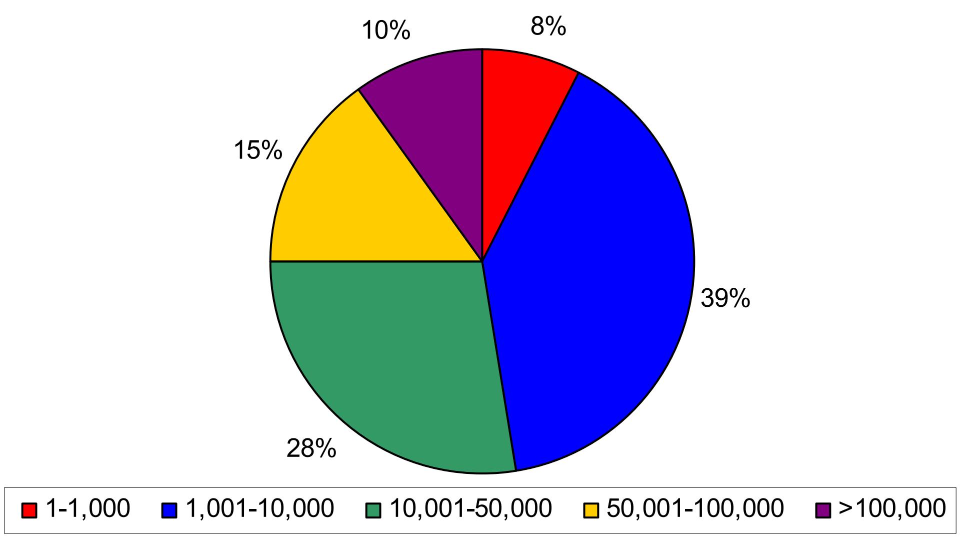
The rural trucking respondents were asked to indicate how many loads (or tonnage) these commodities represent in a typical year. In terms of the number of respondents who reported the number of loads transported in a representative year, one-third indicated that they move on average fewer than five loads per week. Another third moves between 251 and 1,000 loads per year, thus five to 20 loads per week. Eleven percent of the respondents indicated that they move more than 5,000 loads per year. The maximum value reported was 50,000 loads per year.



Number of Respondents = 45

Figure 2.16 Number of Loads Moved/Year

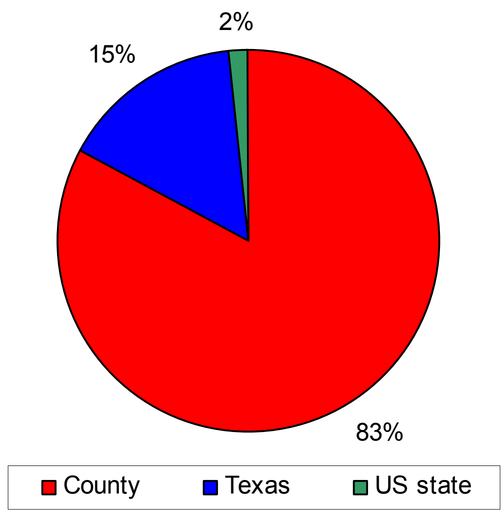
In terms of the respondents who answered the question in terms of tonnage transported, it was found that 8 percent of the respondents moved fewer than 1,000 tons per year—fewer than 20 tons per week. Most of the rural carriers (40 percent), however, move between 1,001 tons and 10,000 tons per year. In addition, 25 percent move more than 50,000 tons per year. The maximum value recorded by a trucking company was 1.3 million tons per year.



Number of Respondents = 40

Figure 2.17 Tonnage Moved/Year

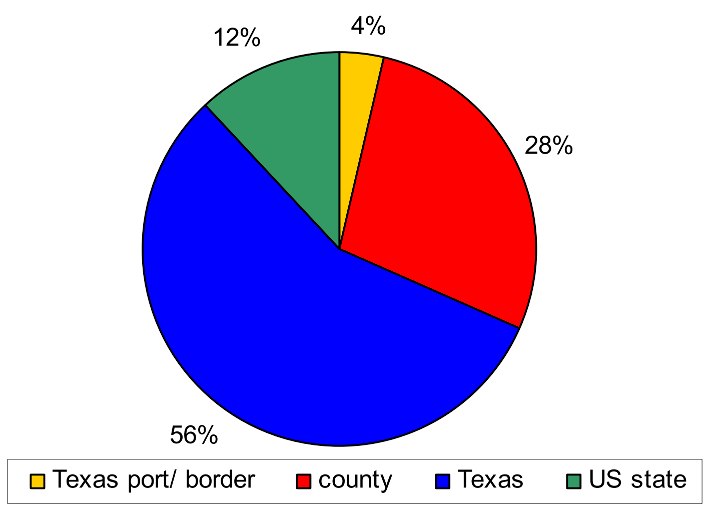
The respondents were asked to indicate the major origins and destinations of the major commodities moved. As can be seen from Figure 2.18, 83 percent of the indicated origins were in the county that the business resides in, 15 percent was in the state of Texas (in another Texas county, but not a Texas port) and only 2 percent of the origins were given as another state.



Number of Responses = 228

Figure 2.18 Major Origins

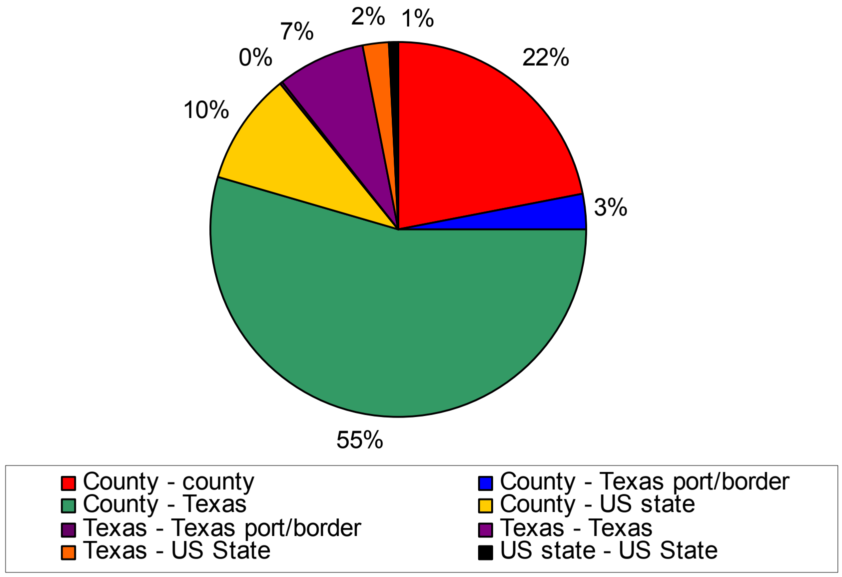
From Figure 2.19 it can be seen that the major destinations provided by the rural trucking companies were in the county that the business resides in (28 percent) and the rest of Texas (56 percent). Twelve percent of the respondents reported that the major destinations in a representative year for the major commodities transported were in another state, and only 4 percent indicated an export location, i.e., Texas port or border port of entry.



Number of Responses = 228

Figure 2.19 Major Destinations

Most of the trips reported by rural trucking companies in terms of their three major commodities transported are between the county the company resides in and another county in Texas (55 percent of the trips). Twenty-two percent of the trips are intra-county, 10 percent are between the county in which the business resides and another state, and finally 7 percent are between two counties in Texas that differ from the county in which the trucking company resides (see Figure 2.20).

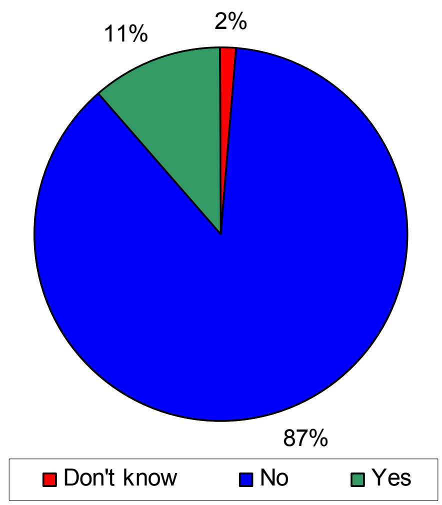


Number of Responses = 228

Figure 2.20 Major Origin/Destinations Pairs

As would be expected, the rural trucking respondents indicated the use of many different road types. Only slightly more than 10 percent indicated that they use the farm-to-market and or the county/local road system exclusively. Interesting, however, was that more than 70 percent of the respondents rated the roads that they drove in an adequate to very good condition, 19 percent rated the roads as good, and 43 percent rated the roads as adequate. Only 22 percent of the respondents rated the roads poor to very poor, including 6 percent of the respondents who rated the roads to be very poor.

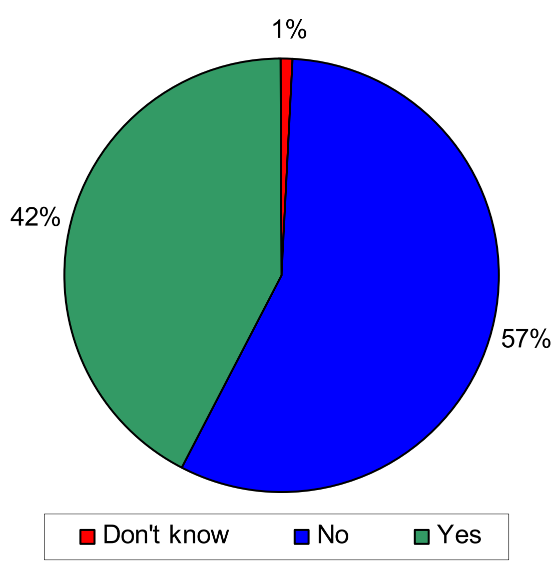
Rural trucking companies were also asked to comment on the impact of rural rail line abandonment on their business. As can be seen from Figure 2.21, 87 percent of the respondents indicated that rural rail line abandonment had no effect on their business.



Number of Responses = 131

Figure 2.21 Effects of Rail Line Abandonment on Rural Trucking

Finally, respondents were asked if rural transportation—both road and rail—presents a major concern or issue in the rural counties served by the truck respondent. As can be seen from Figure 2.22, 57 percent of the respondents said that rural transportation does not present a major concern in rural counties served. On the other hand, 42 percent of the respondents indicated that transportation does represent a major concern. Some of the concerns raised in the space allowed on the questionnaire are summarized in the text box. These concerns include the width of rural roads, inadequate shoulders, a need for better maintenance and rehabilitation (especially with regards to county and farm-to-market roads), and the impact of increased truck traffic on rural roads and towns.



Number of Responses = 132

Figure 2.22 Rural Road/Rail Transportation Concerns

Transportation Concerns in Rural Counties: Comments Received from Rural Trucking Respondents

"The county roads are not paved, nor do they have good caliche on them. Most are only one lane wide and the bridges are weak, and in deplorable shape. The roads in Karnes county are in deplorable shape."

"Almost without exception, where feed lots and dairies have come into our vicinity, the local roads are much to narrow to accommodate the increased truck traffic, which makes them unsafe. As trucks have to pull off the shoulder when meeting other trucks, the edges of the paving stay in a deteriorating condition, and dangerous potholes are created in wet weather...along the edges of the paving. These farm-to-market roads were not meant to carry the large volume of truck traffic that they now have. The narrow FM roads are not adequate or safe, due to greatly increased truck traffic on them."

"Roads are a major issue. Distances to markets are long. Few residents are scattered over large area. All of Real County has 2,500 residents. People live from transporting heavy commodities, such as livestock, cedar posts, cedar logs, building materials, food supplies, cedarwood oil, and cedar fiber!"

"Oil and gas is found outside the city, mostly. The only access is over dirt, gravel, FM and highway roads. Many have been built years ago, not expecting the use that the oil field industry puts on them and the bridges."

"The rural towns in own area are not set up to handle the longer loads and rigs today at intersections. The highways are fine."

"Rail transportation is much more cost effective and saves our rural road from deterioration and truck traffic."

"Our only complaint is that there tend to be no shoulders on these roads and the signs are often placed too closely to the roadway rather than further back on the right of way."

"It is a major concern to us as we use the roads every day. Quality of all roads in our area is on the decline. The only improvements we see are seal coating with large rocks to break our windshields. FM roads would be rated at very poor to downright dangerous-rough and rutted."

"Most of the roads in my area are lower quality now, than I have ever seen them. The rural roads in my area are in need of repair."

"For the development of our area and business, we must have an excellent road system….Our FM road system floods often- we need drainage to clean ditches. Please help us!"

"We use a lot of county and rural roads and most of them are not in very good shape. This causes a lot of wear and tear on our trucks and trailers."

"…But the part we have to drive on has potholes. Bumps. Very poor condition. No one seems to care. Will not patch holes or fix bumps? Please come see.... Then you will know why I am so damn mad."

"With 6 major Limestone Qarries in 20 mile radius. A great number of rock trucks are in the area."

"A lot of the roads need new base put on them to handle the ever increasing traffic."

2.3 Concluding Remarks

Although it is obvious that the survey results are biased toward smaller truck traffic generators and trucking companies, the results do provide useful insights into what constitutes the major rural truck traffic generators, commodities transported, trip patterns, and rural rail and road transportation concerns. As the users of rural infrastructure on a daily basis, rural truckers expressed a number of transportation concerns in rural communities. This point to some concerns about the rural transportation infrastructure—especially with regards to county and farm-to-market roads - and the impact of increased truck traffic on rural roads and towns.

This chapter provided an insight into the demand side of the study and, together with the earlier section on the changed nature of rural transportation needs, illuminates key issues related to rural highway use. But what of these supply highways to meet the changing demand? For the important element, the researchers contacted a large sample of TxDOT districts that have substantial rural networks and asked them to identify their concerns and opinion on needs. The next chapter reports the findings of this exercise.

3. TxDOT Rural District Perspective

This chapter covers that part of the project which examines the impact of trucks on the rural network in Texas from the TxDOT district perspective. Prior to conducting the interviews with district staff, the researchers began with the idea that state truck demand issues fell into two broad categories, namely rural and metropolitan. This simple classification recognizes that trucks impact rural areas differently than metropolitan areas. However, there now seems to be an emerging third category lying somewhere between the two. Because there is no clear term for this phenomenon at the moment, the researchers have termed it "boundary urbanization," defined as impacts on roads within the boundary regions of rural areas that edge growing metropolitan areas. It is in these areas that large distribution centers, new housing subdivisions and retail centers are found, and with these come a variety of new highway demands including large volumes of trucks not previously identified in any formal TxDOT planning process. This chapter presents the information obtained during the district interviews and highlights the "boundary urbanization" issue where this is appropriate.

3.1 Survey Methodology

The survey method adopted to identify truck related issues from the various TxDOT districts was as follows. First, the need to capture a wide geographic dispersion required that both Texas Tech and CTR undertook the fieldwork. Broadly, Texas Tech covered the northwestern half of the state while CTR the southeastern portion. Next, interview documentation was developed, pilot-tested, and sampled districts were sent a description of the project. The majority of the thirteen districts interviews were carried out by making a personal trip to the district offices where face-to-face interviews allowed the subject to be discussed in detail. The rest of the interviews were conducted through personal interviews either with district staff away from the district or by telephone. The early results were published in report 0-4169-1.

The research team divided the state into four geographic areas and surveyed TxDOT districts within each area to identify specific transportation issues related to rural truck traffic within the regions. The sampled TxDOT districts surveyed within each geographic area are given in Table 3.1. Researchers contacted the District Engineer or district senior planner and, where possible, set up a meeting with both the senior planner and any other TxDOT personnel the senior planner deemed pertinent to the survey objectives. A researcher visited the district and met with TxDOT personnel, described the purpose and objectives of the project, and recorded the nature of the rural truck traffic issues identified by the district staff.

Table 3.1 TxDOT Districts Surveyed

Region	TxDOT District
North	Abilene Amarillo Childress Lubbock Wichita Falls
East	Tyler Atlanta Paris Beaumont
South	San Antonio Laredo
West	El Paso Odessa

Each district interviewed mentioned some issues that were relevant mainly to their local area and its economic base. A number of the rural truck traffic issues were, however, found to be similar to those identified by other districts, putting them at a statewide level.

The objective of the research study was to identify the key issues of concern associated with rural freight truck movements and it was decided, after the interviews were complete, to categorize the responses as follows:

- *Statewide*: if the issue came up repeatedly independent of the geographic location within the state, or
- *Regional*: if the issue was regional and related to specific geographical areas of the state.

This was undertaken because it may be of interest to TxDOT to identify those issues that are similar over the entire state network, as opposed to those that are of specific concern to individual regions within the state. For example, this approach allows for the development of a more accurate pattern of needs and may also allow access to different financial sources. Finally, the hybridization of rural roads at the boundaries of large metropolitan areas is highlighted when the issues are described in the following sections.

3.2 Statewide Issues

This section identifies and describes the statewide issues that were identified by TxDOT rural district staff irrespective of the location and economic activity of the counties that comprise their particular district. These issues may need to be considered in developing an updated statewide transportation plan. The issues are numbered based on their position in the questionnaire, rather than their overall ranking.

3.2.1 Trucks Taking Alternative, Less Appropriate Routes

Trucks regularly divert onto farm-to-market (FM) and even county roads as an alternative to highways designed to carry truck traffic. The reasons include winter weather, delays, and avoiding specific weigh station locations when they are open. In some areas, farmers stated that they can tell the days when a weigh station is open by the increased in truck traffic on the FM roads. As the rural network continues to age, this may become a serious problem as pavement sections and bridges are posted for axle and gross loads.

3.2.2 Demographic Changes

Many districts are experiencing a variety of transportation issues associated with the movement of people at the boundaries of metropolitan areas. As these boundaries expand as new residential areas and schools are developed, vehicle demand of all types, including trucks increase. Additionally, new construction creates a demand for sand and gravel. This often results in heavily loaded trucks traveling on previously low-volume roads, consuming the pavements at an accelerated rate. In some cases, aggregates shipped in from out-of-state are moved on trucks using FM roads.

This could be considered a “boundary urbanization” issue.

3.2.3 Distribution Centers

The location of large distribution centers is an issue now faced by the majority of districts as a consequence of changes in the way goods are distributed prior to sale. Led by large retailers, such as Wal-Mart, products are funneled through large load centers or distribution points prior to final sale. Retailing has been “super-sized” since the mid 1980s with distribution centers exceeding 250,000 square feet in area now being used to channel products into the retail stores. Goods are “cross-docked” - a process that entails rapidly unloading a semi-trailer at one side of the building, stacking, sorting and setting up a scheduled delivery to a specific store from the products in the center of the facility for loading the semi-trailer from a bay on the other side of the facility. The turnover of full and empty trailers creates a large number of daily trips which in turn causes accelerated deterioration of pavements, and creates new traffic signal and safety issues associated with the increased truck volumes. It has been observed that the number of distribution centers in rural areas is increasing rapidly. Since these centers hold the potential of increased employment opportunities and an increased tax base for the rural counties, they exhibit substantial negotiating power and often demand certain road improvements to a site under consideration. This places district staff in a difficult position because, while they should support the efforts of local Chambers of Commerce and “boosters” promoting new economic activity, funding these unforeseen needs can be problematic. In the past, TxDOT district staff had to transfer scarce district funds to improve links to such sites, which are substantial truck traffic generators in these counties.

This could also be considered a “boundary urbanization” issue.

3.2.4 New Corridors

Several new corridors could bring significant changes to rural truck traffic. The Port-to-Plains Trade Corridor and Texas Trunk System are major construction programs planned over the next 20 years. Apparently, both these systems are needed to serve the predicted truck traffic demand associated with transporting goods from Mexico to the east coast or Canada. The use of the term “apparent” is deliberate because at this time there are no large volumes of NAFTA trucks using these corridors. In addition, the Trans-Texas Corridor may take shape—albeit slowly—and complement the rural interstate system.

The Midland/Odessa Transportation Alliance (MOTRAN) is promoting truck traffic crossing the U.S./Mexico border at Presidio through a program termed La Entrada. This program supports a Pacific port-of-entry (possibly Topolobampo) then through Chihuahua, continuing through Ojinaga, and entering into the U.S. at Presidio. The Marfa, Alpine and Fort Davis communities along the proposed route between Presidio and Midland/Odessa, however, do not support the planned route. These small communities depend heavily on tourism for their economies, and do not welcome the disruptions caused by truck traffic traversing their communities. They consider such truck traffic detrimental to the quality of life and the majority prefers bypasses.

However, corridors may become contentious in terms of future highway funding. Substantial volumes of truck traffic simply traverse Texas to benefit other regions of the U.S. In these circumstances, why should Texas not receive federal support for corridors carrying truck traffic that principally benefits other states or regions?

3.2.5 Oversized Loads and Tire Issues

Super-heavy loads present occasional challenges in rural transportation. One recent example was the movement of an electrical transformer through the Lubbock district. The total weight of the load was 608,000 pounds and imposed 5,000 pound-per-tire loadings on the pavement surfaces. The transformer was carried on a 216-ft trailer and required police escorts. However, such shipments usually traverse strengthened bridges and pavements along chosen routes and so their impact is generally controlled.

Increases in truck tire pressure, on the other hand, present additional problems in pavement design, especially for pavements designed for lower pressure tires. Special devices employed by some truckers to lift an axle to achieve better fuel mileage are presenting a relatively new problem to TxDOT. The objective of the additional axle is to allow the truck to carry more weight by distributing it over more axles. Lifting an axle from a multiple set is permitted when the vehicle is empty. However, where a device can, however, be actuated when loaded (many devices cannot), truckers have learned that they get better fuel mileage because of reduced rolling resistance and less friction.

A different, and more significant, problem is the use of “super singles,” radial tires that have a cross section smaller than that of the dual tires and which are designed to replace dual rear tires on both trucks and semitrailers. “Super singles” reduce fuel consumption—perhaps by as much as 3 percent—but they increase pavement stress, which would be particularly noticeable on lower designed rural sections of the network. “super singles” have been fitted on agricultural semitrailers, which could result in increased maintenance costs on key agricultural corridors in future.

3.2.6 Rest Area Parking

Most rest areas in rural districts throughout the state have inadequate capacity to accommodate all trucks seeking a parking bay at night. Trucks thus tend to park on the entrance and exit ramps, and sometimes even extend onto the edges of the roadway. This is not simply attributable to nearby metropolitan areas creating truck demand—all trucks, whether they are NAFTA related, in transit through Texas, going to inland ports, marine ports or large distribution retail locations need to follow the new federal driving hour laws which prescribe truckers to stop and take statutory rest breaks.

This issue has been recognized at the federal level and their research indicates that a large number of truck drivers are forced to break the law (i.e., parking illegally) to insure they meet the driver hours legislation. A potential solution is to have a rural ITS system that provides truck drivers with information in real time about available parking bays. Careful planning would, however, be required because the system would need to account for both public (rest area) and private (fuel and food stops) parking bays. The problem will become worse in the future as the number of trucks serving the growing Texas population increase. It is an issue deserving further consideration.

3.2.7 North American Free Trade Agreement (NAFTA)

The method, using Bureau of Transportation Statistics data and key assumptions, of determining U.S. NAFTA trade highway corridors was established by McCray (1998) in the 1990s, and subsequently confirmed by a number of studies at the state and federal levels. Trade with Mexico continues to be of primary economic importance to Texas, notwithstanding the growing importance of Asia in the global trading market. Data for 2004 show that U.S-Mexico trade increased by approximately $30 billion in the year to reach a total of $ 267 billion. Typically, trucks move about 80 percent of the surface trade flows in terms of value. U.S.-Mexico trade thus translates into substantial volumes of trucks. In Texas alone, over 5.6 million trucks crossed the border in 2004, with Laredo maintaining its pre-eminent role as the portal of choice for shippers moving products both truck and rail (Texas Center for Border Economic and Enterprise Development, 2005).

In the 1990s, NAFTA trade grew so quickly—some 220 percent in the decade—that many districts containing segments of IH-10, IH-20, and IH-35 saw truck volumes soar. Most recently, U.S.-Mexico trade has grown at more modest rates and comprises different commodity types as many cheaper products are now made in Asia (especially China) and shipped in containers over the U.S. rail system. This has resulted in lower truck growth rates than trade growth rates at the southern border because the NAFTA commodities frequently have higher values. In 2004, for example, trade grew at Laredo around 13 percent by value while truck crossings grew by under 5 percent (Laredo Development Foundation, 2005)

Nevertheless, two conditions persist relating to NAFTA trucking and highway planning. First, NAFTA traffic impacts the FM roads in districts along the border—such as FM 1472 in Laredo—which are now carrying volumes for which they were never designed. This creates various types of maintenance and rehabilitation needs. Second, districts with NAFTA corridors—like IH-20 in Odessa—are keeping a vigilant watch on the condition of the corridor pavements and are trying to find new ways of meeting the challenge of adding future capacity at potential bottlenecks. Odessa, for example, is evaluating the potential of truck-only toll lanes through the metropolitan areas under its jurisdiction. To conclude, NAFTA may not be as popular a planning subject as it was in the 1990s, but it remains critical to the economic health of the state and region, and will continue to generate substantial volumes of trucks using corridors going through rural areas of the state.

3.3 Regional Issues

This section contains those issues that can be regarded as specific to some TxDOT districts, though this in no way diminishes their importance in this study, nor their significance to

TxDOT planning. Again, the issues are numbered based on their position in the questionnaire, rather than their overall ranking in terms of district interest.

3.3.1 Agricultural Equipment and Goods

Transportation planners in rural districts face several problems caused by the new, larger, agricultural equipment now being introduced in Texas. Often the width of this new agricultural equipment results in stress on the edge of pavement surfaces and causes damage. In addition, turning movements create a variety of edge stresses and pavement loads that causes damage which needs to be corrected quickly before further, more significant, damage occurs. Farm implements can also cut the surface.

Agricultural goods moved along the FM roads can also create loads in excess of the pavement design loads. As an example, receivers of agricultural goods are sometimes willing to accept up to 100,000 lbs of product even though truck weight limits are 80,000 lbs, unless the trucker has a 2060 permit which raises the figure to 84,000 lbs. Shippers see the overloads as a means of increasing their profit by decreasing the number of trips to the receiver. During the harvest season, there are not enough state and local agency personnel to police all roads for weight enforcement. These types of overloads allegedly create significant damage to the FM pavements.

By legislation, instruments of husbandry are exempt from certain weight restrictions. Oversized loadings from harvester equipment and other agricultural implements thus overstress the FM pavements. As an example, anhydrous ammonia used in farming can be delivered by a truck well within the legal weight limits of the truck, but when loaded onto farm equipment which operates near or on a pavement edge pavement failures result that district programs have to fund and remedy. These oversized loads are also detrimental to bridges in rural areas.

3.3.2 Entrance/Exit Lanes and Speed Differences

The acceleration or deceleration of large trucks as they exit or enter cattle feed lots present another rural transportation challenge in some districts. In some instances, trucks queuing to turn can significantly back traffic on the traffic lanes. Similar issues of entering and exiting arise at truck stops.

Two-lane roads in rural districts routinely experience a mix of truck traffic, agricultural equipment, tourists towing large campers (often with vehicles that are underpowered for towing), and passenger cars. This mixture of vehicle types can present a problem as drivers become frustrated when trying to pass slower vehicles and drive more aggressively. Differential speed limits between automobiles and trucks also present a problem in some rural areas. The daytime speed limit for automobiles, for example, in some cases is 75 mph and the daytime speed limit for trucks is 70 mph. Speed differentials are a recognized problem on rural highways, but this can be mitigated with the use of the “super two” design, which provides periodic, short-term passing lanes at intermittent locations along the roadway.

3.3.3 Material Storage Sites

The development of temporary material handling sites during construction or rehabilitation projects results in oversized loads on FM roads. Materials are usually stored or mixed (asphalt plants) at a site near the construction project. Trucks with heavy loadings of materials are brought into and out of the site over roads (typically FM roads) not designed for heavy loads. The oversized loads lead to rapid deterioration of the FM roads. There may be a way of incorporating predicted damage and remedy costs and then folding that into the bid, although no examples of this were found in the study.

3.3.4 New Industrialized Agriculture

Several of the rural districts are experiencing an influx of large dairies and hog farms. TxDOT has assisted counties by providing recycled asphaltic pavement (RAP) to upgrade county roads serving the new industries. Upgrading county roads is used as an incentive to attract the new industries. TxDOT does not anticipate significant pavement problems resulting from truck traffic to and from dairies or hog farms. Feed is delivered to central points in the area, often by rail, and shuttle trucks are then used to move the feed to the dairies or hog farms. Although the trucks delivering feed to the central locations are large, they are within legal load limits and have not significantly increased the truck traffic count. An interesting point is that even though many of the areas are major producers of corn and sorghum used to feed the animals, both commodities are imported into the areas to supply the needs. Texas is now a net grain importer despite growing a wide variety of grains.

3.3.5 Rail Initiatives

Texas is unusual in that it permits counties to form rural rail districts (RRDs) to promote rail and stimulate economic growth. At present, most RRDs are not moving much product but there may be future opportunities, especially once they can interconnect their lines to other RRDs and so form a regional rail network. Several years ago a coalition of six counties near Abilene proposed a Texas/Mexico/Asian transportation initiative. Special legislation was required for the counties to form the coalition. The purpose of the coalition is to create a railroad transportation hub near Roscoe or Snyder to receive large containers by rail from the ports of Texas, Mexico, and the West Coast. It is anticipated that agricultural products from Texas would be loaded into empty containers for shipment back to the containers' points of origin. Currently the containers are returned empty. Such a transportation hub would connect to northbound traffic on Highway 84, southbound traffic on Highway 70, and connect to east-west traffic on Interstate 20. However, this remains a planning proposal, unlike the South Orient Railway (SORR) now owned by TxDOT with operations leased to the Texas Pacifico Railroad (TXPF). This railroad operates between San Angelo Junction and Presidio—a total of around 385 miles—and permits goods to move (rather slowly at the moment) between Presidio and Dallas/Fort Worth. Funds are being sought to improve the track first to 25 mph, and then to 40 mph which would offer a competitive transportation alternative to the highways currently used by shippers.

Another critical rail development impacting rural counties is the movement of the large Class I railroads to hub or "load center" their grain services through large rail facilities. These centers act like the hub of a wheel, with the spokes being the links to smaller grain silos that once may have been served by rail. Such silos—with a capacity under 1 million bushels—can only generate single numbers of carloads whereas the load centers generate 100 car unit trains, substantially reducing costs to the shipper. The 2001 Texas Grain Transportation Study (Fuller et al., 2001) drew attention to the impact of grain load centering, which when linked to unit train operations can reduce shipping costs by as much as 50 percent per mile/bushel. It also noted that Texas rural highways are critical for grain haulage—in part due to the concentration of rail operations at load centers—and the average truck trip for grain was over 200 miles, much higher than in other grain states like Kansas. Moving from grains to other products, containerized international merchandise is flowing into Texas either from Gulf ports or from Pacific and

Atlantic ports outside the state, and is switched to highway at rail intermodal ports which may also impact rural networks. The growth of these sites—sometimes termed inland ports—should be an issue in future state wide planning activities to allow TxDOT to be part of the process that evaluates and costs the impacts of such sites on the highway system for which it is responsible.

3.4 Conclusions

First, it should be reiterated that rural Texas is in flux as it undergoes both social and economic changes which will alter the role of rural TxDOT districts over the next 20 years. In one respect, this is merely the culmination of many years of change, particularly in agricultural practices which have led to larger production units and a greater reliance on capital intensive, rather than labor intensive, practices so lowering employment needs. And, linked to this is the reduction in rail penetration of rural markets—manifested in the abandonment of low-demand rural rail links—and the greater role of the more flexible and competitive trucking market. The text box provides one of the recommendations of a 2001 Texas Grain Study undertaken for the Texas Legislature which measured grain transportation issues in the state. The consequences of the move to trucks are now well known to every TxDOT district planner and maintenance staff. One feature is the length of rural grain trucking which turns out to be much longer than other grain producing states, for example it is twice the average length of a Kansas grain truck trip, so raising the vehicle miles of travel (VMT) for this commodity in Texas.

Truck Recommendations from the Texas Grain Transportation Study, 2001

Truck volumes on rural highways moving grain within the distribution chain will continue to grow, probably significantly. This growth will have an adverse impact on the condition of rural highways and bridges. The problem should be addressed by enhancing activities in three areas: first, within state transportation planning; second, in the funding needs for the rural highway and bridge system; and third, in the construction and connectivity of the Texas Trunk System.

Although not identified directly in the interviews with TxDOT, demographic changes are an important consideration since it drives many of the key issues revealed by this study. On a general planning level, it is clearly important that TxDOT continue to monitor on-going and forecasted changes in state demographics so that a clearer picture of rural traffic demand, including that for trucking, is identified and incorporated into future rural highway planning.

Turning to specific issues, Table 3.2 provides the ranking of the main issues of concern raised by district staff and Table 3.3 provides a detailed breakdown of the issues by TxDOT district.

Table 3.2 Ranked Rural Issues Raised by TxDOT District Staff

Ranking	Issues	Districts
First Place	Agricultural Equipment and Goods	10
Second Equal	Distribution Centers Oversized Loads Tire Issues	9
Fourth Equal	Trucks Taking Alternative, Less Appropriate Routes Rest Areas	8
Sixth Equal	Truck Corridors Entrance/Exit Lanes Speed Differentials	7
Eighth Equal	New Industrialized Agriculture Rail Initiatives NAFTA	4

Table 3.3 Rural Transportation Issues for Districts Surveyed

Issue	Abilene	Amarillo	Childress	El Paso	Lubbock	Wichita Falls	Tyler	Atlanta	Paris	San Antonio	Laredo	Odessa	Beaumont
Statewide Issues													
Truck taking alternative, less appropriate routes		●	●		●	●	●	●	●			●	
Demographic Changes						●	●						
Distribution Centers		●		●	●	●	●			●	●	●	●
New Corridors	●			●	●					●	●	●	●
Oversized Loads and Tire Issues	●	●	●		●	●	●		●			●	●
Rest Area Parking	●	●	●		●	●		●	●				●
North American Free Trade Agreement (NAFTA)				●						●	●	●	
Regional Issues													
Agricultural Equipment and Goods	●	●	●	●	●	●	●	●	●				●
Entrance/Exit Lanes and Speed Differences		●	●	●	●	●				●			●
Material Storage Sites			●			●					●		
New Industrialized Agriculture			●	●	●	●							
Rail Initiatives	●			●						●	●		●
Others	●	●	●	●		●	●		●		●		

Perhaps it is unsurprising that agriculture in various forms ranks as the highest ranked issue. Texas, like other agricultural producing states, will continue to evolve its agricultural production patterns which means the industry will always be near the top of any list of rural transportation concerns.

The next ranked issue contains one of the most interesting, and for TxDOT challenging, developments - namely the growth of "big box" distribution centers. The element of concern is created because TxDOT is often excluded from the process of negotiation until towards the end of the deal making, and this results in district planning staff having to struggle to fit the increased truck numbers, pavement condition and geometry needs, together with safety and signaling issues, into a planning process already inadequately funded. Since the demographics of the state indicate larger metropolitan populations, all presumably supported by a myriad of goods and services, such distribution centers are likely to grow in number, either in the form of solitary large sites, or as part of inland port areas, some linked to rail or air services. TxDOT supports local economic activity as part of its general mission statement but district planners frequently find they are not able to support endeavors such as big boxes in the most effective manner. The challenge facing TxDOT is to encourage local developers to work with its District planners to address the highway needs of "big boxes" at an early stage in the planning of such developments.

Finally, there are a series of issues related to trucking operations, incorporating loads, tires, speed differentials, rest periods for drivers, route choice, and various Department of Public Safety (DPS) enforcement programs. A new issue, or rather an old one made more significant by recent changes in federal law, relates to drivers hours and statutory rest. In a number of rural highway sections in Texas, truckers needing to comply with rest periods end up taking them in wholly inappropriate and sometimes illegal locations. State rest areas are inadequate to meet this demand at certain times of the 24 period and funds to remedy this deficiency are unlikely to be provided from TxDOT's shrinking revenue base. There may be opportunities to provide ITS driver information where the supply of rest area places is adequate—perhaps through a private-state partnership of some kind—but until such action is forthcoming, the problem will remain. One of the key issues of increased truck use in rural areas is the effect truck VMT has on pavement performance, particularly when trucks are heavily loaded and the pavements have a light design. This issue remains a critical problem within TxDOT rural districts and is the subject of the next chapter.

4. Pavement Impacts

The state of Texas has one of the most extensive farm-to-market (FM) and ranch-to-market (RM) road networks in the U.S., of which approximately 17,000 miles consist of load-zoned roadways, the majority of which are posted at 58,420 lb. Flexible granular bases with thin asphalt surfaces are typical pavement structures for these roads. As indicated in the previous chapters, FM and RM roads are particularly vulnerable in the case of increased truck traffic, especially when trucks are heavily loaded.

The newly mechanistic-based analysis approach developed through the National Cooperative Highway Research Program (NCHRP) research project 1-37A entitled "2002 GUIDE: Using Mechanistic Principles to Improve Pavement Design" provides valuable tools for quantifying the damage caused by trucks to the road network. A number of typical pavement structures have been modeled, different axle loads have been applied, and the response and performance of the sections have been estimated under five typical environmental conditions, which fully represent the state of Texas.

This chapter presents and discusses the results of the mechanistic-based performance analysis and the use of the results together with statistical tools to develop a methodology for estimating load-associated pavement damage. The methodology also enables equivalent damage factors (EDFs) to be determined for similar pavement structures.

4.1 The New Mechanistic Design Method

4.1.1 Main Features

A new mechanistic-based design and analysis method have been developed through research project NCHRP 1-37A (www.2202designguide.com). This new method (hereafter referred to as the Design Guide) is being developed by incorporating many years of existing research into a very powerful tool for the design and performance analysis of pavement structures. The Design Guide covers new and rehabilitated pavements, including procedures for life-cycle cost analysis and evaluation of existing pavements. It is based on a calibrated mechanistic design procedure, which integrates all design variables, such as material characterization, environmental conditions, traffic analysis, axle load distributions, and design reliability. For flexible pavements, the structural models include both a multi-layered linear-elastic program and a finite element program for non-linear analysis.

The Design Guide uses a hierarchical approach for incorporating design input variables according to the importance of the project. There are three levels of inputs that can be selected, depending on the requirements of the project. Level 1 is based on site-specific measurements, and it is reserved for the most accurate designs where the consequences of early failure are economically significant. Level 2 is based on regional values or regression equations and is consistent with the current version of the AASHTO Guide (1996). Finally, Level 3 design makes use of default values, and hence is the least accurate.

The Design Guide uses the full spectra of the axle loads and has eliminated the use of the equivalent single-axle load (ESAL) approach. However, an ESAL conversion capability will be included in the guide to allow for the use of earlier mathematical models based on the ESAL approach.

4.1.2 Distress Models

The mechanistic-empirical approach proposed in the Design Guide has two components. The first component (the mechanistic component) involves the use of a structural model to determine critical stresses, strains, and displacements within the pavement structure. The second component (the empirical component) involves the use of empirical distress models (or transfer functions) to predict expected damage. When the damage exceeds acceptable limits for each of the distress types, the proposed structural design of the pavement is modified (e.g., by increasing the layer thickness), and the analysis is carried out again until a suitable structure is found.

The distress models take the form of regression equations consisting of several variables and parameters that need to be estimated and updated to obtain the best fit between actual field performance and predicted distresses. The disadvantage of the regression approach is that the models are conditional to the circumstances under which they are developed because they cannot include variables that were not observed. When the values of these variables are similar to the ones in the original data set, the regression models work well. However, if the models are applied to a different situation involving unaccounted factors, the predictions are not accurate and hence the model requires recalibration.

4.1.3 Fatigue Cracking

The transfer function that is used in the Design Guide to determine the allowable number of load repetitions to fatigue cracking failure is an extension of the one developed by the Asphalt Institute and it is represented by Equation 1.

$$N_f = 0.00432 * C * \beta_1 k_1 \left(\frac{1}{\varepsilon_t}\right)^{\beta_2 k_2} \left(\frac{1}{E}\right)^{\beta_3 k_3} \qquad \text{Equation (1)}$$

$$C = 10^M \quad and \quad M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

Where

N_f	: number of load repetitions to fatigue cracking
ε_t	: tensile strain at the bottom of asphalt layer
E	: elastic modulus of the asphalt layer
k_1, k_2, k_3	: regression parameters: 0.00432, 3.9492, and 1.281, respectively
$\beta_1, \beta_2, \beta_3$	: calibration constants

The regression parameters are determined in the laboratory using fatigue beam tests at constant stress or constant strain. However, these parameters need to be adjusted to represent actual field conditions. The ratio of the actual number of load repetitions to the allowable number of load repetitions is referred to as damage ratio (D_R), which is computed for each load in all seasons and is accumulated over the design period. This damage ratio is then correlated to the percentage of pavement cracking.

4.1.4 Rutting

In the case of bituminous materials, the permanent strain is assumed to be proportional to the resilient strain as shown in Equation 2. The equation parameters are obtained from laboratory tests and should be adjusted, depending on the actual field conditions, using the calibration factors β_1, β_2, and β_3. Equation 2 indicates that a plot of the log ε_p versus log N results in a straight line. The permanent vertical strain ε_p can be determined by substituting the average vertical compressive strain, ε_r in the asphalt layer computed by a multi-layer linear elastic program (Groenendijk, Vogelzang, Miradi, Molenaar, and Dohman, 1997).

$$\frac{\varepsilon_p}{\varepsilon_r} = \beta_1 10^{k_1} T^{\beta_2 k_2} N^{\beta_3 k_3} \qquad \text{Equation (2)}$$

Where

ε_p	: permanent strain
ε_r	: resilient strain
T	: AC temperature
N	: number of load repetitions
k_1, k_2, k_3	: -3.51108, 1.5606, and 0.4791, respectively
$\beta_1, \beta_2, \beta_3$	: calibration factors

It should be noted that regression parameters k_1, k_2, and k_3, and the calibration factors β_1, β_2, and β_3 in Equations 1 and 2 are not the same.

4.1.5 Material Characterization

Two categories of material properties are considered for pavement design: response properties and distress properties. The response properties, such as the elastic modulus and Poisson's ratio, are required to calculate the states of stress, strain, and displacement within the structure. On the other hand, the distress properties are used through transfer functions, to predict the major modes of distress associated with a particular material, such as fatigue cracking and permanent deformation of asphalt pavements (Croney and Croney, 1997).

The elastic modulus of asphalt mixtures is determined by means of the dynamic modulus test (Holtz and Kovacs, 1981). The dynamic modulus of asphalt materials varies with temperature, rate of loading, and age. For each asphalt mix, a relationship is developed between the dynamic modulus, the material temperature, and the rate of loading. This relationship is known as the "master curve," which along with an asphalt binder aging model is used to estimate modulus values of the mixture at incremental times during the analysis period. The three levels of inputs for the asphalt materials are shown in Table 4.1 (Huang, 1993).

Table 4.1 Three Levels of Inputs

Design Type	Input Level	Description
New	1	Laboratory dynamic modulus test conducted, perform tests on binder, simulate aging of mix, develop mix master curve.
	2	Use predictive equation for dynamic modulus, perform tests on binder, develop mix master curve.
	3	Use predictive equation for dynamic modulus, develop mix master curve.
Rehabilitation	1	Back calculate by FWD, develop mix master curve with aging, and test cores in laboratory.
	2	Determine mix properties from cores, develop mix master curve.
	3	Develop undamaged mix master curve from typical mix properties; adjust for damage based on distress surveys.

4.2 Design Inputs

4.2.1 Environmental Conditions

To account for environmental conditions, the Design Guide uses historical weather data from hundreds of weather stations located around the United States. When weather data for the specific project location are not available, interpolated data from neighboring locations can be used. In this research five different locations in Texas were selected. These locations are shown in Table 4.2. The rationale behind selecting these locations was to represent all major geographical locations and varying climatic conditions existing in Texas.

Amarillo (dry/cold) represents the Texas Panhandle region, having dry cold weather and high elevation. Amarillo has a maximum temperature of 75°F (24°C) in summer and a minimum temperature of -5°F (-21°C) in winter, with an annual rainfall of 19.5 inches (495 mm).

Dallas/Fort Worth (wet/cold) was chosen to represent wet and cold weather in the state of Texas. Dallas has an annual rainfall of 32 inches (813 mm), along with slight snowfall of 3 inches (76 mm) annually.

El Paso (dry/warm) lies in the southwest Texas at the border of Mexico and represents dry warm weather. Temperature in El Paso varies from 100°F (38°C) to 64°F (18°C) in summer and from 55F (13°C) to 25°F (-4°C) in winter.

Houston (wet/warm) lies along the Gulf of Mexico, representing hot and humid weather.

Austin (mixed) represents central Texas, having moderate climate, with a maximum temperature of 98°F (37°C) in summer and a minimum temperature of 30°F (-1°C) in winter, with an annual rainfall of 32.5 inches (826 mm).

Table 4.2 Test Locations

Code	Station	Latitude (deg, min)	Longitude (deg, min)	Elevation (ft)
AUS	Austin	30.19	-97.46	648
AMA	Amarillo	35.13	-101.43	3,586
DFW	Dallas/Fort Worth	32.54	-97.02	559
ELP	El Paso	31.49	-106.23	3,942
IAH	Houston	29.59	-95.22	118

4.2.2 Pavement Layers

For the purpose of this research, three four-layer pavement structures were considered and modeled, each of the structures having different layer thicknesses, but consisting of the same materials. The three pavement structures, as shown in Table 4.3, consisted of dense asphalt surface, A-1-b base and A-2-4 subbase on top of the natural soil. The pavements were originally designed using the 1996 AASHTO Design Guide for 700,000, 3,000,000, and 9,200,000 ESALs, resulting in structural numbers of 2.6, 3.3, and 4.0, respectively (AASHTO, 1993). This level of traffic is characteristic of higher volume facilities, such as the state highways in Texas, and lower volume facilities more representative of the FM and RM network in Texas. The methodology can thus be applied to determine the impact of truck traffic on facilities carrying this range of traffic.

Table 4.3 Pavement Structures and Layers

Structure	Layer	Material	a	Thickness(in.)	Modulus(psi)
# 1	Surface	Asphalt	0.44	2	
SN = 2.6	Base	A-1-b	0.14	6	75.000
700.000 ESALs	Subbase	A-2-4	0.11	8	45.000
	Subgrade	A-6	-	Semi-Infinite	8.000
# 2	Surface	Asphalt	0.44	3	
SN = 3.3	Base	A-1-b	0.14	8	75.000
3.000.000 ESALs	Subbase	A-2-4	0.11	8	45.000
	Subgrade	A-6	-	Semi-Infinite	8.000
# 3	Surface	Asphalt	0.44	4	
SN = 4.0	Base	A-1-b	0.14	10	75.000
9.200.000 ESALs	Subbase	A-2-4	0.11	8	45.000
	Subgrade	A-6	-	Semi-Infinite	8.000

4.2.3 Vehicle Classification

The small axle loads imposed by cars and light panel trucks cause negligible structural damage to the pavement. The heavier axle loads associated with the larger commercial vehicles damage the pavements (Luskin and Walton, 2001). The types of vehicles using the pavements are broadly divided into fifteen categories by the Texas Department of Transportation (TxDOT). On the other hand, the Federal Highway Administration (FHWA) proposes thirteen vehicle classes. Classes 4 to 13, which accounts for most of the pavement damage, are illustrated in Figure 4.1.

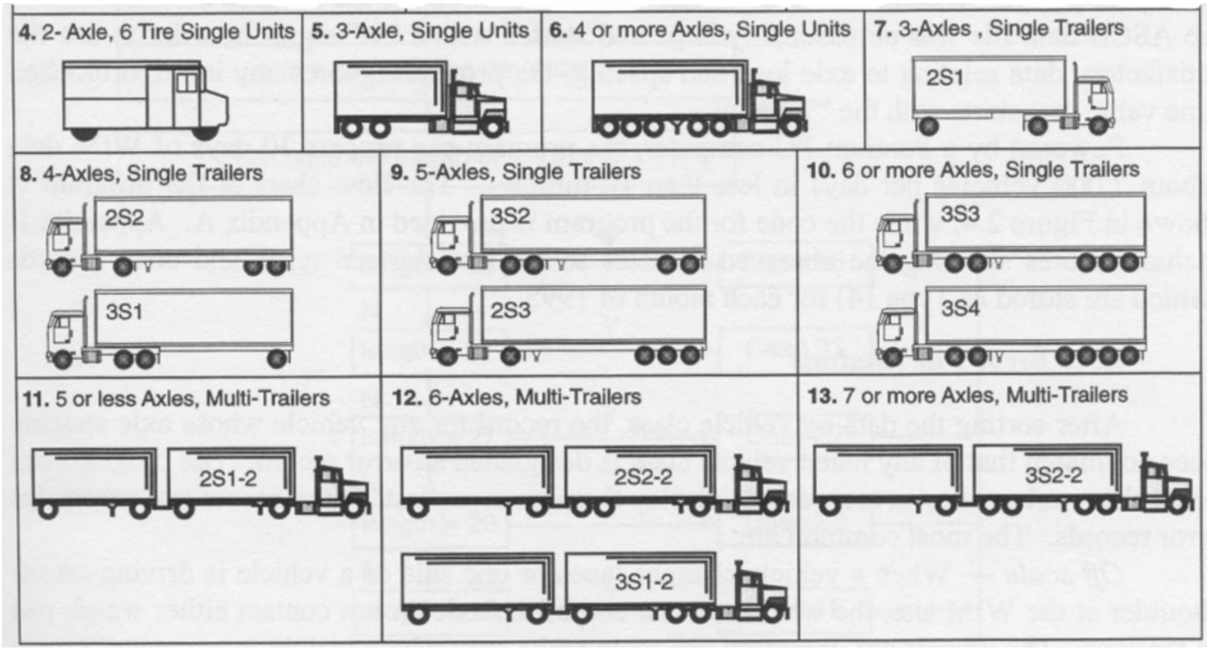


Figure 4.1 Vehicle Classification (FWHA's Traffic Monitoring Guide, 2001)

For this research, the percentage distribution of the various vehicle classes was obtained from the data available for the state of Texas. The data were converted into the FHWA system. The percentages of various classes of vehicles used in this research are given in Table 4.4. The average number of each type of axles for each vehicle class used for all the simulations is also given in Table 4.4.

Table 4.4 Vehicle Class Distribution and Number of Axles per Truck

Vehicle Class	Class Distribution	Expected number of axles			
		Single	Tandem	Tridem	Quad
4	2.8 %	1.41	0.59	0	0
5	24.4 %	2.06	0.07	0	0
6	5.4 %	1	1	0	0
7	0.0 %	1	0	0	0
8	5.2 %	2.67	0.67	0	0
9	57.8 %	1.11	1.94	0	0
10	0.4 %	1	1	0.99	0.07
11	3.1 %	5	0	0	0
12	0.9 %	3.85	1.04	0	0
13	0.0 %	3	2	0	0

The axle load distributions (axle load spectra) used in this research were measured on Intestate Highway 37 (IH-37) near Three Rivers[4], Texas. The impact of increasing and decreasing average axle loads was calculated by "shifting" the full axle load distribution to the right (load increase) or to the left (load decrease) in increments of 1,000 lb.

4.3 Work Methodology

4.3.1 Phase A

The first phase of this research consisted of the estimation of pavement damage in terms of surface rutting and fatigue cracking to evaluate the impact of the traffic volumes on the three pavement structures. For this purpose, an analysis period of ten years was used. The Design Guide makes use of a number of failure criteria: surface rutting, layer rutting, fatigue cracking, bottom-up cracking, top-down cracking, roughness progression, etc. However, only fatigue cracking and surface rutting were considered in this research because the other functions have not been calibrated for Texas conditions. The results of this phase showed that, while everything else is kept constant, as the annual daily truck traffic (AADTT) volume increases, the life of the pavement decreases by the same proportion. In other words, a pavement structure designed for twenty years for an AADTT of 5,000 trucks would only last ten years if the AADTT were to increase to 10,000 trucks. These results would indicate that the aging models incorporated into the Design Guide have an almost insignificant effect.

4.3.2 Phase B

The next phase in the research was to evaluate the impact on pavement life of increasing and decreasing axle loads by means of increasing or decreasing the mean of the axle load distributions. For this purpose the axle loads were increased in the range of 1,000 lb to 9,000 lb and decreased in the range of 1,000 lb to 6,000 lb. Using these axle load configurations, the structures were simulated, and the impact on the structures in terms of surface rutting and fatigue

[4] Texas has 21 weigh-in-motion (WIM) stations. Only two stations – one on IH-35 and one on IH-37 – collected the comprehensive data required for developing this methodology. The research team chose to use the data gathered at the WIM station on IH-37 for this research.

cracking was obtained and analyzed (see "Results and Analysis"). In addition, the axle load averages were computed, and their impacts on rutting and fatigue cracking were analyzed.

4.3.3 Phase C

In the last phase of this research project, the relative pavement life of the pavements is evaluated, relative to the standard 18,000 lb (80 kN) single-axle load. Because the load repetitions indicate the pavement life under each condition, the pavement lives are different under different conditions, making it difficult to determine generalized trends. This analysis was carried out by applying the equivalent damage factor (EDF) concept developed in South Africa (Prozzi and de Beer, 1997).

4.4 Results and Analysis

4.4.1 Overall Performance

The performance of the three structures was estimated for each of the five locations. The failure criterion for this analysis was considered to be 0.5" (12.7 mm) of surface rutting and 10 percent of fatigue cracking. Rutting life is then expressed as the number of repetitions total trucks for the surface to reach 0.5" of surface rutting. It should be noticed that Structure 1 does not reach 0.5" of rutting for any of the locations. This could be attributed to very low traffic volume. Also, fatigue life is defined as the number of repetitions of all trucks for the surface to reach 10 percent fatigue cracking. The results for all sections and locations are represented in Figure 4.2. It is interesting to notice that the mechanistic-based approach predicts the pavement structures with lower structural numbers to have a longer rutting life than those with higher structural numbers. This is because the structures with higher SN have thicker asphalt layers, and under the hot conditions prevailing in Texas, most rutting occurs in the surface asphalt layer.

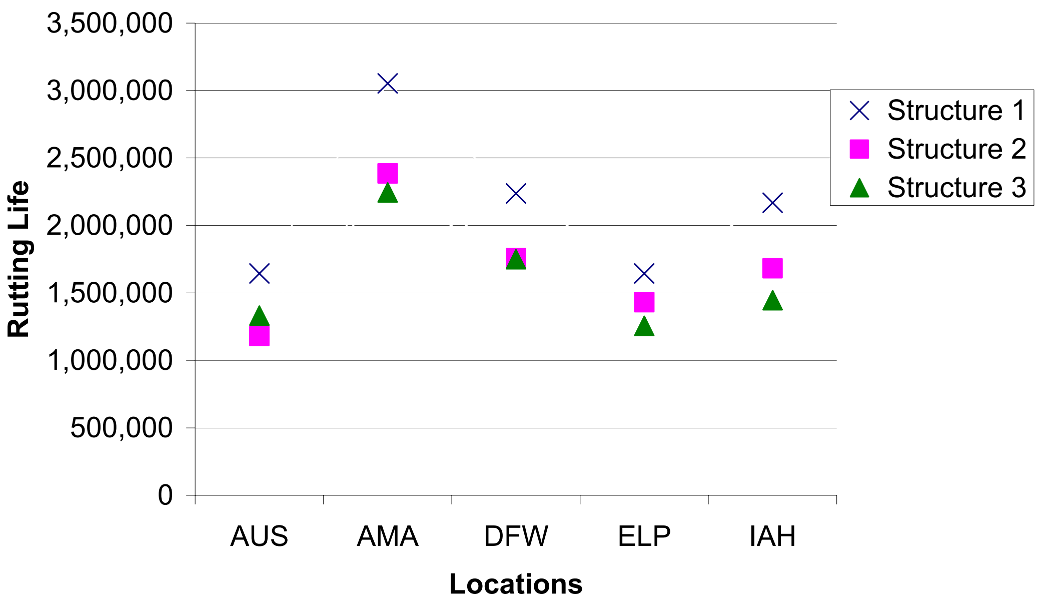


Figure 4.2 Number of Repetitions for 0.5" Rutting

Furthermore, when comparing with the empirical design based on AASHTO 1993, the mechanistic-based analysis estimates longer life for pavement structure 1, but shorter lives for pavement structures 2 and 3. However, the failure criterion in AASHTO 1993 is serviceability, whereas Figure 4.2 represents rutting life.

As can be seen from Figure 4.2, while everything else is kept constant, amongst the five stations Amarillo requires the highest number of repetitions to reach 0.5” of rutting for all the three structures, indicating slow deterioration in terms of rutting in Amarillo. Also, Austin and El Paso can be seen as the cities reaching 0.5” of rutting with the least number of repetitions, as compared to the other locations. The slow pavement deterioration in Amarillo can be attributed to the cold weather conditions prevailing in Amarillo.

4.4.2 Results of Phase B

In Phase B of this research, the effect of axle load on the pavement life in terms of rutting and fatigue was evaluated. This was done by increasing and decreasing the mean of the axle load distribution while keeping the variance constant. The axle loads were reduced in the range of 1,000 lb to 9,000 lb and increased in the range of 1,000 lb to 9,000 lb. The corresponding means were obtained and are shown in Table 4.5. This was done to simulate the potential effect of a sudden increase in average axle loads as a result of increasing axle load limits. The three structures were then simulated for all the locations with different axle load configurations.

Table 4.5 Mean Axle Loads as a Result of Shifting the Load Spectra

	Axle Load (lb)						
Shift	-6,000	-3,000	-1,000	0	1,000	3,000	6,000
Mean Single	3,558	5,998	8,180	9,254	10,254	12,254	15,254
Mean Tandem	7,079	11,103	14,787	17,426	19,365	23,242	29,057

Rutting

The number of repetitions for the surface to reach 0.5” of rutting was obtained for all the structures and locations and for all the varying axle load configurations, and these are given in Figure 4.3. As can be seen from Figure 4.3, in some cases the rutting reached, in the 10 years of design life, was less then 0.5”. Also from Figure 4.3 it is evident that the number of repetitions required for the surface to reach 0.5” rutting decreases as the mean of the axle load is increased, indicating faster deterioration of the pavements in terms of rutting, with higher axle loads. For a few structures simulations were also done for reduced axle means by 9,000 lb, but most of them did not reach 0.5” of rutting.

As seen before, for the standard load distribution, for all pavement structures to reach 0.5” rutting, the maximum number of repetitions in Amarillo is required as compared to the other locations under consideration. This implies that the pavement deterioration (in terms of surface rutting) is the slowest in Amarillo, independent of the load level. Also as before, it is observed that in most of the cases, for a given location, structure 1 reaches failure with maximum number of repetitions, indicating slowest deterioration in terms of rutting in structure 1, as compared to structures 2 and 3.

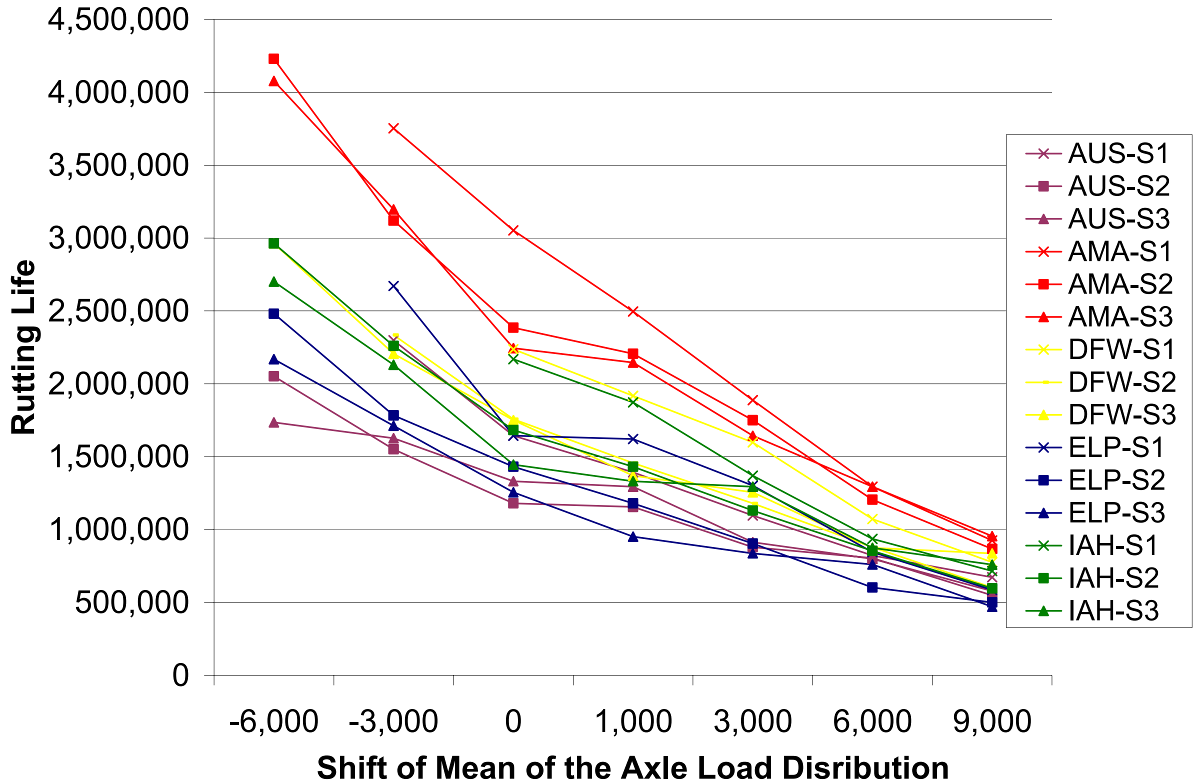


Figure 4.3 Number of Repetitions for All Locations and Structures to Reach 0.5" Rutting

Fatigue Cracking

As discussed earlier, the failure criterion for fatigue cracking is 10 percent. The number of repetitions of all vehicles for the pavements to reach 10 percent of fatigue cracking is obtained for the various axle load configurations and is represented graphically in Figure 4.4. It can be observed that some of the simulations for pavement structure 1 do not reach 10 percent fatigue cracking. It can be observed from this figure that pavement structure 3 (for all the locations other than Amarillo) lies in the lower part of the figure, while pavement structure 1 lies in the upper part. This indicates that for this particular axle load distribution and everything else the same, structure 3 requires the least number of repetitions to reach failure in terms of fatigue cracking as compared to the other two structures. This indicates that, for the conditions given, the surface thickness for structures 1 and 2 are below the critical thickness. In addition, it can be observed that Amarillo reaches failure for much higher numbers of repetitions, implying slowest deterioration in Amarillo in terms of fatigue cracking, as compared to other locations.

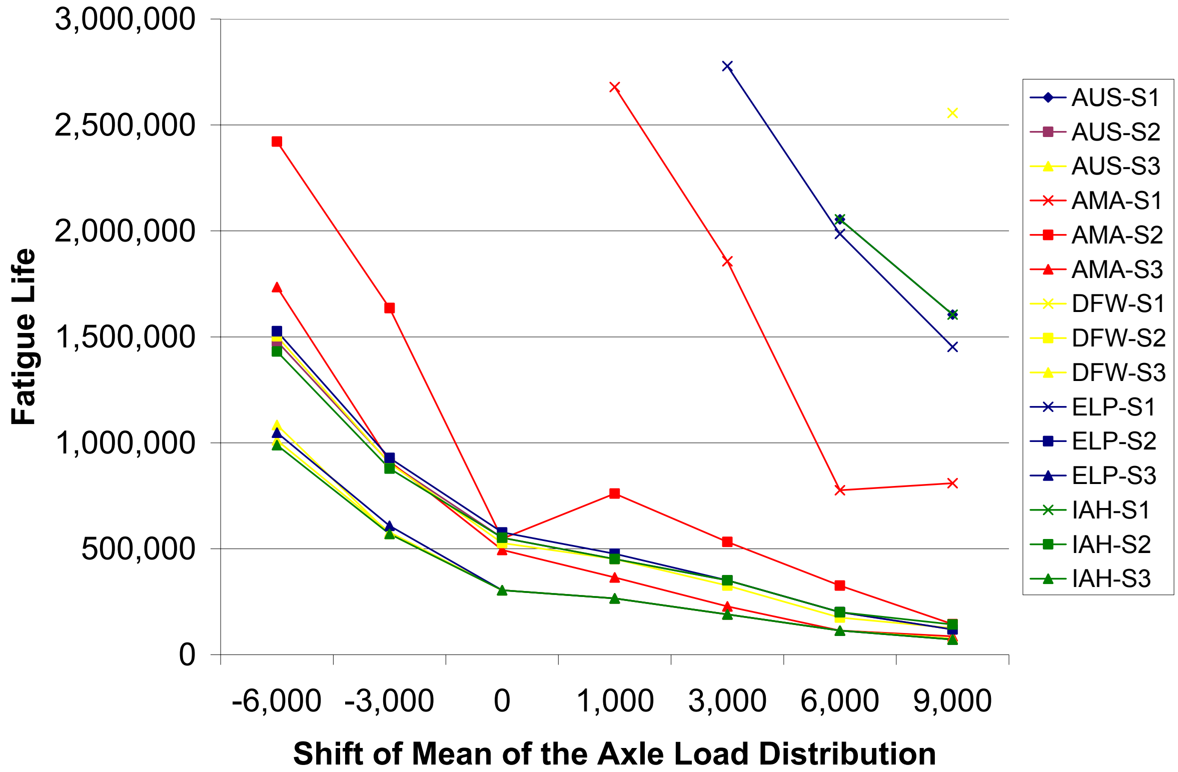


Figure 4.4 Number of Repetitions for All Locations and Structures to Reach 10% Fatigue Cracking

4.4.3 Results of Phase C

Because the load repetitions for pavement failure are different for different conditions, it becomes important to compare the results of pavement lives under different conditions. To compare the pavement deterioration under different conditions and analyze the affect of loads only on the pavement structures, the concept of equivalent damage factors (EDF) is used (Prozzi and de Beer, 1997). EDF helps in analyzing the relative pavement life based on a standard load, which is an 18,000-lb (80 kN) single-axle load for the purpose of this research. EDF is the ratio of the number of repetitions for a standard load (18 kips) to the number of repetitions for any given load, when both pavements have reached the same failure condition. The EDF equation is as follows:

$$EDF = \frac{N_{18}}{N_L} \qquad \text{Equation (5)}$$

Where

N_{18} : load repetition to pavement failure under a standard axle load (18 kips)

N_L : load repetition to pavement failure under any axle load (L)

Hence, EDF represents the relative pavement life, based on standard 18 kips single-axle load. To undertake the EDF calculations, simulations were run for all truck traffic composed of

18 kips single-axle loads only. Following are the results and analysis for rutting and fatigue cracking of the pavement structures.

Rutting

The number of repetitions of the standard single-axle load of 18 kips for the pavements to reach 0.5” of rutting in the five locations kips are shown in Figure 4.5. As before, the highest number of repetitions for the surface to reach failure in terms of rutting is found in Amarillo, implying slowest deterioration in Amarillo. It can also be observed that the fastest deterioration takes place in Austin and El Paso, as compared to the rest of the stations.

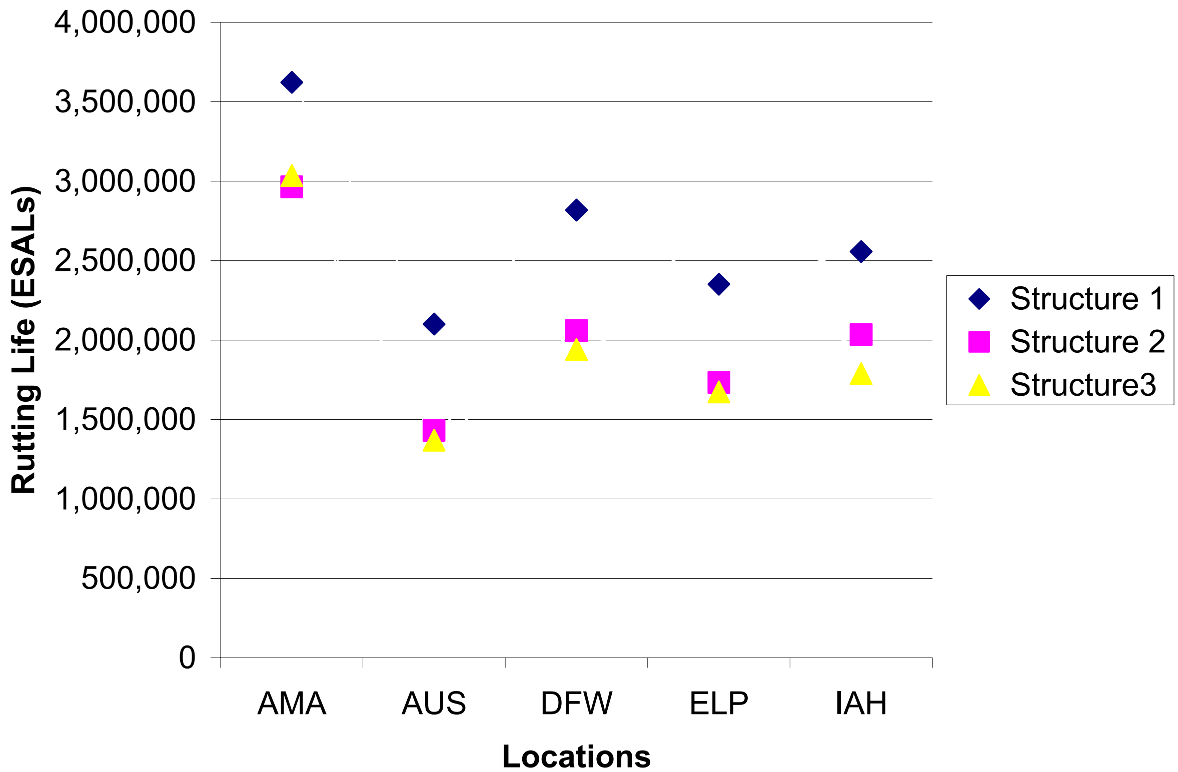


Figure 4.5 Number of Standard Axle Loads to Reach 0.5” Rutting (18 Kips)

Using the performance results obtained under standard axle load (Figure 4.5), Equation 5, and the number of repetitions to failure for different axle load configurations given in Figure 4.3, EDF values are obtained. A plot showing all the EDF values for all the structures at all locations is shown in Figure 4.6. It can be observed from the rutting-based EDF values that as the axle loads are increased the EDF values increase.

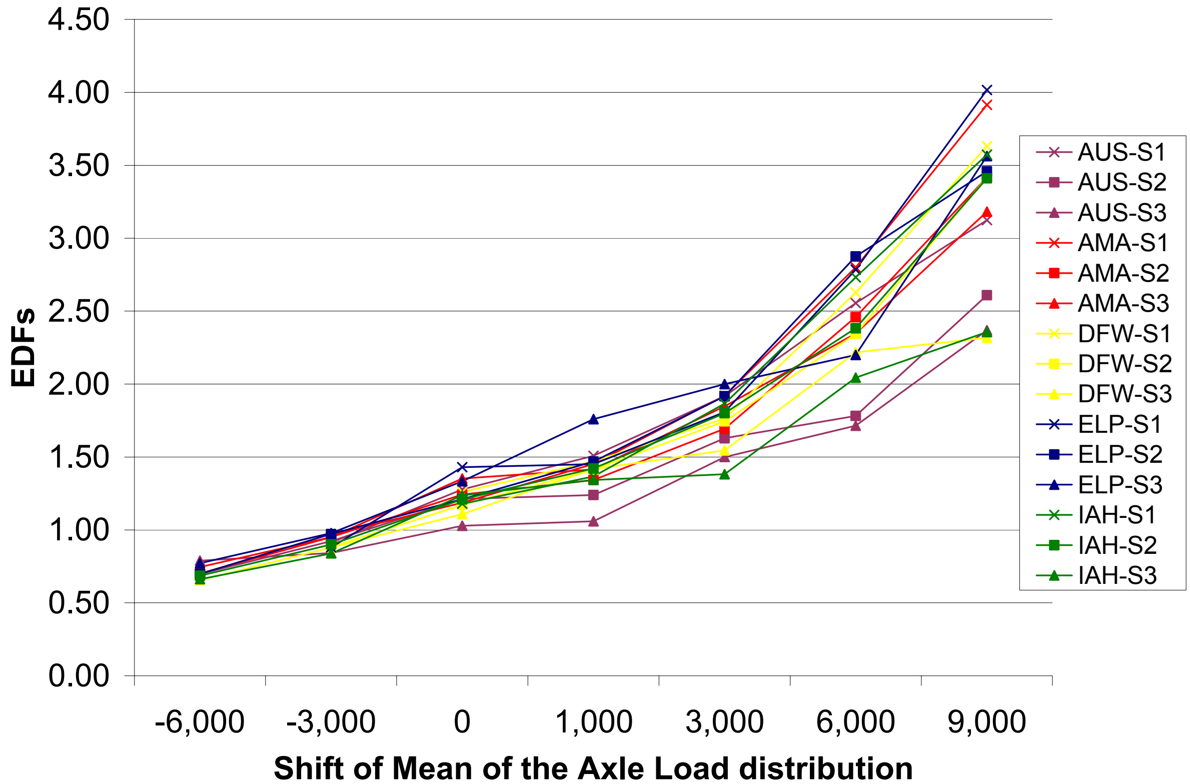


Figure 4.6 EDF for Different Axle Loads in Terms of Rutting

It can be observed from Figure 4.6 that as the axle loads are increased the EDF values, for each of the stations, are higher for structure 1 as compared to the other two structures. Furthermore, it can be seen that the relationship between EDF and mean axle load is almost linear.

Fatigue Cracking

From the output summary obtained from the simulations of the structures with the standard load of 18 kips axle load, the number of repetitions of the vehicles for the pavements to reach 10 percent fatigue cracking is obtained for the three structures at all the five locations. These results are shown in Figure 4.7. It should be noted that other than Amarillo, at none of the other locations, pavement structure 1 reaches 10 percent fatigue cracking. It can also be observed that pavement structure 2 takes more repetitions to reach failure as compared to structure 3, and hence structure 2 has a slower deterioration rate as compared to structure 3.

To analyze the impact of varying axle loads on pavement deterioration in terms of EDF toward fatigue cracking, the data from Figures 4.4 and 4.6 are used in conjunction with Equation 5. The corresponding EDF values are shown in Figure 4.8. It shows that as the axle loads increase the corresponding EDFs increase but at a higher rate. That is, the relationship is not linear but exponential.

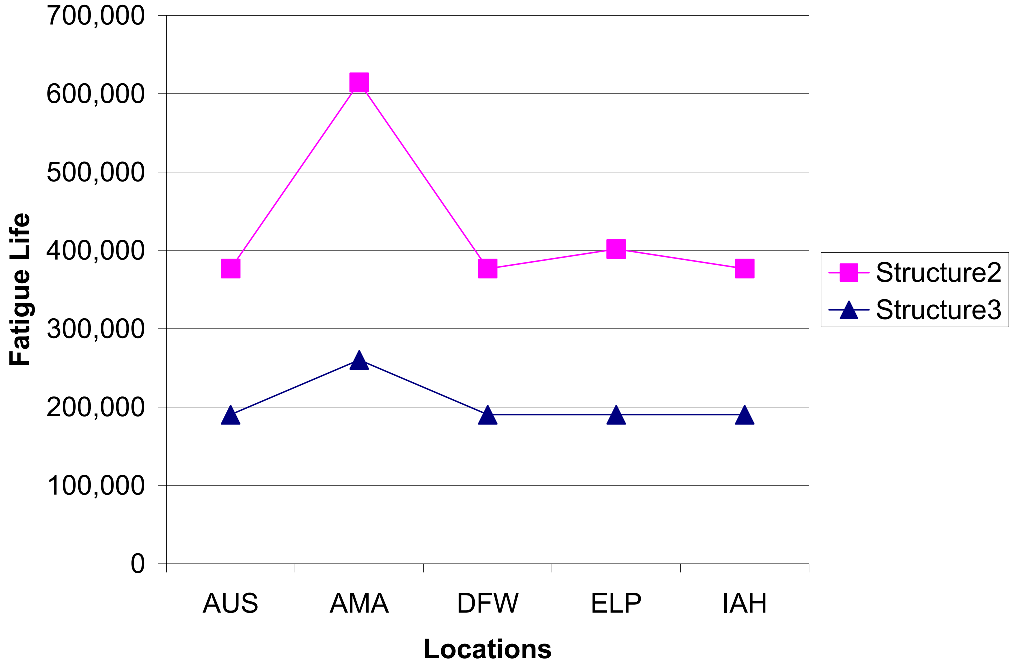


Figure 4.7 Number of Standard Axles for 10% Fatigue Cracking (18 kips)

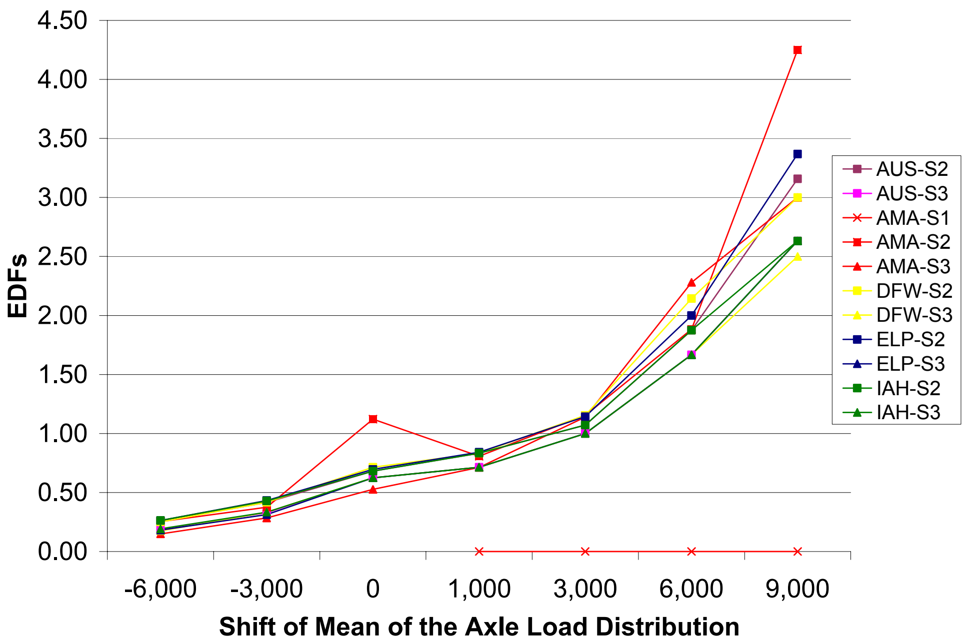


Figure 4.8 EDFs for Different Axle Load Configurations to Reach 10% Fatigue Cracking

It is observed from Figure 4.8 that for each of the locations, pavement structure 2 has higher EDF values as compared to pavement structure 3, for each of the locations.

4.5 Regression Analysis

Two regression equations were developed for estimating equivalent damage factors (EDFs) directly. The equations estimate EDFs as a function of the relative load (RL) based on the original traffic distribution. Thus, *RL* = 1.10 indicates a 10 percent increase in the mean axle load, while *RL* = 0.95 indicates a 5 percent decrease in mean axle load. The resulting equation developed for rutting- and fatigue-based EDFs are:

$$\ln EDF_{rut} = 0{,}95 \ln R_L + 0{,}122 \quad , R^2 = 0{,}89$$ Equation (6)

$$\ln EDF_{fat} = 1{,}60 \ln R_L - 0{,}416 \quad , R^2 = 0{,}94$$ Equation (7)

The form of the above equations was used because both the intercept and the slope parameters have a physical meaning. The slope parameter represents the average sensitivity of the analyzed pavement structures to load increase. This is equivalent to the exponent of the so-called power law. The intercept parameter represents the natural logarithm of the average truck in the traffic distribution used. In other words, it is equivalent to the average number of ESALs/truck (or E80s/truck). In this particular example the values are 1.13 and 0.66 for rutting and fatigue, respectively.

Another interesting result of these two analyses was that, although fatigue and rutting performance are significantly different in the various locations, the EDF formulation has not show any statistically significant difference. Thus the same equations (Equations 6 and 7) can be used to estimate EDF in all regions in Texas.

By comparing the slope parameters in Equations 6 and 7, it can be concluded that as load increase, fatigue damage increases more rapidly than rutting damage. As rutting damage increases almost linearly with load increase (slope parameter = 0.95), fatigue damage increases exponentially (slope parameter = 1.60). The increase in fatigue damage is, however, slower than what the fourth power law would suggest.

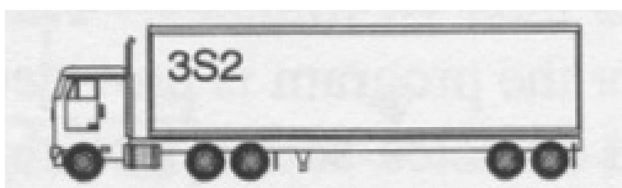
4.6 Case Study

To apply the results of this research to a different set of conditions, a case study was undertaken. For this case study, a pavement structure which lies between structure 2 and structure 3 was considered. This structure was assumed to have a structural number of 3.65. The properties of this structure are shown in Table 4.6. For this structure, the pavement deterioration had to be evaluated in terms of the number of repetitions needed for the pavement to reach 0.5” of rutting and 10 percent fatigue cracking. This structure was assumed to be in Waco, which is located midway between Austin and Dallas–Forth Worth. By linearly interpolating the results of structures 2 and 3 for Austin and DFW, the number of repetitions required for this new structure to reach 0.5” rutting and 10 percent fatigue cracking was obtained. The estimated rutting and fatigue lives under the original axle load distribution were 1,504,945 and 422,131, respectively. These lives could be also expressed in terms of E80s (or ESALs) by using the conversion factors obtained in the previous section. Hence the rutting and fatigue lives are 1,332,000 and 640,000 ESALs (or E80s), respectively. The actual fatigue and rutting lives (in term of total trucks) obtained by running the full simulation under the original traffic were 1,428,415 and 425,320, respectively (or 1,264,000 and 644,000 ESALs). This represents an error of -5.4 percent and +0.7 percent, respectively, which are well within acceptable limits.

Table 4.6 Structural Properties of the Case Study Structure

Structure	Layer	Material	Thickness(in.)	Modulus(psi)
Sample	Surface	Dense Asphalt	3.5	
	Base	A-1-b	9	75,000
	Subbase	A-2-4	8	45,000
	Subgrade	A-6	Semi-Infinite	8,000

The second part of this case study consisted of evaluating the effect of load change. For this purpose, all traffic was assumed to consist of Class 9 vehicles loaded under three different scenarios. This first scenario corresponds to the case of load-zoned roads before HB2060 legislation was passed: maximum legal load equals 58,420 lbs, which corresponds to approximately one ESAL/truck. The second scenario corresponds to the new legal load after HB2060 legislation: 84,000 lbs (including tolerances). The third scenario represents the hypothetical case of vehicles which are 20 percent overloaded. The three load scenarios are represented in Figure 4.9.



Scenario	Steering	Tandem	Tandem	Total
1	10	24	24	58
2	12	34	34	80
3	14.4	40.8	40.8	96

Figure 4.9 Axle Loads (Kips) for A Class 9 Vehicle Used in the Case Study

By increasing the load from scenario 1 to scenario 2 (38 percent load increase), the rutting damage will increase by 35.7 percent, while the fatigue damage will increase 67.3 percent. Thus, the impact on these types of pavements in Texas will be to reduce the rutting and fatigue pavement lives by 26.3 percent and 40.2 percent, respectively.

On the other hand, by increasing the load from scenario 1 to 3, the rutting damage will increase by 61.4 percent, while the fatigue damage will increase by 129.9 percent. Thus, if overloading is not well controlled and enforced on the rural network, Texas will be forced to rehabilitate or reconstruct its network in less than half the original pavement design period.

4.7 Conclusions and Recommendations

The recently developed Mechanistic Design Guide (www.2002designguide.com) was used in this research for the evaluation of pavement performance and the determination of equivalent damage factors (EDFs). The four major variables which were considered in this research study were:

- pavement structural capacity, expressed in terms of the structural number (SN);
- environmental conditions—five locations representative of the most typical Texas conditions were investigated;
- mean of the axle load distribution; and
- rutting and fatigue cracking performance.

The failure criterion of the pavements in terms of surface rutting was 0.5” and in terms of fatigue cracking was 10 percent. When compared to the empirical design based on AASHTO 1993, the mechanistic-based analysis estimates longer rutting life for pavement structure 1, but shorter lives for pavement structures 2 and 3. However, the failure criterion in AASHTO 1993 is riding quality in terms of present serviceability index (PSI). The fatigue life estimated by the mechanistic-based approach is always shorter than that predicted by AASHTO 1993. Expected life as a function of the structural number is very sensitive when applying the empirical method but markedly less sensitive when the mechanistic approach is used.

Based on the performance analyses, it was observed that Amarillo had the slowest pavement deterioration as compared to the rest of the four stations that were chosen for this research project. This was attributed to the colder weather prevailing in Amarillo. On the other hand, the fastest pavement deterioration was observed in Austin and El Paso as compared to the other three locations.

The effect of increased average axle loads was also investigated. It was observed that as the mean axle load was increased, the pavement reached failure at a faster rate, requiring fewer repetitions to fail. It was observed that rutting life decreased almost linearly with axle load increase, while fatigue life decreased at a faster rate (exponentially). In all instances, it was observed that the deterioration was slowest in Amarillo as compared to the other four locations. This and the previous chapters provide the major components of the rural highway network, namely history, changing patterns of demand and use, the major issues facing TxDOT districts containing rural networks, and, in this chapter, the current condition of the system and how engineers might improve their ability to both measure and predict pavement life. At this moment, use of EPFs from the Mechanistic Design Guide appears to be a major complement to the 2002 Design Guide. With these elements it is possible to construct a method to evaluate the rural network and offer priorities to district planning staff working under constrained budgets. This is the subject of the next chapter.

The analyses carried out enables the formulation of simple equations for estimating equivalent damage factors as a function of the relative load increase. This can, for example, be used to assess the effect of HB2060 legislation on Texas’ rural network.

5. Prioritization to Address Rural Road Issues

5.1 Introduction

The Texas state-maintained rural road network consists of farm-to-market roads, state highways, U.S. highways, and interstate highways. Funding for projects falls into three categories: routine maintenance, preventative maintenance, and rehabilitation funding. In each funding category formulas considering a number of factors are used to determine a district's needs. Maintenance and rehabilitation funding allocations among TxDOT districts are thus made centrally and are based on formulas[5] that consider such variables as regional rainfall, pavement condition scores (failures and ride quality), number of lane miles, average daily traffic, daily vehicle truck miles, and a myriad others. After funding allocations for maintenance projects are made from the state to each individual district, each district decides on what projects will be undertaken. The farm-to-market system thus competes with the demands of the rest of the system as districts are responsible for balancing rural and metropolitan needs and for balancing maintenance funding by highway type (personal communication with Richard Kirby, July 2003). The objective of this chapter is to provide an overview of how TxDOT districts prioritize rural infrastructure needs and to propose a methodology to help TxDOT staff to rank and prioritize rural infrastructure needs before concluding with a number of policy options to address the TxDOT district concerns about the widening gap between available funding and the unforeseen and unmet needs of the rural system.

5.2 Prioritizing District Needs

TxDOT, through its twenty five district offices, is responsible for rural transportation planning and the provision and maintenance of rural infrastructure. Determining maintenance and rehabilitation priorities are thus decentralized at the district level for all projects. The research team interviewed a number of representatives (e.g., District TP& D directors, maintenance supervisors, design engineers, operations directors, etc.) from seven districts (i.e. Tyler, Odessa, Laredo, Yoakum, Lubbock, Pharr, and Bryan) to determine how rural needs (maintenance and rehabilitation) are prioritized and who decides the priorities. These districts were selected to gain insights into the different approaches and factors adopted to prioritize maintenance and rehabilitation needs.

Table 5.1 summarizes which factors are considered in determining priorities, as well as who sets the priorities. As can be seen from Table 5.1, maintenance priorities are usually set by the maintenance supervisors or by the district staff (in some instances in consultation with the area engineers or maintenance supervisors). In the cases where maintenance prioritizing is delegated, it was reported that the maintenance supervisors regularly drive the roads under their jurisdiction and thus have a solid knowledge of the condition of the roads and which sections are in need of maintenance. In the cases where district staff prioritize maintenance, it is clear from Table 5.1 that the districts use different factors to prioritize maintenance, although pavement condition scores are—as would be expected—a factor considered by all districts.

---

5 For example, almost fifty individual needs-based formulas exist for the allocation of the available routine maintenance funding among the twenty-five districts.

Rehabilitation priorities are mostly determined by district staff. As can be seen from Table 5.1, each district has its own selection criteria that are used to prioritize projects. The criteria used vary substantially, but most districts consider traffic volumes in their allocation of rehabilitation funding. The Laredo District also considers the economic benefits associated with the proposed project.

These methods of priority determination have been tailored by each district to the specific circumstances of the district. Most districts interviewed thus felt that their adopted prioritization approach is working well.

Table 5.1 Responsibility and Factors Considered in Setting Maintenance and Rehabilitation Priorities

District	Maintenance Priorities		Rehabilitation Priorities	
	Responsible	Factors	Responsible	Factors
Bryan	Maintenance supervisors	• Maintenance supervisor knowledge of road conditions • Public complaints	District staff	• District evaluation • Cost • Average daily traffic • Political concerns
Laredo		Pavement condition		• Cost-effectiveness • Safety • Project economic benefits • Ranking of area engineer
Lubbock	Maintenance supervisors	Maintenance supervisor's knowledge of road conditions	Area engineers	District funds all first priorities, then second priorities and so on until budget is exhausted.
Odessa	Area engineers in consultation with maintenance supervisors	Maintenance supervisor's knowledge of road conditions	District in consultation with area engineers	• Pavement condition (rutting, cracking, failures, etc.) • Average daily traffic • Average daily truck traffic • Past maintenance expenditures
Pharr	District staff in consultation with area engineers	• Pavement condition (rutting, cracking, fatigue) • Facility type (volume, speed)		• Average daily traffic • Safety index
Tyler	District staff in consultation with maintenance supervisors	• Pavement condition • Expenditures incurred	District staff	• District evaluation • Cost • Traffic volumes • Past expenditures • Visual inspection data from area engineers
Yoakum	District staff	• Lane-miles • Cost of materials • Pavement condition	District staff	• PMIS scores • Traffic volumes

5.3 Proposed Additional Criteria for Prioritizing Rural Needs

Given the fact that the available funding currently does not cover all the identified district needs requires districts to prioritize their needs. As indicated before, each district has its own prioritization procedure that varies from less formal assessments to some form of ranking considering different criteria. If this disparity between available funding and rural needs increases, as anticipated, effective prioritization will become more important in the future. The objective of this section is to propose a number of additional parameters and criteria in a "multi-attribute criteria methodology" framework that can be considered by TxDOT to prioritize significant maintenance and rehabilitation projects.

Multi-attribute criteria analysis is founded in benefit cost analysis (BCA), but unlike BCA, which requires the quantification of all impacts (benefits and costs), multi-attribute criteria analysis does not require the expression of all impacts in monetary terms. This type of analysis allows the analyst to rank identified impacts in a structured framework.

The first step is to identify the important parameters and criteria (impacts) associated with the identified rural projects. A number of parameters and criteria that TxDOT might want to draw from are summarized in Table 5.2. This list is by no means exhaustive, and in some cases a number of criteria are presented for the same parameter. The TxDOT districts can use this as a basis to expand the factors currently considered, if so desired.

It is suggested that TxDOT produce a scoring method after agreeing on the parameters and criteria. For example, TxDOT staff can be asked to rank the parameters and criteria on a scale of 1 to 5, where 1 represents a very high cost or low benefit and 5 represents a very low cost or high benefit.

At the same time, not all the parameters might be of equal importance. When parameters of differing importance are combined into a single decision-making tool, a weight should be assigned to each of the parameters to prevent less important parameters from driving the decision.

Table 5.2 Multi-Attribute Criteria Example

Parameter/Criteria	**Projects**								
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**
Project Cost (Weight = 15)									
$									
$/vehicle mile									
$/mile									
Pavement Condition (Weight = 15)									
PMIS scores (distress, ride score, overall condition)									
Demand (Weight = 15)									
Average daily traffic									
Vehicle-miles traveled									
Average daily truck traffic									
Truck-miles traveled									
Past Agency Maintenance Expenses (Weight = 5)									
$									
$/vehicle mile									
$/mile									
Connectivity (Weight = 15)									
Access to rural farms and industry									
Links between towns and cities									
Link for travel across the state									
Access to parks, wildlife and recreational opportunities									
Alternative roads available									
Safety (Weight = 15)									
Number of incidents									
Number of injuries									
Number of fatalities									
Economic Benefits (Weight = 10)									
Number of farms or rural shippers served									
Potential to attract new business and jobs									
Social Benefits (Weight = 10)									
Serving poor or minority community									
Number of schools									
Number of clinics									
Number of religious centers									

5.4 Rural Strategies

Of concern to six of the seven districts interviewed was the widening gap between available funding and the needs of the rural road system. Because more emphasis is typically placed on addressing the needs of the higher-volume facilities, i.e., interstate, U.S., and state highways, and urban areas, some districts have expressed concern about maintaining the farm-to-market system. In addition, districts find it challenging to address unforeseen needs. This section highlights a number of policy options that can be considered to fund unmet and unforeseen[6] maintenance needs in rural areas.

5.4.1 Texas' Rate of Return

A number of Texas legislators and many Texas representatives in Congress have worked together to change the current percentage that Texas receives as its rate of return of gas tax revenues in an attempt to increase the highway funds available to the state. These congressional representatives believe Texas is entitled to a higher return on the gas tax revenues than what is currently being allocated to the state. Historically, for every dollar Texas has contributed to the Highway Trust Fund, it has received less than a dollar back. For example, since the inception of ISTEA in 1991, Texas has received approximately 77 cents in highway program funds for each dollar contributed. The Texas delegation in the U.S. House and Senate has thus been advocating that all states should receive at least a 95 percent rate of return (Senate Research Center, n.d.). This would increase the funding available to Texas for maintaining and rehabilitating its extensive road system, including hypothetically its rural system.

5.4.2 Texas Trunk System

The objective of the envisioned Texas Trunk System is to complement the Interstate Highway System and to provide an efficient and effective rural transportation system for the movement of goods and people by upgrading designated two-lane highways to four lanes that will link rural and urban areas. The program, which was adopted in 1990 and updated in 2001, is part of the Unified Transportation Program (UTP) and encompasses a total of approximately 10,247 roadway miles, 4,075 miles of which are two-lane highways. The Texas Trunk System will essentially create corridors that promote the free flow of traffic and allow motorists to avoid highly congested metropolitan areas (Texas Trunk System, n.d.). Criteria for selecting which two-lane highways will be converted into corridors include:

- Traffic on existing roadways,
- Uncompleted gaps (stretches) of existing corridors,
- Congestion in metropolitan areas, and
- Mexico border access.

---

6 For example, if a large truck traffic generator locates in a rural county, the immediate impact will be point loadings to the facility. This will impact the pavement, which will have to be maintained using TxDOT rehabilitation or maintenance dollars.

Using the aforementioned criteria as a guide, TxDOT originally identified 11 projects that needed conversion from two- to four-lane divided highways. As part of completing these projects, 831 miles of rural highways will be upgraded as part of a Phase 1 plan to convert two-lane highways to four-lane divided highways. Phase 1 corridors are expected to be completed in 2013. It was estimated that Texas spends approximately $130 million per year upgrading roads on the trunk system (Texas Trunk System, n.d.). Funding for the Texas Trunk System program will come mostly from Category 4 (the Statewide Connectivity Corridor Projects) under the UTP, although funds from the Texas Mobility Fund can also be used for Texas Trunk System conversion projects (Kerr, n.d.).

Anticipated benefits of the system include safer roadways and a spur for economic activity. A Texas Transportation Institute study, however, pointed out that a myriad number of interrelated factors go into creating economic growth. While transportation is an integral component, it will not necessarily help bring business to an area.

5.4.3 Super 2 Highways

Texas' Farm-to-Market roads were built to provide access to rural areas of the state. With increased rural traffic, there has been a growing demand to increase the capacity of some of these roads. As mentioned in Chapter 2, a number of rural trucking companies were concerned about the width of rural roads and inadequate shoulders, especially with regards to county and farm-to-market roads. Super 2 Highways are seen as a possible solution to increase the capacity of many rural roads. Super 2 Highways are two-lane roadways with improved operating features, such as:

- added passing lanes in one or both directions of travel to facilitate easier passing.
- increased lane and shoulder width to give motorists more time to recover from driver error and thereby to reduce the number of roadway accidents.
- improved signing and marking to enhance the safety and efficiency of Super 2 Highways in Texas (Wooldridge et al., 2001).

For additional information on Super 2 Highways, the reader is referred to the TTI study by Wooldridge et al. entitled "Design Guidelines for Passing Lanes on Two-Lane Roadways (Super 2)".

5.4.4 Toll Roads in Rural Texas

Toll equity and regional mobility authorities—allowed for by Senate Bill 342 and the Constitutional Amendment—are voter-approved financial tools that have the objective to leverage limited state transportation funds. A possible solution for modernizing and rebuilding existing infrastructure in rural areas is thus to fund the projects through investments that can be recouped from tolls charged to users.

Toll roads are, however, most commonly found in urban areas where potentially high traffic volumes and thus revenues can ensure the financial feasibility of the road. But TxDOT is supporting a plan to build a tolled urban/rural highway in Tyler. According to the district engineer for TxDOT's Tyler district, Mary Owen, a toll road in a mid-sized city such as Tyler was met enthusiastically by the community: "The community took this idea and said it was a perfect corridor for consideration of a toll implementation because we designed it with controlled access, grade separation and no access points" (Texas Transportation Researcher, 2003). The first phase of the project will determine the feasibility of tolling Loop 49 by addressing the following areas: planning, conceptual design, and financing. In addition, project coordinators will also gather public perception data during the first phase of the project. The second phase of the project will combine the public perception data with public information and outreach strategies to develop and host educational programs (Texas Transportation Researcher, 2003).

Having said this, the merits of toll roads in rural areas are speculative at best, because of anticipated low traffic volumes. Another and possibly more appropriate option for rural areas might be using pass-through tolls to finance individual projects. In using pass-through tolls, a local government or private partner provides the funding for transportation improvements on a state highway. The entities are reimbursed later by the state through a fee based on the number of vehicles using the highway. In effect, the toll typically paid by the motorist is paid for or "passed through" to the state.

5.4.5 Restructuring the Rural Road Network

One aspect of interest is the justification for maintaining a large rural network when the communities are shrinking in terms of population and transportation demand. Given the inability of fuel revenues to meet current highway needs, should large rural networks be maintained? The financial short-fall, of course, is not unique to Texas—almost all U.S states are facing the same problem. It is interesting; therefore, to note that in North Dakota, the state DOT has developed a highway designation related to use that parallels the traditional state and farm to market terms known to all state planners. This new designation allows planners to "substantially reduce" investment in lower-tier highway segments if funding is not forthcoming for the entire system. In one sense, it formalizes what is being done at times in many TxDOT districts, namely that funds for one category of highway may be moved to another if the need is deemed sufficient. The subject is clearly a sensitive one, based on social as well as economic factors but nonetheless deserves scrutiny in the light of diminishing highway revenues.

5.4.6 Rural Rail Transportation Districts

Rural rail transportation districts (RRTDs) were formed in 1981 by the Texas Legislature to preserve abandoned Class I rail lines as a viable transportation option for rural Texas. RRTDs have several key objectives, including saving rail service for use by small farmers and providing them with an alternative to more expensive forms of transportation. At the same time, increased use of rural rail is often seen as a potential solution for diverting truck traffic away from the rural road network, thus preserving the system. The program, however, had variable results, working well in some instances but not in others (see Table 5.4). NETEX and Centex Rural Rail Districts are considered the most successful in terms of the RRTD program. Centex, for example, was servicing 65 shippers, and annual traffic levels exceeded 20,000 carloads in 2001 (Roop et al., 2001). Centex's success has been predicated on its commodity diversification.

Table 5.3 Status of Texas Rural Rail Transportation Districts (August 31, 2001)

Rural Rail Transportation District	Number of Counties	Formed	Primary Motivation	Current Board Status	Status of Line	Ownership	Outside Funding Sources
Burnet County	1	2000	Abandonment	Inactive	Operational	None	N/A
Calhoun County	1	1999	Economic Development	Inactive	N/A	None	N/A
Centex	5	Early 1990s	Abandonment	Active	Operational	Right-of-Way	Texas Department of Agriculture (to operator)
Deep East Texas	12	1993/94	Abandonment	Inactive	SP Line Abandoned	None	N/A
Ellis County	1	1998	Economic Development	Active	Progressing as Planned	Right-of-Way & Structures	Public-Private Partnership
Fannin	1	1999	Abandonment	Active	Impending Abandonment	None	N/A
Gulf Coast	2	1993/94	Abandonment	Inactive	Inactive line; Purchased by TM	None	N/A
Gulf Link	2	1998	Economic Development	Inactive	N/A	None	N/A
Matagorda County	1	2001	Economic Development	Active	N/A	None	N/A
North Central	2	1995	Abandonment	Inactive	Operational	None	N/A
North Texas	2	1995/96	Abandonment	Active	Abandoned	Purchased 7-mile segment	Texas Parks & Wildlife Department (for trails)
Northeast Texas	4	1994	Abandonment	Active	Operational	Right-of-Way & Structures	Texas Legislature & U.S. Department of Agriculture
Northwest Texas	7	1993	Abandonment	Inactive	Abandoned	None	N/A
Nueces County	1	2001	Economic Development	Active	N/A	None	N/A
South Orient	11	1991	Abandonment	Inactive	Operational	TxDOT	Texas Legislature
South Texas	3	Early 1990s	Abandonment	Inactive	Abandoned	Right-of-Way	N/A

(Source: Roop et al., 2001)

From Table 5.3, it is evident that if rural rail is to be operationally effective and offer rail services to rural entities it has significant hurdles to overcome in Texas. For one, transporting goods by truck are often less expensive and more efficient than rural rail. Also, financing for rural rail remains problematic because the only funding source that is available to RRTDs, other than receiving donations of cash and property, has been the districts' authority to issue revenue bonds. In essence, rail districts are expected to charge rents sufficient to maintain their properties and pay off their revenue bonds. To date, no RRTDs have issued any revenue bonds, although two RRTDs have been successful in securing specific legislative "riders" that granted them funds from state general revenue through TxDOT. Attracting clients is thus essential for the rural rail district to stay active

Having said this, the distribution and transportation demands of traditional rail clients, such as the agricultural industry, have changed significantly. Innovations in information technology now allow daily tracking of customer demand, which ultimately shapes farmers' production strategies (Branscomb, 1994). The new technological capabilities results in small, just-in-time deliveries. These types of deliveries make it difficult for rail to compete with trucks because rail is usually more competitive transporting bulk commodities over longer distances. At the same time, the nature of business has also changed. Large retailers now demand specific and consistent product characteristics, assured supplies, and timely delivery, which favor the trucking industry.

Similarly, identity preservation typically works against transporting goods by rail. Identify preservation, which can take on many forms, usually carries with it the need for smaller shipment sizes, careful handling to prevent damage to fragile cargo, and reduced transit times, all of which tend to favor trucking.

On the other side, the Texas and Mexican economies are becoming more inextricably linked. Mexico remains an important market for Texas-produced commodities, and the efficient transportation of agricultural products to Mexico is critical for Texas farmers to ensure competitiveness in the market. The South Orient and Centex RRTDS have been successful in transporting agricultural exports to Mexico. This may be an area where rural rail can fulfill a growing need, especially if the border crossings become more congested for trucks.

5.4.7 Private Road Associations

In Sweden, private road associations (PRAs) manage two-thirds of the Swedish road network at less than half of the cost of maintaining government-provided roads. The system has proved remarkably effective because the users of the roads are responsible for the financial and physical consequences of any delayed intervention in treating emerging problems. The members of the PRA (property owners along the road) own individual shares in the road. The individual shares are a proxy for the maintenance and other road costs they have to incur, which is based on the size of their property and the traffic they generate. Financial responsibility for the construction, upgrading, operation, and maintenance of private roads thus rests with the PRA members.

The Swedish government subsidizes private roads that are, among other considerations, open to the public. The PRA sizes vary quite dramatically. Most PRAs own or manage a few kilometers, but some have 70 kilometers of road and include up to 3,500 properties (Ivarsson and Calvo, 2003).

For numerous reasons, the Swedish government supports this program:

- encourage living and settling in remote and sparsely populated areas,
- promote trade and industrial development in areas where the cost of providing roads might be high,
- provide access to areas of public recreation and leisure,
- secure the public capital investment in roads, and
- ensure general traffic safety and environmental interests (Ivarsson and Calvo, 2003).

Although most of the private roads are low-volume roads, RMAs provide an example of how public funding can be supplemented to fund unmet maintenance needs. Private roads support the notion that those directly benefiting from and consuming rural pavements (i.e., large truck-traffic generators) can be asked to contribute to the strengthening, rehabilitation, and maintenance of rural roads.

5.4.8 Outsourcing

Outsourcing aims to use resources more efficiently and capture economies of scale. In the National Cooperative Highway Research Program's (NCHRP) *Synthesis 313* (2003) it was reported that many state DOTs have started to outsource traditionally undertaken activities (i.e., administration, construction, design, maintenance, operations, planning, and right-of-way) in an effort to improve efficiency and reduce costs.

Two important aspects of outsourcing are the selection of the provider and determining the effectiveness of outsourcing. Different DOTs measure effectiveness differently. Some of the measures include:

- cost-effectiveness—the cost of outsourced services relative to in-house services, calculated using the "current cost" or lifecycle cost approach;
- schedule constraints—resulting from staffing shortages;
- product delivery—because the state agency is not in a position to perform the task;
- legal requirement—in South Carolina, for example, legislation mandated increased privatization of maintenance operations; and
- legislative or executive intent—for example, in Florida DOT the governor required a reduction of 25 percent in staff over a three-year period, necessitating the outsourcing of some activities (NCHRP, 2003).

Overall satisfaction with outsourcing was reported to vary, although satisfaction with administration, maintenance, and operations ranked higher than that with the other activities (i.e., construction, design, planning, and right-of-way). TxDOT already uses contractors to undertake some of the maintenance, rehabilitation, and reconstruction projects. The agency could consider outsourcing all maintenance, for example, in an effort to achieve economies of scale and reduce costs. On the other hand, TxDOT is a significant employer in many of the rural areas, so that a move to 100 percent outsourcing could have substantial social and economic impacts on communities that are already struggling to keep and attract new jobs.

5.5 Concluding Remarks

Despite evidence of increased average annual daily truck-traffic volumes in rural Texas, the 2003 PMIS data revealed that the condition of the rural infrastructure was rated well. Statewide, approximately 85 percent of the rural road network is rated good to very good in terms of the distress score, 88 percent is rated good to very good in terms of the overall condition score, and about 70 percent is rated good to very good in terms of the ride score. But looming behind the ratings are concerns about maintaining and upgrading rural infrastructure in the wake of increased truck traffic on roads that were never designed for the current volumes or loads. In addition, many trucks are carrying heavier-than-permissible loads that damage these structures further.

TxDOT districts also indicated that priority is often given to high volume projects when prioritizing maintenance and rehabilitation needs. With urban and rural areas competing for the funding allocated to TxDOT districts, districts find it increasingly challenging to balance urban and rural needs. Prioritizing is thus likely to become even more important in the future because of the gap between available funding and rural needs. Techniques to prioritize projects, such as using the multi-attribute criteria methodology framework proposed in this Chapter is a possible alternative to current prioritization methods. But even improved prioritization methods do not alleviate the root problem—the lack of funding to maintain and rehabilitate the state's extensive rural road system.

This and the earlier chapters have demonstrated the dynamic quality of managing the rural highway network in Texas. In an effort to avoid an inventory approach to the subject, a series of subject areas considered issues ranging from pavement engineering to statewide planning. To close the work, several key operational issues are noted and four major recommendations offered. These are described in the next, and concluding, chapter.

6. Conclusions and Recommendations

Texas' rural road network was largely established in the period 1930–1950 as a result of improvements to existing unpaved roads linking rural settlements, much of it in the form of moving from unpaved to all-weather designs. This resulted in the creation of a large rural network linked by arterials acting as intercity connectors between the larger Texas cities. For example, US 281 was the major route between Dallas and San Antonio on this network at this time. In the late 1950s the Texas Highway Department, under the leadership of Dewitt C. Greer, positioned itself to take advantage of funding related to a federal program that later became the Interstate Highway (IH) Program. This program was unusual in that it linked all U.S. cities with populations exceeding 50,000, irrespective of demand. Neither Texas' rural road network nor the IH system was thus designed to meet the existing needs of commercial vehicles and the overall demand for highway use. At that time trucks were limited to 58,200 lbs gross vehicle weight, although the interstate design was at a much higher pavement level, together with bridges capable of carrying heavy military equipment such as tanks. Since the 1980s the system of rural, interstate, and city roads has been supplemented by tolled highways which offer alternative routes to metropolitan users facing heavy congestion and who can afford the fees.

6.1 Changing Rural Truck Patterns

Over the past two decades, the changing transportation demands of agriculture and rural industry, and the strategic rail decisions that resulted in the abandonment of many rural rail links, have had severe impacts on rural road infrastructure. Many TxDOT districts have seen an increase in the volume of truck traffic on rural infrastructure as a result of agricultural industrialization, resulting in fewer but larger farms and the trend toward moving products between specialized operations, increases in the physical sizes of agricultural equipment, the economic revival of the oil industry, House Bill 2060 that allows 84,000-lb vehicles (gross vehicle weight) to traverse roads posted for 58,240 lb (gross vehicle weight), the location of large distribution centers of retail chains in rural counties, the location of landfill sites in western and northern Texas, dramatic increases in truck traffic resulting from the North American Free Trade Agreement (NAFTA), and the abandonment of approximately 2,400 miles or rail track in Texas following the Staggers Act. Many TxDOT districts have thus seen an increase in the truck numbers and axle loads on their network and have found disequilibrium between rural demand and highway supply, often necessitating increased maintenance. But with the state changing from its traditional agribusiness economy to more of a service-oriented economy, concern has thus been expressed that rural interests are often overlooked to satisfy the demands of the urban areas.

6.2 Corridors

TxDOT rural districts spend substantial amounts of their maintenance budgets maintaining state and regional corridors—generally interstates—that cross their domains. However, many of corridor users are not stimulating economic demand in the rural areas through which they are traveling. This creates a paradox in terms of state economic development and fiscal responsibility. First, corridors are clearly important to maintain economic activity and the vitality of key sectors in the state. In addition, they allow goods to move across the nation, for example from coast (e.g., Southern California) to population centers (e.g., New York City). This therefore has federal and national significance. Because corridors play such a key role in the national economy, it is likely that at some point in the future their finance, funding, and maintenance may well receive special federal attention. Such attention could take many forms, but it could be that the maintenance and rehabilitation of such corridors will be carried move by federal funds than from state gas tax returns, disaggregate into district programs.

6.3 Districts Doing a Great Job Maintaining Rural System

Despite evidence of increased average annual daily truck-traffic volumes in rural Texas, the 2003 PMIS data revealed that the condition of the rural infrastructure was rated well. Statewide, approximately 85 percent of the rural road network is rated good to very good in terms of the distress score, 88 percent is rated good to very good in terms of the overall condition score, and about 70 percent is rated good to very good in terms of the ride score. In general it was found that TxDOT district staff is maintaining the state's rural roadbed section-miles very well, although certain districts are more impacted by larger and heavier trucks traversing their roadways. Specifically, there is concern about the condition of the farm-to-market roads in a number of districts.

6.4 Highway Needs

But looming behind the ratings are concerns about maintaining and upgrading rural infrastructure in the wake of increased truck traffic on roads that were never designed for the current volumes or loads. As users of rural infrastructure on a daily basis, rural truckers expressed a number of transportation concerns in rural communities. These point to concerns about the width of rural roads, inadequate shoulders, a need for better maintenance and rehabilitation—especially with regards to county and farm-to-market roads—and concerns about the impact of increased truck traffic on rural roads and towns.

TxDOT districts indicated that priority is often given to high volume projects when prioritizing maintenance and rehabilitation needs. With urban and rural areas competing for the funding allocated to TxDOT districts, districts find it increasingly challenging to balance urban and rural needs. Incidentally, the metropolitan centers account for much of the TxDOT budget and are the predicted growth centers for Texas' increasing population up to 2020. In the coming years, much of the current rural highway system will need to be either rehabilitated or posted at lower truck weights. Prioritizing is thus likely to become even more important in the future because of the gap between available funding and rural needs.

6.5 New Initiatives Are Challenging

As it is foreseen that TxDOT districts will find it increasingly challenging to maintain and repair the rural road system, improved methodologies to determine the pavement impacts, techniques to prioritize projects are necessary to address rural maintenance and rehabilitation concerns. But even improved techniques to calculate pavement impacts and prioritization methods do not alleviate the root problem—the lack of funding to maintain and rehabilitate the state's extensive rural road system.

The state gas tax has not been raised since 1993 and the 2005 legislative session failed to remedy this situation. As TxDOT activities—i.e., maintenance, rehabilitation, and construction—are in current dollars less can be done from traditional state and federal gas revenues. This means that innovative measures to preserve the rural highway system need to be adopted. Future initiatives can take the form of more toll road choices, but to a large extent toll solutions are the purview of metropolitan, not rural communities. There has been some discussion on privatization efforts, particularly with respect to maintenance and this has caused concern amongst those responsible for rural economic development. The TxDOT district system carries with it many advantages as far as rural communities are concerned ranging from professional employment opportunities through to distinct knowledge of the local highway needs which give rise to dynamic and efficient decision-making, particularly related to emergency maintenance. Moreover, privatizing rural maintenance without raising current revenue levels is not a reasonable solution to the problem. The initiative that has to be addressed is not who should do the work but how it should be financed. In this regard Private Road Associations provide an example of how public funding can be supplemented to fund unmet maintenance needs. Private roads support the notion that those directly benefiting from and consuming rural pavements (i.e., large truck-traffic generators) can be asked to contribute to the strengthening, rehabilitation, and maintenance of rural roads. While the authors do not recommend implementing such programs, it is believed that they should be considered. In addition, there are the newly formed Regional Mobility Authorities and opportunities for consortia to offer services through a Comprehensive Development Agreement. At this time both of these mechanisms, however, favor urban investments and it might be some time before they provide services on the rural system.

6.6 Recommendations

The Texas highway system, as currently structured and financed, is too large and its needs too great when evaluated over a 20 year planning cycle. The problems noted in this report on current highway funding and financing suggest that the 2005 network cannot be fully funded in the period to 2025 from traditional sources, unless fuel taxes are raised. What can be done about this problem? Given that there is little political interest to raise gasoline taxation further (at least at the moment) and given inadequate state budgets in the near future the following are a list of recommendations for TxDOT to consider:

- Should TxDOT restructure its rural network? The rural network should be carefully evaluated and, and perhaps formally, reclassified to target the maintenance and rehabilitation funding of the system. Some states, for example North Dakota, have begun to reclassify their systems using a hierarchy which allows them to direct the funding only into higher need categories where funds are scarce. In one sense, this way of approaching a problem which could be done in a more direct way by simply removing certain highways from the state system. One of the critical aspects that require dedicated maintenance and rehabilitation activities are the major highway corridors passing through the rural regions carrying much of the regional trade. Secondly, the links to the specific rural generators associated with employment and wealth generation need similar support.
- Much greater information needs to be collected on the demand for (use of) rural highways, and the study finds that this should be done through a panel system which would collect data from users and discuss possible changes in policies with them. This

type of demand analysis will generate different types of data that will sharpen state planning, particularly where additional funding is concerned.

- Designate key state supply chains. This study recognizes that users develop their highway routes based on the needs of their shippers and the commodities that are being moved. The designation of supply chains for key commodities should therefore assist statewide planning and the targeting of funding on those sections of highways passing through rural areas. Moreover, it will link into those generators within different parts of the state and ensure that the supply chains are not simply portions of the interstate but cover the movement of goods from origin to destination within a district network.

- Rural freight corridors would benefit from ITS to raise service (weather, accidents, incidents). Almost all medium to large trucking companies now have information technologies (IT) which allow the tracking of tractors and therefore more precise determination of fleet utilization and commercial opportunities for new business. The vehicles are capable of providing valuable information for highway management, and this is something that deserves further examination. As an example, the federal government has been evaluating the use of QualComm devices which are able to provide time/location information which can be translated to speed over the corridors. In addition, they are capable of transmitting other changes in the environment such as bad weather. This offers the potential for transmitting useful information over the rural systems of ITS information which will strengthen safety and efficiency for other truck users. Instead of expensive hardware and infrastructure collecting IT information the hardware would simply relay information to drivers using data and information supplied by other truckers. If this can be shared with dispatchers, there is a possibility of significantly improving not only the management of the rural system but the operations systems.

References

AASHTO. 1993. *Guide for Design of Pavement Structures.* Washington, D.C.: American Association of State Highway and Transportation Official

Branscomb, A. W. 1994. "Who Owns Information?" From Privacy to Public Access. Basic Books. A Subsidiary of Perseus Books, L.L.C.

Brian, P. 2001. "Texas Highways Primer." Available at: http://home.att.net/~texhwyman/tex.htm (accessed on June 24, 2003).

Chen, J. S., and K. Y. Lin. 2002. "Evaluation of an Accelerated Pavement Testing Facility and Development of its Load Equivalence Factors." *American Society for Testing and Materials Journal of Testing and Evaluation* 30:103–109,

Croney, D., and P. Croney. 1997. *Design and Performance of Road Pavements.* Third Edition, McGraw-Hill Book Co., London.

Federal Highway Administration. 2001. "Traffic Monitoring Guide." Office of Highway Policy Information, FHWA-PL-01-021, May 1. Available at http://www.fhwa.dot.gov/ohim/tmguide/

Fuller, S., T-H. Yu, D. Collier, J. Jamieson, and R. Harrison. 2001. "Texas Grain Transportation Study." Report to the 77th Texas Legislature, Center for Transportation Research, University of Texas at Austin.

Groenendijk, J., et al. 1997. "Rutting Development in Linear Tracking Test Pavements to Evaluate Shell Sub-Grade Strain Criterion." TRR No. 1570: Pavement Design, Management and Performance, 23–29.

Holtz, R. D., and W. D. Kovacs. 1981. *An Introduction to Geotechnical Engineering.* Prentice-Hall, Inc., Englewood Cliffs, N.J.

Huang, Y. H. 1993. "Pavement Analysis and Design." Prentice Hall. Englewood Cliffs, N.J.

Ivarsson, S., and C. M. Calvo. 2003. "Private-Public Partnership for Low-Volume Roads: Swedish Private Road Associations." *Transportation Research Record, Journal of the Transportation Research Board* 1:1819.

Jarrett, J., et al. 2000. "Economic Effects of Highway Relief Routes on Small and Medium-Size Communities: Literature Review and Identification of Issues." Center for Transportation Research. Bureau of Engineering Research. The University of Texas at Austin. Research Report 1843-1, April.

Laredo Development Foundation. 2005. *Inland Port of the America's—2004 Commerce up $11 Billio*n. Laredo 2020, Volume 6, Number 1, Spring.

Luskin, D. M., and C. M. Walton. 2001. "Effects of Truck Size and Weights on Highway Infrastructure and Operations: A Synthesis Report." TxDOT, CTR, Report FHWA/TX-0-2122-1.

McCray, J.P. 1998. "North American Free Trade Agreement Truck Highway Corridors: U.S.-Mexican Truck Rivers of Trade." *Transportation Research Record, Journal of the Transportation Research Board* 1:1613

Middleton, D., and J. A. Crawford. 2001. "Evaluation of TxDOT's Traffic Data Collection and Load Forecasting Process." FHWA/TX-01/1801-1. College Station, Texas: Texas Transportation Institute, the Texas A&M University System.

Murdock, S. 2005. "The Texas Challenge of the Twenty-First Century: Implications of Population Change for the Future of Texas." The Institute for Demographic and Socioeconomic Research, College of Business, University of Texas at San Antonio.

National Cooperative Highway Research Program. 2002. "2002 GUIDE: Using Mechanistic Principles to Improve Pavement Design." NCHRP Project 1-37A. Available at http://www.2002designguide.com/

National Cooperative Highway Research Program. 2003. "State DOT Outsourcing and Private-Sector Utilization: A Synthesis of Highway Practice." *Synthesis 313,* Transportation Research Board of the National Academies, Washington DC.

Prater, M. E. 2001. "The Implications for U.S. Agriculture of Long-Term Trends in Railroad Service." *Journal of the Transportation Research Forum* 55: 121–132.

Prozzi, J., and K. Lo. 2003. "What Is Moving in Rural Texas?" Center for Transportation Research. The University of Texas at Austin. Research Report 4169-P3, October.

Prozzi, J. A., and M. de Beer. 1997. "Mechanistic Determination of Equivalent Damage Factors," Proceedings, Eighth International Conference on Structural Design of Asphalt Pavements, University of Washington, Seattle.

Roop, S. S., et al. 2001. "Texas Rural Rail Transportation Districts: Characteristics and Case Studies." FHWA/TX-02-4007-1. College Station: Texas Transportation Institute, the Texas A&M University System.

Senate Research Center. n.d. "Federal Highway Funding Formulas and the Reauthorization of ISTEA: What's at Stake for Texas." *In Brief,* Austin, Texas. Available at: http://www.senate.state.tx.us/SRC/pdf/trans.pdf

Texas Center for Border Economic and Enterprise Development data accessed at http://texascenter.tamiu.edu/texas_services/border_crossing.asp. 2005.

Texas Transportation Researcher. 2003. *"Exploring Toll Road Options in Texas."* Texas Transportation Institute, Member of the Texas A&M University System, Vol. 39, No. 4. Available at http://tti.tamu.edu/researcher/v39n4/39_4.pdf

Texas Trunk System. *Port-to-Plains Trade Corridor.* Available: http://www.ports-to-plains.com/state_rep/roacan/txtsys/txtsys.htm

Turnbull, K. F., G. B. Dresser, and L. L. Higgins. 1999. "The Rural Transportation Network in Texas" FHWA/TX-99/1437-1. College Station: Texas Transportation Institute, the Texas A&M University System.

Wooldridge, M.D., C.J. Messer, B.D. Heard, S. Raghupathy, A.H. Parham, M.A. Brewer, and S. Lee. 2001. "Design Guidelines for Passing Lanes on Two-Lane Roadways (Super 2)." College Station: Texas Transportation Institute, the Texas A&M University System.