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16. Abstract

Average Daily Truck Traffic (ADTT) increased dramatically in Texas in the 1990s partly because of the implementation of the North American Free Trade Agreement (NAFTA). Accurate information on truck volumes and truck characteristics is critical to transportation planning and infrastructure investments conducted by the Texas Department of Transportation (TxDOT) and other public agencies responsible for the road system in the State of Texas. This report covers the second year activities of TxDOT Research Project 0-5339. The objectives in the second year were to (a) collect data from a statistical sample of Mexican carriers – those that have applied to operate beyond the current commercial zones once the border opens – on the size of the Mexican companies, the types of operations, and equipment currently used and anticipated to be used for cross-border movements, and (b) to collect and analyze weigh-in-motion data from Texas and Mexico in order to establish their main characteristics as they affect pavement performance.

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). 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 FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

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CHAPTER 1:
BACKGROUND AND SIGNIFICANCE OF WORK

A major objective of the North American Free Trade Agreement (NAFTA) signed on January 1, 1994, as elaborated more specifically through its principles and rules[1] was to eliminate barriers to trade and facilitate the cross-border movement of goods and services between the territories of the parties [1]. As such, the original trucking provisions were designed to improve transportation efficiency by enabling more seamless cross-border trucking movements. The Agreement stipulated that restrictions on the movement of Mexican trucks beyond a narrow commercial zone extending 3 to 20 miles into the United States were to be phased out between 1995 and 2000. Enactment of this timetable was postponed by the U.S. Congress in 1995. The United States alleged that the inability of Mexico's regulatory regime to adequately ensure the safety of its commercial drivers and carriers would pose a safety risk to the U.S. public. Consequently, the moratorium on long-haul trucking crossing the U.S.-Mexico border was upheld.

This situation has persisted for the past decade due to ongoing litigation and disputes regarding Mexican truck safety, emissions, and inspections. Driver-related concerns included inadequate training for the safe operation of Mexican trucks on U.S. roads, the undercutting of U.S. driver wages, long operating hours, inadequate levels of English proficiency, and the inability to maintain adequate records, such as logbooks. Equipment-related concerns included inadequate truck maintenance, the impact of overloaded trucks on U.S. roads, and the higher average age of Mexican trucks and associated emissions impacts [2].

Most of the concerns about safety were founded in two studies that reported poor performance of Mexican trucks inspected at the border. For example, in 1997, of 17,000 trucks inspected, 44 percent failed inspection, and in 2001, 36 percent of trucks failed the inspection. However, the trucks surveyed were not representative of those that would be traveling on U.S. roads once the border opens to long-haul trucking. Currently, freight moved by truck between the United States and Mexico requires three trucks:

- a long-haul service that transports the cargo from Mexico/United States to a place near the border,
- a short-haul drayage truck that moves the goods across the U.S.-Mexico border, and

- a third truck that delivers the cargo to its final destination beyond the U.S.-Mexico border commercial zone.

Since cross-border movements typically involve idling for long periods in border queues and traveling distances of fewer than 40 miles round trip, there is no incentive for Mexican carriers to dedicate expensive new equipment to drayage activities [3]. Both prior studies reported out of service rates for drayage vehicles. The findings of these studies can thus not be extrapolated to the safety of vehicles that will be used for long-haul movements from Mexico into the United States.

Furthermore, most of the concerns that prevented the implementation of the trucking provisions established in NAFTA have been addressed. Many Mexican motor carriers have thus begun to prepare for cross-border operations. According to the Federal Motor Carrier Safety Administration (FMCSA), over 700 Mexico-domiciled motor carriers have applied for authority to operate beyond the U.S. commercial zone once the border opens [4].

Since most of the environmental and safety issues have been addressed, the U.S. Department of Transportation (USDOT) proposed a truck pilot program as a first step in the opening of the border. The pilot program was envisioned as a limited, year-long demonstration program that would give 100 Mexican and 100 U.S. trucks permission to operate beyond the commercial zones into the interior of Mexico and the United States. On February 23, 2007, the USDOT Secretary announced the truck pilot program, which was to start in June 2007. Secretary Peters argued that once the environmental and safety issues have been addressed, it will be time to move forward on the longstanding promise to Mexico by implementing the trucking provision of the NAFTA. She further argued that the current way of operating the border wastes precious time, energy, and money [5]. However, on May 15, 2007, the House of Representatives passed the Safe American Roads Act of 2007. This act limits the authority of the Secretary of Transportation to grant access to Mexican motor carriers to operate beyond the current commercial zones. On September 9, 2007, Transportes Olympic became the first long-haul Mexican trucking company to operate beyond the commercial zone into the United States as part of the USDOT pilot program [6]. However, on September 12, 2007, the Senate voted overwhelmingly to prevent the use of Federal funds for the one-year pilot program [7]. The consequences of this vote for the pilot program were unclear at the time of writing this report.

[1] Including national treatment, most-favored nation treatment, and transparency.

It is, however, believed that the border will open sometime in the future. When this happens, accurate information on truck volumes and truck characteristics will be critical to proactive transportation planning and infrastructure investment decisions performed by TxDOT and other agencies responsible for the roadway system in Texas. This report covers the second year activities of TxDOT Research Project 0-5339. The objectives in the second year were to (a) collect data on the size of the Mexican companies, the types of operations, and equipment currently used and anticipated to be used for cross-border movements from a statistical sample of Mexican carriers that have applied to operate beyond the current commercial zones once the border opens, and (b) collect and analyze WIM data from Texas and Mexico in order to establish their main characteristics as they affect pavement performance.

This report addresses these objectives as follows. Chapter 2 provides the original plan and the events that transpired in implementing the NAFTA trucking provisions. Chapter 3 presents the survey approach, response rates, and major findings from the telephone survey that was administered to a sample of Mexican truck companies between June 12 and July 25 of 2007. Chapter 4 introduces the methodology that was used to estimate pavement damage associated with given axle load spectra, and Chapter 5 summarizes and analyzes the sample data obtained from Texas and Mexico and establishes some basic comparisons. Finally, Chapter 6 highlights some of the report's main findings and conclusions.

CHAPTER 2:
NAFTA TRUCKING PROVISIONS

ORIGINAL PLAN

Over 5 million trucks crossed from Mexico into the United States in 2006. This represents 17 percent growth from 2001, and the number of crossings is expected to continue growing as trade between the two NAFTA partners continues to grow. NAFTA's original trucking provisions regarding opening the U.S. border to Mexican trucks were designed to improve transportation efficiency by enabling more seamless cross-border trucking operations.

NAFTA's agreement stated that U.S. and Mexican trucks would be allowed to travel within the border states beginning December 1995 (Texas, New Mexico, Arizona, and California in the United States and Tamaulipas, Nuevo León, Coahuila, Chihuahua, Sonora, and Baja California in Mexico). By 2000, reciprocal nationwide trucking access was to be authorized. The implementation of these provisions has been postponed on multiple occasions and for a variety of reasons.

RELATION OF EVENTS

In 1995, the U.S. Congress upheld the moratorium on direct long-haul trucking from Mexico to the United States, arguing that Mexico's truck safety regulations could not adequately ensure the safety of its commercial drivers and carriers. Less stringent safety regulations and enforcement practices in Mexico were deemed a potential safety risk to the U.S. public. Citizens for Reliable and Safe Highways (CRASH) representatives cited other problems with Mexican trucks. They pointed out that the average age of a U.S. truck is 4.5 years old, while Mexican trucks averaged 15 years. In addition, Mexican trucks often are driven on much poorer roads [8].

Continuation of the moratorium in subsequent years led the Mexican government to request that a NAFTA arbitration panel rule on the matter. On September 22, 1998, Mexico requested a required arbitration panel from the North American Free Trade Commission, attempting to compel the United States to open the border for Mexican trucks. Mexican officials called this refusal a continuing violation of NAFTA, contending that "no safety issue is related to the U.S. obligation to allow entry of trucks into the United States" [8].

In 2001, the arbitration panel concluded that Mexico's less rigorous truck safety inspection system was inadequate justification for the United States' blanket refusal to allow Mexican carriers to operate beyond the U.S. commercial zone. However, it also declared that a more comprehensive application process for Mexican carriers applying to operate in the United States was acceptable in light of disparate U.S. and Mexican truck laws, regulations, and procedures.

In the fall of 2001, a newly elected U.S. administration vowed to comply with the panel's findings. The Transportation Appropriation Act included 22 safety requirements which, among others, required the law for:

- stricter application procedures,
- stricter inspection requirements, including inspection by U.S. safety personnel of Mexican trucking firms in Mexico,
- stricter enforcement requirements,
- stricter maintenance requirements,
- stricter weight compliance verification measures, and
- more comprehensive cooperation between U.S. and Mexican law enforcement agencies [10].

President Bush subsequently announced he intended to lift the moratorium and the Federal Motor Carrier Safety Administration (FMCSA) published proposed rules that both created an application form for Mexican trucks seeking to operate in the larger United States and established a related safety inspection system. Congress then demanded that the Department of Transportation not spend any of its appropriations to permit Mexican trucks to operate beyond border zones until FMCSA implemented certain application and safety monitoring requirements, some of which were more extensive than the FMCSA's proposed rules.

FMCSA revised its regulations but opted not to conduct a comprehensive environmental impact statement (EIS). Instead, it declared there would be no significant environmental impact warranting an EIS. FMCSA prepared a less comprehensive environmental assessment for the application and one of the safety monitoring rules, excluding its rule for certifying safety inspectors altogether from environmental review. FMCSA also failed to determine whether any of the proposed regulations complied with the Clean Air Act (CAA) because, it maintained, the proposed rules fell within certain categorical exemptions from the requirement of determining conformity with the Clean Air Act.

A number of public interest groups including Public Citizen and the Natural Resources Defense Council petitioned the Ninth Circuit, challenging the validity of FMCSA's proposed rules. The appeals court held that FMCSA violated both the National Environmental Policy Act of 1969 (NEPA) and the CAA by failing to consider the increase in traffic and pollution that would result. The Ninth Circuit reasoned FMCSA was required to consider the significant increase in traffic and emissions, which was the reasonable foreseeable indirect effect of FMCSA's rules, and which therefore triggered both NEPA's requirement for a full EIS and CAA's requirement for a conformity determination. The Supreme Court disagreed, holding that FMCSA's rulemaking should not be considered a proximate cause of either the moratorium's end or the resulting emissions increase [11].

In February 2007, the United States and Mexico announced a one-year pilot program that would allow approximately 100 Mexican trucking companies to operate beyond the 20-25 mile commercial zones, provided they adhere to stringent safety requirements. The demonstration project also calls for approximately 100 U.S. trucking companies to travel to and from destinations in Mexico. The agreement does not allow Mexican trucks to carry shipments between U.S. cities, only international shipments to and from destinations in the United States. The pilot program will not include hazardous materials shipments or the transport of passengers, such as in a bus. In the announcement of the pilot program, U.S. Secretary of Transportation Mary Peters indicated that U.S. inspectors will conduct in-person safety audits of Mexican carriers to ensure compliance with U.S. safety regulations. Secretary Peters noted that the regulations "require all Mexican truck drivers to hold a valid commercial driver's license, carry proof they are medically fit, comply with all U.S. hours-of-service rules, and be able to understand questions and directions in English" [12]. The Mexican truck companies are also required to have insurance with a U.S. licensed firm. The official pilot program initiation announcement was posted to the *Federal Register* on May 1, 2007, by the FMCSA.

In August of 2007, the USDOT and the FMCSA announced their intent to proceed with a pilot program that would allow up to 100 Mexican carriers to operate in the U.S. beyond the commercial zone for one year. A report will be created after one year to evaluate the progress of the pilot.

Figure 1 presents a timeline diagram with the most important events of the U.S.-Mexico trucking provisions and the original plan.

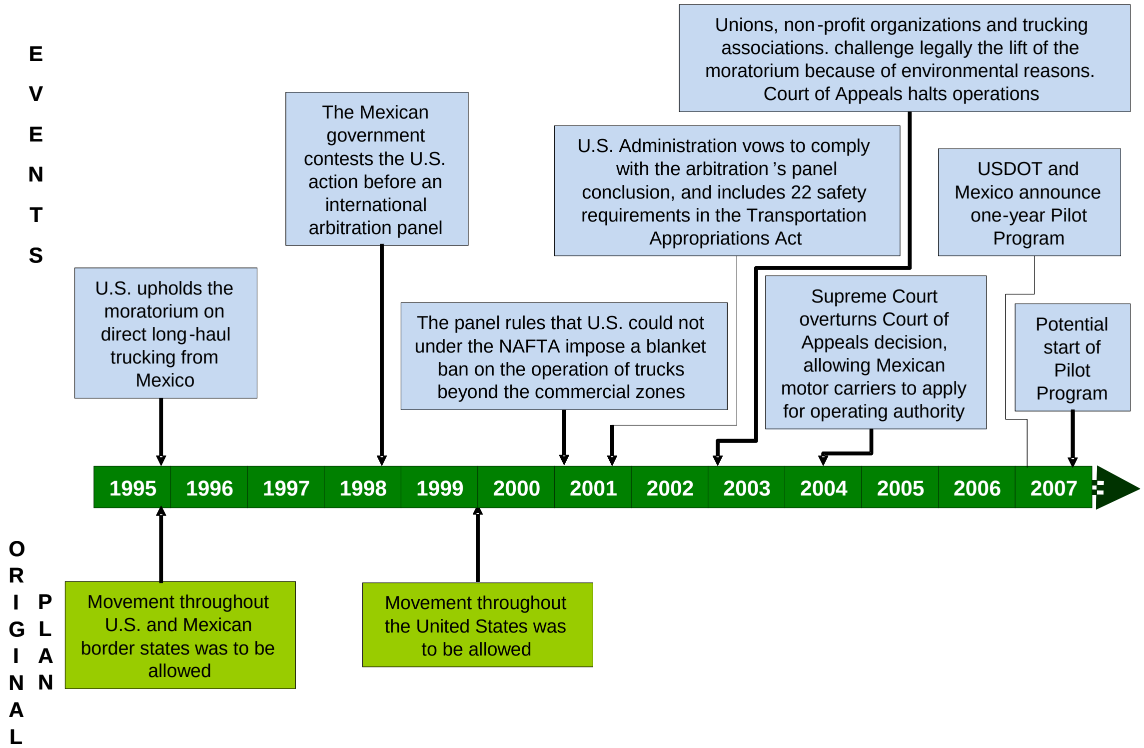


Figure 1. NAFTA Truck Provisions Outline.

CONCLUDING REMARKS

Even though the development of the pilot or demonstration program is still uncertain, international trends to increase trade facilitation practices and cooperation between U.S. and Mexican customs agencies will provide additional incentives for motor carriers to participate in the demonstration program. A coordinated effort between transportation agencies and other stakeholders involved in the border crossing process will eventually streamline the process, making it more efficient and allowing long-haul Mexican carriers to cross beyond the commercial zone. This will be a gradual process that requires motor carriers not only to acquire equipment that meets U.S. standards but also to establish the marketing networks required to operate in a cost-effective manner in both countries.

CHAPTER 3: MEXICAN CARRIER CHARACTERISTICS

The Center for Transportation Research (CTR) research team conducted a telephone survey[2] to collect data on the characteristics of the Mexican companies (i.e., size, types of operations, and equipment currently used and anticipated to be used for cross-border movements) from a statistical sample of Mexican carriers that have applied to operate beyond the current commercial zones once the border opens. The data collected can be used to inform the analysis of the potential infrastructure impacts of Mexican trucks on Texas's road system once the border opens to facilitate future planning. This section of the report documents the survey approach and major findings.

TARGET POPULATION AND SAMPLING UNITS

The target population was Mexican truck companies that have applied for the OP-1 permit from the FMCSA to operate beyond the commercial zone once the border opened. The sampling units were selected from two existing lists. The first list of sampling units was compiled from Mexican carrier information on FMCSA's website (see http://li-public.fmcsa.dot.gov/LIVIEW/pkg_html.prc_limain) [13]. Under the menu option "Mexican Application Status Selection" a company name search that included the text "*SA DE CV" was conducted. The search produced relevant contact details for companies that applied for both OP-1 and OP-2 permits. The research team extracted only the contact details for the 55 Mexican truck companies that have applied for the OP-1 permit. From these 55 companies, only 11 had contact details in Mexican states adjacent to the Texas border. These companies thus have the highest probability of crossing the Texas-Mexico border. The research team sampled 25 companies from the list of 55 companies: the 11 companies that had contact details in the Mexican states neighboring Texas and 14 additional companies that were randomly selected with contact details in states that are not bordering Texas.

[2] In addition to this survey, the CTR research team conducted in-person and telephone surveys with TxDOT employees to identify the NAFTA truck related data and information required by TxDOT for transportation planning and infrastructure management. This was a follow up survey to the survey that was conducted during the first year of this research project. The Appendix summarizes the major findings of this second round of interviews.

In addition to the contact details of Mexican companies that have applied for the OP-1 permit that were obtained from the FMCSA website, a second list of Mexican carriers that have applied for the OP-1 and OP-2 permits was obtained from the Freedom of Information Act (FOIA) office by the Center for Transportation Research in 2002 [2]. The FOIA list provided the contact information for 135 companies that had applied for the OP-1 permit by 2002. From this list, 41 companies were sampled: 30 Mexican carriers that had contact details in a Mexican state neighboring Texas and an additional 11 that were randomly selected with contact details in Mexican states not bordering Texas.

SURVEY METHODOLOGY

Researchers conducted telephone surveys with the Mexican truck companies. Typically, this survey method is more expensive than mail-out surveys in terms of resources required, but it proved to be the most effective method in obtaining the relevant information from the Mexican truck companies. All the telephone surveys were conducted during the daytime hours (8:00 a.m. to 5:00 p.m.) Monday through Friday between June 12 and July 25, 2007.

SURVEY FORMS

Figures 2, 3, and 4 provide the survey instruments (i.e., English and Spanish) and the Mexican truck classification used during the telephone surveys. The survey questions were grouped into four categories:

- business information,
- type of operation,
- equipment, and
- comments.

QUESTIONNAIRE

1. Will your company operate into the United States once the US-Mexican border opens?
2. Will your trucks cross one of the ports-of-entry on the Texas-Mexico border?

BUSINESS INFORMATION

3. Where is your headquarters?
4. How many trucks (e.g., tractors and trailers specified separately) do you operate?
5. How many drivers do you employ?

TYPE OF OPERATION

6. How many truck trips across the border are you expecting to make per week?
7. What commodities do you normally transport?
8. What commodities will you transport into the United States?
9. What are the major U.S. destinations for the commodities that you will be transporting to the U.S.?
10. Do you expect to secure a return load with a U.S. origin on your return to Mexico?

EQUIPMENT

11. What is the average age of your vehicle fleet (e.g., tractors and trailers specified separately)?
12. Will you use vehicles from your existing fleet to operate into the United States?
    a. If no, what will be the average age of the vehicles that you will use to operate into the United States (e.g., tractors and trailers specified separately)?
13. What type of vehicles do you currently operate (C2, C3, T2-S1, T2-S2, T3-S2, T3-S3, T2-S1-R2, T3-S1-R2, T3-S2-R2, T3-S2-R3, T3-S3-S2, T3-S2-R4, C2-R2, C2-R3, C3-R2, CR-R3, others)?
14. Which type of vehicles will you use to operate into the U.S.? (C2, C3, T2-S1, T2-S2, T3-S2, T3-S3, T2-S1-R2, T3-S1-R2, T3-S2-R2, T3-S2-R3, T3-S3-S2, T3-S2-R4, C2-R2, C2-R3, C3-R2, CR-R3, others)?
15. What tire types do the vehicles have that you currently operate (please specify for steering axle, single (other than steering), and tandem axles separately)? What is the percentage of each type?
16. What tire types will the vehicles have that you will use to operate into the U.S. (please specify for steering axle, single (other than steering), and tandem axles separately)? What will be the percentage of each type?
17. What are the tire inflation pressures of the steering, single (other than steering) and tandem axles of the vehicles that you currently operate?
18. What will be the tire inflation pressures of the steering, single (other than steering) and tandem axles of the vehicles that you will use to operate into the U.S.?

COMMENTS

19. Do you have any other comments or concerns about operating into the United States?

CUESTIONARIO

1. Tiene su compañía intensiones de operar en los Estados Unidos una vez que la frontera sea abierta?
2. Sus camiones cruzarán algún paso fronterizo entre México y Texas?

INFORMACION DE SU EMPRESA

3. Donde están sus oficinas centrales?
4. Cuántos tractocamiones y cajas operan?
5. Cuántos operadores trabajan en su empresa?

CARACTERISTICAS DE SU OPERACION

6. Cuántos viajes a través de la frontera planea realizar por semana?
7. Qué tipo de productos transporta normalmente?
8. Qué productos transportará a los Estados Unidos?
9. Cuáles serán los principales destinos dentro de los Estados Unidos para estos productos?
10. Tiene expectativas de volver de Estados Unidos cargado?

EQUIPOS

11. Cuál es la edad promedio de su flota de tractocamiones? Y la de sus cajas?
12. Usará los vehículos de su flota existente para operar en Estados Unidos?
    a. En caso que no lo haga, cual es la edad promedio de la flota de tractocamiones que pretende usar? Y la de las cajas?
13. Cuáles configuraciones de vehículos opera actualmente? (C2, C3, T2-S1, T2-S2, T3-S2, T3-S3, T2-S1-R2, T3-S1-R2, T3-S2-R2, T3-S2-R3, T3-S3-S2, T3-S2-R4, C2-R2, C2-R3, C3-R2, CR-R3, otras)?
14. Cuáles configuraciones de vehículos operará en los Estados Unidos? (C2, C3, T2-S1, T2-S2, T3-S2, T3-S3, T2-S1-R2, T3-S1-R2, T3-S2-R2, T3-S2-R3, T3-S3-S2, T3-S2-R4, C2-R2, C2-R3, C3-R2, CR-R3, otras)?
15. Qué tipo de neumáticos tienen los vehículos que actualmente operan? (Favor especifique para el eje direccional, eje simple y tandem por separado)? Cuál es el porcentaje de cada tipo?
16. Qué tipo de neumáticos tendrán los vehículos que operarán en los Estados Unidos? (Favor especifique para el eje direccional, eje simple y tandem por separado)? Cuál es el porcentaje de cada tipo?
17. Cual es la presión de inflado de los ejes direccional, simple y tandem con la que opera actualmente?
18. Cual es la presión de inflado de los ejes direccional, simple y tandem con la que operarán en los Estados Unidos?

COMENTARIOS

19. Tiene algún comentario o inquietud respecto a la posible operación de su flota en los Estados Unidos?

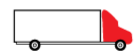
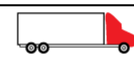
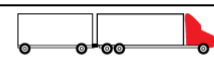
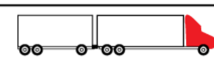
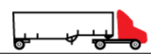
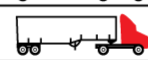
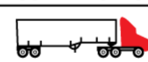
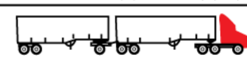
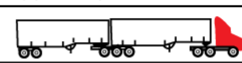
Nomenclature	Number of Axles	Number of Tires	Vehicle Configuration
UNITARY TRUCK			
C2	2	6	
C3	3	8-10	
TRACTOR TRAILER			
C2-R2	4	14	
C3-R2	5	18	
C3-R3	6	22	
C2-R3	5	18	
ARTICULATED TRACTOR TRUCK			
T2-S1	3	10	
T2-S2	4	14	
T3-S2	5	18	
T3-S3	6	22	
DOUBLE ARTICULATED TRACTOR TRUCK			
T2-S1-R2	5	18	
T3-S1-R2	6	22	
T3-S2-R2	7	26	
T3-S2-R4	9	34	
T3-S2-R3	8	30	
T3-S3-S2	8	30	

Figure 4. Truck Classifications Used in Mexico [14].

EFFECTIVE RESPONSE RATE

Of the 66 sampled companies that were contacted, 20 had an incorrect or a disconnected telephone number listed, 1 abandoned the application process, 8 were incorrectly listed as a trucking company, and 2 of the companies decided to buy pickup vehicles instead of using a commercial truck to transport goods across the border. Table 1 lists the number of Mexican trucking companies contacted, the number of trucking companies that completed a telephone interview, and the reasons for the non-response. The overall response rate was thus 66 percent, but the effective response rate was 100 percent in that all the sampled Mexican companies that could be reached participated in the survey and are still applying to operate in the United States once the border opens.

Table 1. Survey Response Statistics.

	Lists	
	FMCSA	**FOIA**
Disconnected/Wrong Telephone Number	5	15
Terminate OP-1 Application	0	1
Not a Truck Company	1	7
Use Pick-Ups	0	2
Responses	19	16
Total Called	25	41
Response Rate %	**76**	**39**
Effective Response Rate %	**100**	**100**

Table 2 lists the names of the 19 companies that participated in the telephone survey whose contact details were obtained from the FMCSA website. Nine of these Mexican companies listed a telephone number in a Mexican state neighboring Texas as the contact number. The other 10 had a contact telephone number listed in a Mexican state that was not bordering Texas.

Table 2. Interviewed Mexican Companies (FMCSA Website) [12].

Legal Name	State
AMETEK LAMB MOTORES DE MEXICO SA DE CV	Tamaulipas
HECAR LOGISTIC DE MEXICO SA DE CV	Tamaulipas
FLETES MEXICO CHIHUAHUA SA DE CV	Tamaulipas
TUM TRANSPORTISTAS UNIDOS MEXICANOS SA DE CV	Tamaulipas
PRAXAIR MEXICO SA CV	Nuevo León
ENERTEC MEXICO S DE RL DE CV	Nuevo León
TRINITY INDUSTRIES DE MEXICO S DE R L DE CV	Mexico
AUTOFLETE ALCON	Tamaulipas
TRANSPORTADORA ZAM	Tamaulipas
TECNOLOGIA MEXICANA SA DE CV	Sonora
ITT CANNON DE MEXICO SA DE CV	Sonora
AMCOR DE MEXICO SA DE CV	Baja California Sur
ALDILA DE MEXICO SA DE CV	Baja California Sur
BLOCK MEDICAL DE MEXICO SA DE CV	Baja California Norte
ELECTRONICA LOWRANCE DE MEXICO SA DE CV	Baja California Norte
LEACH INTERNATIONAL DE MEXICO S DE RL DE CV	Baja California Norte
LAX FREIGHT DE MEXICO S DE RL	Baja California Norte
INDUSTRIAS NEM DE MEXICO, SA DE CV	Baja California Norte
ANAYA'S TRUCKING	Baja California Norte

Table 3 lists the names of the 16 companies that participated in the telephone survey whose contact details were obtained from the FOIA list. Fourteen of these Mexican companies listed a telephone number in a Mexican state neighboring Texas as the contact number. The remaining two had a contact telephone number listed in a Mexican state that was not bordering Texas.

Table 3. Interviewed Mexican Companies (FOIA List) [2].

Legal Name	State
GERARDO LOEWEN FROESE	Chihuahua
CARPINTERIA HERMANOS CORRAL S DE RL MI	Chihuahua
AVOMEX INTERNACIONAL SA DE CV**	Coahuila
CARLOS FERNANDEZ VILLARREAL	Nuevo León
RICARDO CESAR MARTINEZ MONTEMAYOR	Nuevo León
JACOB DYCK FRIESSEN	Chihuahua
JUAN GARZA REINA	Nuevo León
FRANCISCO CEPEDA MORENO	Tamaulipas
EDMUNDO JESUS GUAJARDO BURSIAN**	Coahuila
DIONICIO SANTOS TROYO	Coahuila
JUAN CANO OROZCO	Nuevo León
GILBERTO HERNANDEZ PORTILLO	Sonora
ALMA AURORA VILLAREEAL HUERTA	Nuevo León
JUAN MIGUEL VILLARREAL ESCALERA	Nuevo León
SISTEMA DE RIEGO DEL NORTE SA DE CV	Chihuahua
TRANSPORTES UNIDOS ARECHIGA	Jalisco

** Company is included in the pilot program

Of the 35 Mexican trucking companies interviewed, 7 had contact details in Tamaulipas, 8 in Nuevo León, 4 in Chihuahua, 3 in Coahuila, 1 in Estado de Mexico, 1 in Jalisco, 3 in Sonora, 6 in Baja California Norte, and 2 in Baja California Sur (see Figure 5). With the exception of two companies, the contact details of all the Mexican trucking companies interviewed were thus listed in a state bordering the United States. Furthermore, most of the trucking companies (66 percent) – if located in the Mexican state in which their contact details are provided – will probably cross the Texas-Mexico border. Only the Mexican trucking companies located in the states of Baja California Norte, Baja California Sur, Jalisco, and Sonora will probably not cross the Texas-Mexico border into the United States.

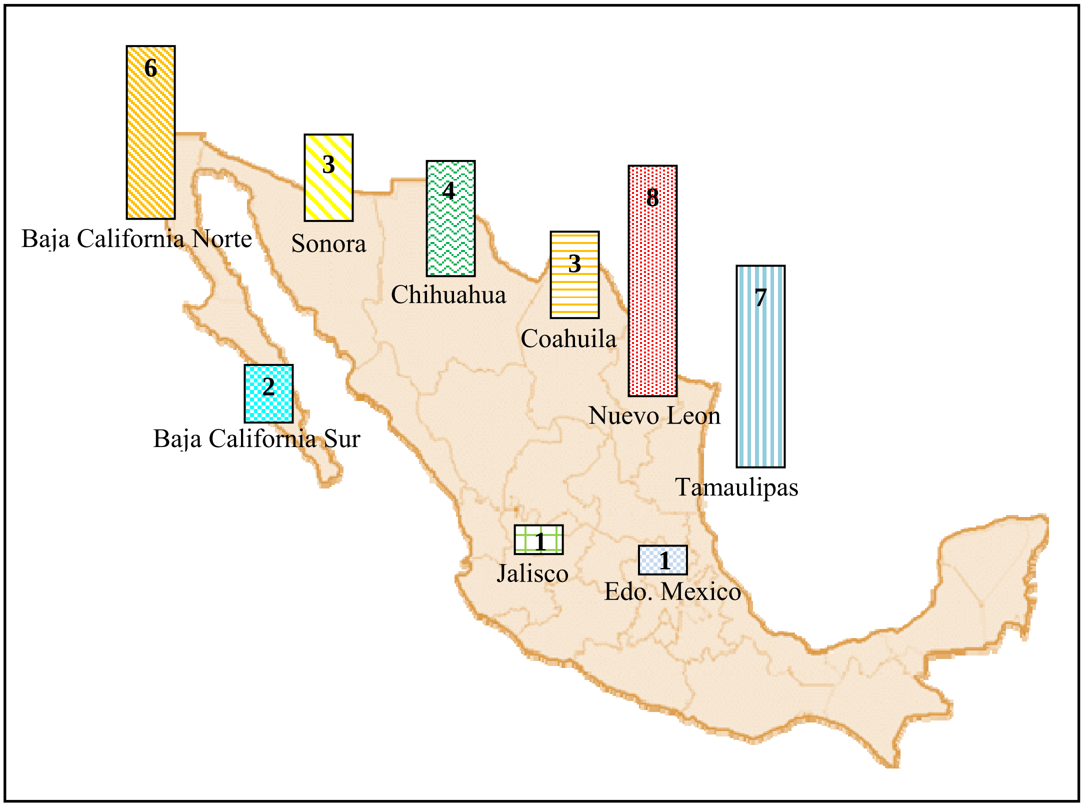
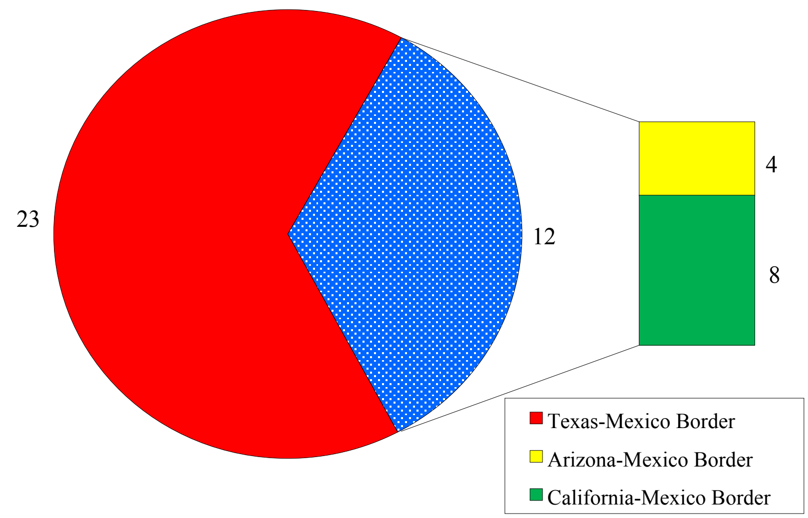


Figure 5. Locations of Mexican Trucking Companies Interviewed.

MAJOR SURVEY FINDINGS

The first survey question asked whether the respondent's company will operate into the United States once the U.S.-Mexico border opens. All 35 respondents indicated that they want to operate into the United States once the U.S.-Mexico border opens. This was expected because all the companies interviewed had applied for the OP-1 permit. Furthermore, 23 of the 35 (almost 66 percent) interviewees indicated that their company trucks will cross one of the ports-of-entry on the Texas-Mexico border, 8 indicated that their trucks will cross the California-Mexico border, and the remaining 4 indicated that their trucks will cross the Arizona-Mexico border (see Figure 6).

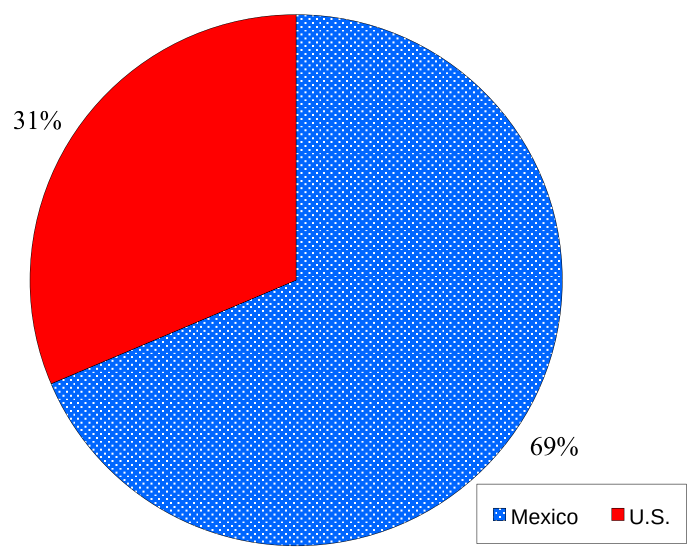


Number of Responses: 35

Figure 6. U.S. State-Mexico Border to Be Crossed by Companies Interviewed.

BUSINESS INFORMATION

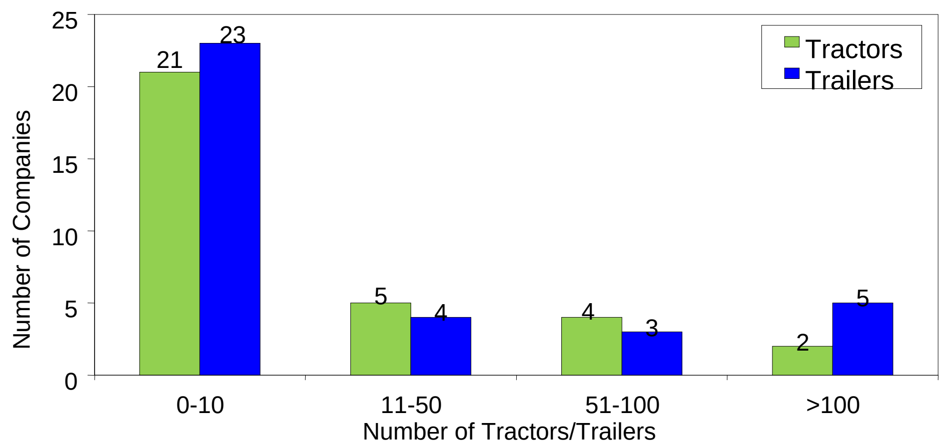
Questions 3, 4, and 5 attempted to gather information about where the trucking companies are headquartered, the size of their truck and trailer fleets, and the number of truck drivers that they employ. One of the most interesting findings of the telephone survey was that about 31 percent of the trucking companies interviewed indicated that their headquarters were in the United States (see Figure 7). These also tended to be the larger companies.



Number of responses: 35

Figure 7. Headquarters of Companies Interviewed.

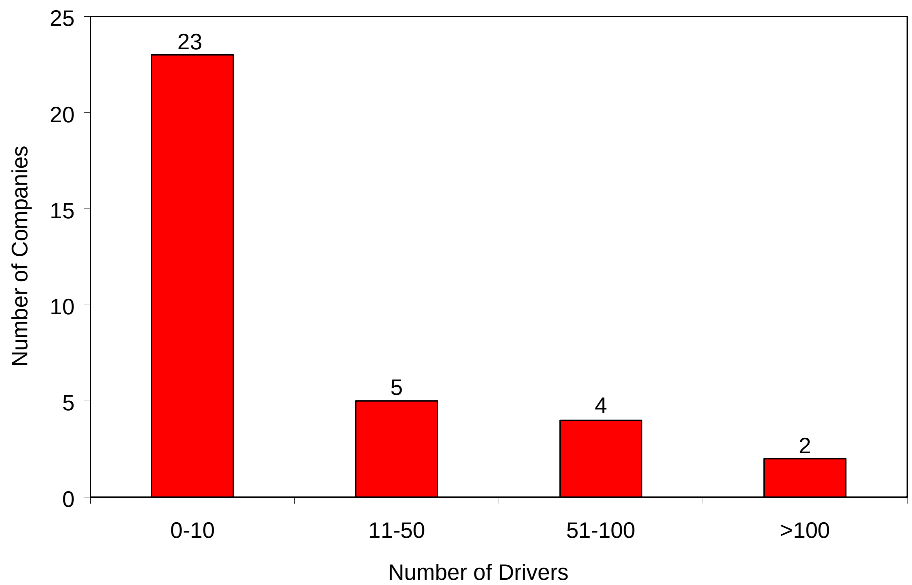
One way of characterizing the Mexican trucking companies that have applied to operate beyond the commercial zone is in terms of the size of the company. Figure 8 illustrates the number of tractors and trailers operated by those interviewed. From Figure 8, it is evident that the majority of Mexican trucking companies interviewed operate 10 tractors or fewer and/or 10 trailers or fewer. Included in the data on tractor ownership are four Mexican companies that have fewer than 10 vans/pickups that they use for the transportation of goods. Another three respondents use pickups to transport commodities but did not provide information on the number of pickups/vans that they operate. Seven of the respondents also did not operate any trailers, five of which operated only vans or pickups.



Number of responses: 32 for tractors and 35 for trailers

Figure 8. Number of Tractors and Trailers Operated by Companies Interviewed.

Similarly, the number of drivers employed by the Mexican companies interviewed revealed that the majority of the companies interviewed were smaller, employing 10 or fewer drivers (see Figure 9). Also of interest is the fact that the two Mexican trucking companies that indicated that they were part of the U.S. pilot program employed 1 and 25 drivers, respectively. Only six companies (around 18 percent) reported that they employed more than 51 drivers. One company (whose response is not included in Figure 9) indicated that the company did not employ any drivers, but rather entered into contracts with owner operators.

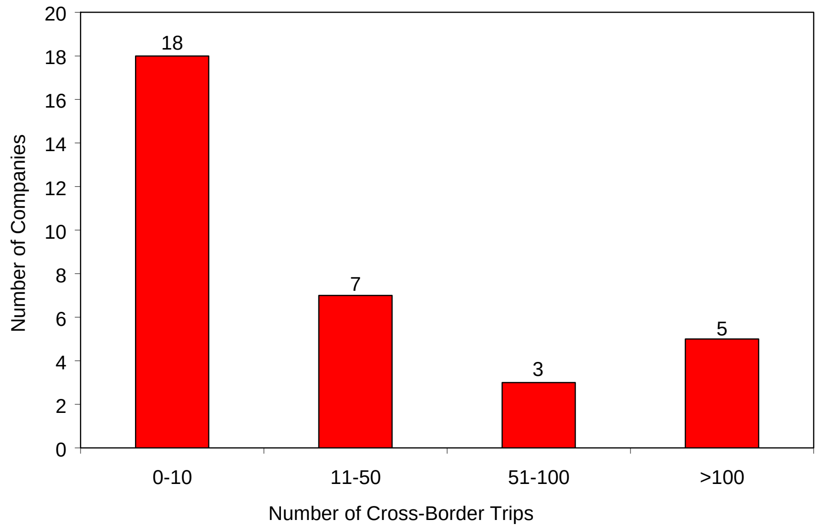


Number of responses: 34

Figure 9. Number of Drivers Employed by Companies Interviewed.

TYPE OF OPERATION

To form an analysis of the infrastructure impacts of opening the border, the telephone survey included five questions about the company's anticipated cross-border operations. Figure 10 illustrates that more than half of the companies interviewed indicated that they anticipated 10 trips or fewer per week across the border. Only five companies indicated that they will make more than 100 trips per week – two of which indicated more than 500 truck trips per week.



Number of responses: 33

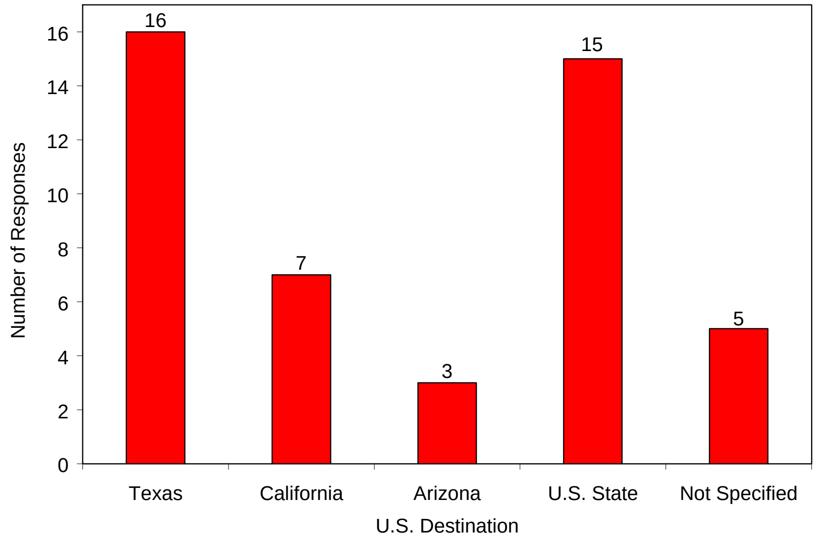
Figure 10. Number of Anticipated Cross-Border Trips per Week Reported by Companies Interviewed.

When asked about the commodities transported, most companies indicated that they are currently transporting *maquiladora*[3] products, which are for the most part finished goods (e.g., electronic products, medical products, automotive parts) produced in factories relatively close to the U.S.-Mexico border. The majority indicated that these will be the products transported by the company into the United States when the border opens.

Most respondents indicated a U.S. border state when asked about the major U.S. destinations for the commodities that the company will be transporting into the United States (see Figure 11). Respondents mentioned Texas 16 times compared to California 7 times and Arizona 3 times. Other destinations were Nebraska, Chicago[4], Ohio, Pennsylvania, Oklahoma, Louisiana, Seattle, Washington, Kansas, South Dakota, Rhode Island, New York, and Florida. Five respondents did not provide a specific destination.

[3] A maquiladora is a factory in Mexico along the U.S.-Mexico border that imports and assembles duty-free and tariff-free components for export to the U.S.

[4] Chicago and Nebraska were each mentioned twice, while the other destinations were only mentioned once.



Number of responses: 47

Figure 11. Major U.S. Destinations for Companies Interviewed.

Also, almost all the respondents (34) expected to secure a return load with a U.S. origin on their return to Mexico.

EQUIPMENT

The final section of the questionnaire attempted to gather information about the current equipment used by Mexican truck carriers and the equipment that they plan to use once they are allowed to cross the border into the United States. Figure 12 illustrates the average age of the respondents' truck fleet (i.e., tractors and trailers combined). Anecdotal information and observations suggested that a substantial number of Mexican long-haul carriers that transport freight to and from the Mexican border zones utilize relatively modern equipment and practices that are comparable to those encountered in the U.S. trucking industry [3]. Figure 12 illustrates that almost half (16 companies) reported that their truck fleets are five or fewer years old. On the other hand, only six companies (approximately 17 percent) reported that their fleet is more than 10 years old. Two respondents – each owning one tractor and one trailer – reported that their equipment is 22 and 21 years old, respectively.

Number of responses: 35

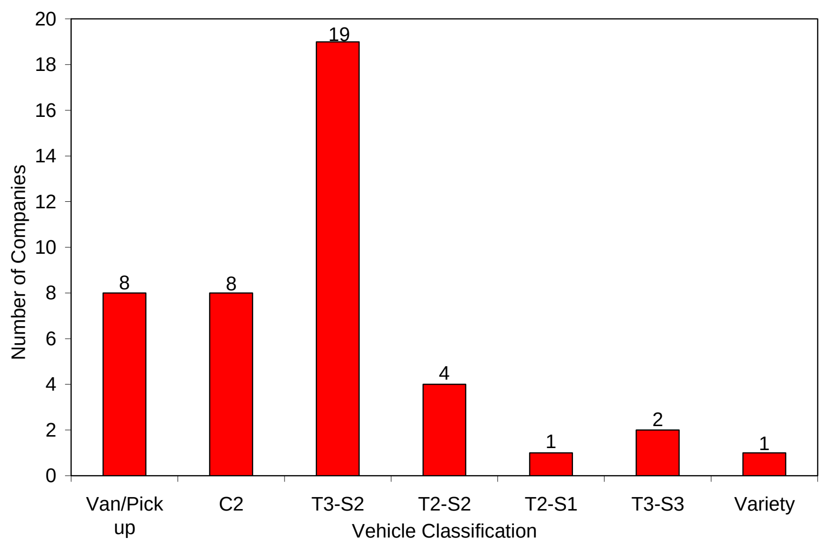
Figure 12. Age of Truck Fleet for Companies Interviewed.

Most of the respondents (25 companies) indicated that they are planning to use their existing fleet of vehicles to operate into the United States once the border opens. Another six companies indicated that they plan to use only some of their existing vehicles – i.e., the newer vehicles – to operate into the United States. Four respondents[5] indicated that they will not use their existing fleet to operate into the United States. Of the four, two indicated a vehicle age of one year for the vehicles that they will use to operate into the United States.

The respondents were also asked about the type of vehicles that they currently operate and which type of vehicles they are planning to operate into the United States once the border opens. Figure 13 illustrates the vehicle classifications for the companies that responded. From Figure 13, it is evident that Class T3-S2 is the most popular truck type operated by the respondents – almost half (19 responses) indicated this truck type. This is also by far the most popular long-distance vehicle used in the United States. In addition, eight responses indicated that vans/pickups are currently used and another eight responses indicated the use of the smaller Class C2 truck – a two-axle six-tire truck. The next most popular vehicle class currently operated is the T2-S2 (four responses), while the T2-S1 and the T3-S3 were also mentioned. Of the 31 respondents that answered the question on which vehicle types they will use to operate

[5] One of these four respondents owned a tractor and trailer that was 22 years old.

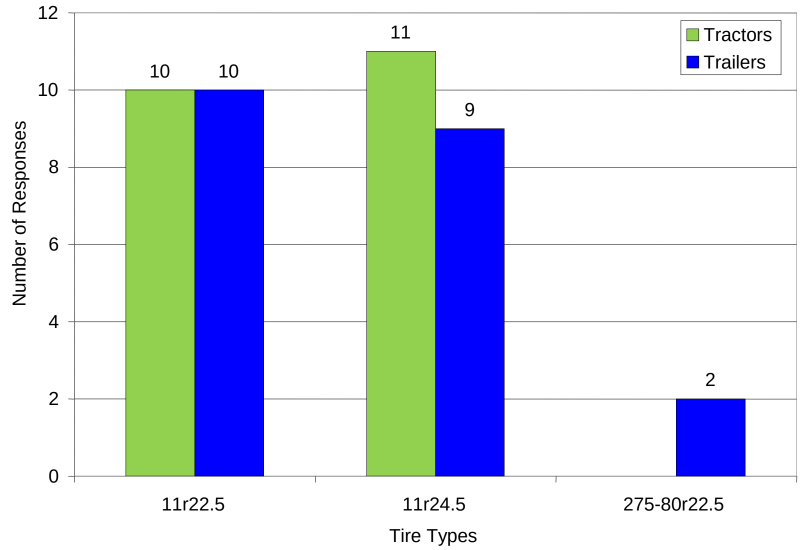
into the United States, 27 (87 percent) answered that it would be the same vehicle types they currently operate. The remaining four respondents – all currently operating pickups – indicated that they will operate a truck into the United States once the border opens. Two of these respondents indicated that they will operate a C2 truck.



Number of Responses: 43

Figure 13. Truck Classifications Owned by Companies Interviewed.

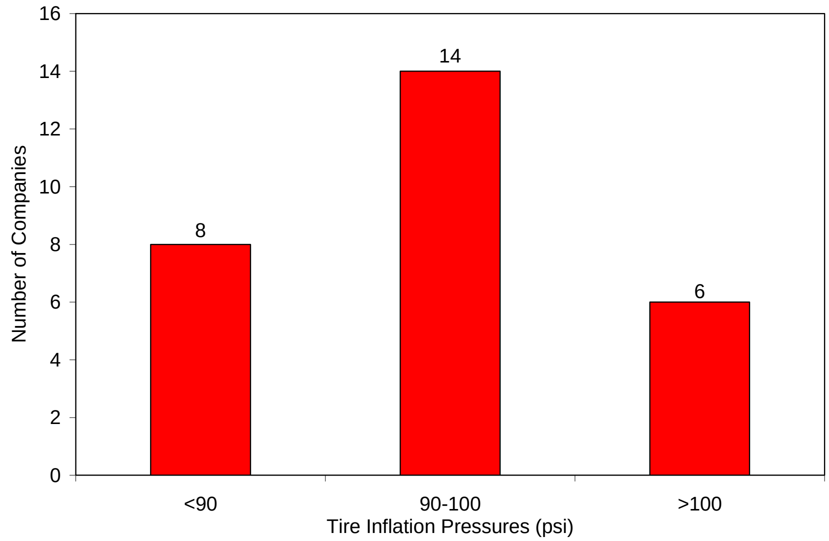
A relatively higher invalid and non-response rate was observed for the question relating to the tire types on the vehicles currently in operation. Of the 35 companies interviewed, 29 respondents answered this question, and of those 29 respondents, 8 provided an invalid or incorrect answer. Of the 30 respondents that answered the question about the types of tires on the vehicles that they will use to operate into the United States, 28 indicated that they would be the same as those currently being used (see Figure 14).



Note: Respondents were asked to specify the tire types for tractors and trailers separately. When only one tire type was provided, it was assumed that the same tire type is used for both tractors and trailers.
Number of Responses: 42

Figure 14. Truck Tire Types Provided by Companies Interviewed.

The final two questions (before the open-ended question asking for additional comments or concerns) asked about the tire inflation pressures of the steering, single, and tandem axles of the vehicles they currently operate and if that will differ with the vehicles used to operate into the United States. Twenty-five company representatives provided tire inflation pressures (or ranges) for the truck fleets they currently operate. Figure 15 summarizes their responses. Twenty-four of these representatives indicated that the same tire inflation pressures would be used for the vehicles that will operate into the United States.



Number of Responses: 28

Figure 15. Tire Inflation Pressures (psi) Provided by Companies Interviewed.

Finally, the respondents were asked if they have any other comments or concerns about operating into the United States. Only 11 respondents answered this question. Their comments varied from being affiliated with a U.S. company with industries in the United States (four respondents) to being ready to operate into the United States and urging the opening of the border. One respondent indicated that the opening of the border will be to the benefit of the Mexican trucking industry. Some respondents voiced concerns related to obtaining permission to operate into the United States, unfair inspections of Mexican drivers, and how truck weights are going to be measured.

CONCLUDING REMARKS

This chapter presented the findings of a telephone survey that was conducted with 35 Mexican companies that have applied for the OP-1 permit to operate into the United States once the border opens. The most important findings revealed that:

- 31 percent of the Mexican companies interviewed have their headquarters in the United States,
- the majority of respondents (around 65 percent) were smaller Mexican trucking companies operating 10 or fewer trucks and/or trailers, including seven responses that indicated they currently use vans/pickups to transport commodities,

- more than half of the companies interviewed (18 respondents) anticipated 10 trips or fewer per week across the border and most respondents (55 percent of the responses) indicated a U.S. border state when asked about the major U.S. destinations for the commodities that the company will be transporting into the United States,
- almost half the respondents (16 companies) have truck fleets that are five or fewer years old and most respondents were planning on using their existing fleet to operate into the United States once the border opens, and
- the most common (57 percent) truck configuration is the T3-S2 (5 axles with 18 tires). This is also by far the most popular long-distance vehicle used in the U.S.

A relatively higher invalid and non-response rate was observed for the questions relating to tire types and tire inflation pressures, but in general the tire types used are the same tire types that are used in the United States and the provided tire inflation pressures would meet U.S. standards. These types of survey responses can be very useful in performing analyses about the infrastructure impacts of Mexican trucking companies on the Texas road infrastructure once the border opens.

CHAPTER 4:
TRAFFIC CHARACTERIZATION AND IMPACT ON ROAD INFRASTRUCTURE

DEVELOPING RELEVANT STATISTICS

The use of WIM traffic data for mechanistic-empirical (M-E) pavement design has been gaining nationwide attention in recent years. Traffic is indeed one of the most critical pavement design inputs, determining how a pavement will perform and how long it will last. Traditionally, traffic data are associated with a high level of uncertainty.

The M-E approach accounts for traffic loading by axle load spectra instead of equivalent single axle load (ESAL) as in the traditional empirical approach. Research has been conducted on the statistical characteristics of axle load spectra, however, with focus on goodness of fit of the data. Little, if any, of the past research has been directly aimed at accounting for the impacts of traffic load on pavement damage. To address this particular issue, this research proposes a comprehensive statistical methodology that includes not only improved fitted axle distribution functions but also sound statistics representing load-pavement impact.

Mixed lognormal distributions are employed to fit the observed axle load spectra. Two fundamental advantages of the fitted functions are: 1) both the physical and statistical meanings of the load spectra are properly accounted for, and 2) the load spectra data are well fitted and can be statistically tested. In addition, researchers investigated the load-pavement impact based on axle load distributions through the concept of moment statistics. The moment order (or power) is generalized to both integer and non-integer conditions. Different power values are examined concerning load-pavement impact, representing two typical distress modes: surface rutting and fatigue cracking.

EXISTING TRAFFIC CHARACTERIZATION APPROACHES

One of the most significant improvements of the M-E design approach relates to the manner in which traffic loads are accounted for. In the traditional empirical design approach, traffic is accounted for by the number of ESALs. The concept of ESAL was established through empirical regression analysis based on the results of the American Association of State Highway Officials (AASHO) Road Test data [15]. The concept reflects the relationship between traffic load and pavement damage in terms of serviceability loss. Since then, the ESAL-based empirical pavement design process has been widely used by most highway agencies for pavement structural design. Empirically determined load-pavement impact represented by ESALs is known to vary with the change of vehicle configurations, pavement structures, materials, environment, tire pressure, and failure criterion. In the recently proposed M-E Design Guide [16], traffic load will be accounted for by axle load spectra instead of ESALs. Pavement responses (stress or strain) under each given axle load are calculated and pavement performance is then empirically estimated. Thus, accurate axle load distribution is of critical importance and WIM technology can provide the desired information at the desired level of accuracy.

Previous research into the probabilistic characteristics of the traffic load distribution has been conducted. The following paragraphs summarize some of the most important findings in this regard.

Mohammadi and Shah [17] used two separated beta distributions to fit gross vehicle weight (GVW) data for within and over legal limit samples, respectively. They found that the beta distributions fit the observed data with very small fit errors. In another study, Kim et al. [18] fit the cumulative distribution function (cdf) of single and tandem axle loads by piecewise distributions. The S-shaped cdf were described by four polynomial functions, with each representing a segment of cdf for a load magnitude range. Fourteen to sixteen parameters were employed to fit the individual axle load distributions with fairly high coefficients of determination (R^2), varying from 0.93 to 0.99. For the same purpose of fitting the S-shaped axle load cdf, sigmoid curves were used to fit axle load data in National Cooperative Highway Research Program (NCHRP) 1-37A [19]. Although relatively high fit precision was obtained in the past studies, their deficiencies were pointed out in recent work by Timm et al. [20], with the most significant being from the lack of sound statistical meaning of the fitted functions. To address this particular issue, the weighted sum of a normal and a lognormal distribution was applied to capture the peaks of typical axle load spectra by the latter authors.

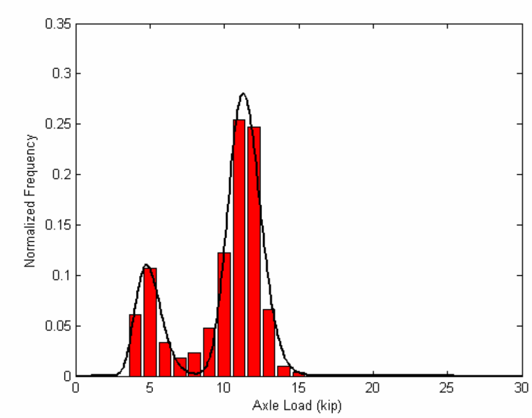
To date, however, an in-depth investigation into load-pavement impact in conjunction with the load spectra fit functions remains unaddressed in the literature. For pavement engineers, the ultimate purpose for establishing sound axle load spectra is to accurately account for pavement damage within a mechanistic framework. In addition to axle load spectra fit functions, two other aspects should be considered.

Is the data fit represented by high R^2 sufficient? From a pavement performance perspective, how sensitive load-pavement impact is to the fit function with varying fit precisions should be of more interest than the data fit per se. It is unreasonable to assume that the estimated precision of load-pavement impact is equal to the fit precision of the data since it has been well established that load-pavement impact is not a linear function of axle load.

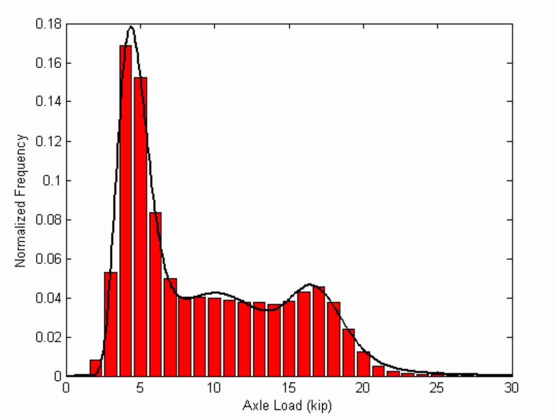
It is not adequate to evaluate and compare axle load spectra from different WIM sites only through the parameters of the fitted functions. For instance, the comparison of the means of two fitted functions can provide a relationship between two axle load spectra in terms of which one is heavier in magnitude but may provide little information concerning their relationship in terms of load-pavement damage. Thus, sound statistics regarding load-pavement impact based on axle load fit function remain to be established.

FITTING CONTINUOUS DISTRIBUTIONS TO TEXAS DATA

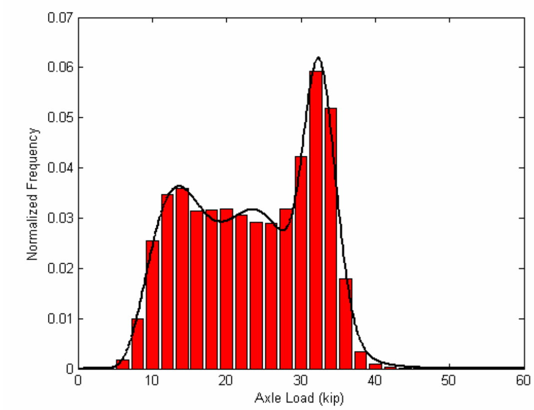
WIM systems are deployed nationwide, with almost every state operating its own WIM systems and reporting data on an annual basis to the Federal Highway Administration (FHWA). In principle, a WIM scale is capable of continuously recording traffic load data since its installation. Axle load distribution for a given axle type can be obtained by counting the number of loads falling into each individual load interval, referred to as a load bin. FHWA's Traffic Monitoring Guide (TMG) [21] categorizes axles into four types: single, tandem, tridem, and quads. Figure 16 (a, b, and c) shows three examples of typical axle load spectra for steering, single, and tandem axles respectively. The bars in each figure represent the normalized frequencies of all load bins (histogram), while the line represents the best fitted continuous distribution. The adjective "best" is referred to as the ability to more accurately represent expected pavement damage (load-pavement impact).



a) Steering Axles



b) Single Axles (With Dual Wheels)



c) Tandem Axles

Figure 16. Observed Axle Load Spectra and Fitted Continuous Distributions.

The traffic data used in this section of the research study were collected from the WIM systems deployed in Texas, where there are currently approximately 20 permanent WIM stations. The characteristics of axle load spectra are investigated based on available traffic information from all the WIM stations. These WIM stations are located on interstate, U.S., and state highways, with the majority being on rural interstate highways. In particular, the data used in this section to demonstrate the concepts were obtained from WIM Station D516, located on Interstate Highway 35 (IH-35) near San Antonio. The traffic sample of this particular WIM station covers data collected from January 1998 to March 2002.

Thorough examination of the axle load distributions from the aforementioned WIM stations indicates that these distributions show multi-modal patterns. More precisely, the majority of axle load spectra are composed of two pronounced or main peaks (modes), as shown in Figure 16. This characteristic has also been observed through studies in other states such as

Long Term Pavement Performance (LTPP) North Center Region (NCR) [17], California [22], and Alabama [19]. This multiple-peak characteristic leads to the use of a mixture of theoretical distributions to represent an axle load spectrum as done by Timm et al. [19].

It should be noted that, merely from the perspective of data fit, a wide range of distributions can apply with fairly high precision. However, it is not always clear which one is the "best." The meaning of "best" is relative and depends on the objectives of the specific study. In the context of axle load and its impact on pavement performance, the range of candidate distributions can be narrowed. The first restriction comes from the fact that axle load is non-negative. Thus, those distributions with feasible region including negative values should be excluded or, if used, should be truncated at zero. For instance, if a normal distribution is used for fitting either of the peaks, its left tail should be truncated for negative loads. Truncation, however, introduces more complexity in characterizing load spectra. Second, ensuring the existence of statistics that capture load-pavement impact places self-imposed restrictions on the selection of theoretical functions. It will be shown in the following discussion that load-pavement impact is mathematically equivalent to the moment statistics of the axle load distribution, and not all probability density functions have a close-form for their moment statistics. Hence, the use of distributions with close-forms for obtaining their moments offers a significant advantage. To address these two issues without sacrificing fit precision to the data, researchers investigated a variety of theoretical distributions. As a result, the mixed lognormal distribution was established as "the best." The advantages of mixed lognormal distribution as the load spectrum fit function are discussed in the following section.

The Mixed Lognormal Distribution

If a random variable *X* has a lognormal distribution

$$Y = \ln(X) \sim N(\mu, \sigma) \tag{4.1}$$

its probability density function (*pdf*) is given by:

$$f(x;\lambda,\zeta) = \frac{1}{\sqrt{2\pi}x\zeta}\exp\left(-\frac{1}{2}\left(\frac{Ln(x)-\lambda}{\zeta}\right)^2\right) \tag{4.2}$$

where λ and ζ are the parameters of the lognormal distribution, representing the mean and standard deviation of *Ln*(*X*). Thus, the mixed lognormal distribution pdf representing a multi-modal load spectrum is given by:

$$f(x;\lambda_k,\zeta_k,W_k)=\sum_{k=1}^{K}\frac{W_k}{\sqrt{2\pi}x\zeta_k}\exp\left(-\frac{1}{2}\left(\frac{Ln(x)-\lambda_k}{\zeta_k}\right)^2\right) \tag{4.3}$$

where λ_k and ζ_k are the parameters for each lognormal distribution (*k* represents the *k*th piece of lognormal distribution, denoted as mode); W_k represents the weight of the *k*th mode, and $\sum_{k=1}^{K}W_k=1$.

It is implied in Equation 4.3 that the *k*th peak of a load spectrum is captured by the *k*th piece of lognormal function. The mean and spread of each peak can be closely reflected through the two parameters, λ_k and ζ_k, of the corresponding piece of lognormal function.

Load-Pavement Impact

Despite the controversy over empirical pavement design and performance analysis being based on ESALs, the concept is expected to continue to play a major role in pavement design and rehabilitation in the future. Rather than precisely reflecting the relationship between axle load and a particular distress type such as rutting or cracking, the use of ESALs will continue to approximately compare or evaluate load distributions in a simple and familiar way. In addition, because ESALs have been applied in pavement design since the early 1960s, highway agencies have accumulated large amounts of traffic information in terms of ESALs. Thus, it is necessary to establish a sound relationship to bridge the gap between ESALs and axle load spectra.

Analysis of the data from the American Association of State Highway and Transportation Officials AASHTO Road Test established that the impact of each individual axle load on flexible pavements can be estimated according to the fourth power law [22, 23]. The fourth power law implies that pavement damage by passing axles increases exponentially with the increase of their axle load. This relationship is captured by load equivalence factor (LEF) as follows:

$$LEF=\left(\frac{x_r}{L_s}\right)^m \tag{4.4}$$

where x_r = weight of axle load in the *r*th bin, (kip); L_s = load on a standard axle with the same number of axles as x_r, usually 18 kip for the single axle and it is dependent on pavement structure for the tandem axle; and *m* = power denoting the relative damage to the pavement of a given load x_r, typically in the range 3.8-4.2.

The fourth power law represents the relationship between axle load and the loss in pavement serviceability. Numerous studies have investigated the power's value and evaluated the dependence of this power with particular distresses. Some of their findings and recommendations are listed in the next paragraph.

In terms of fatigue cracking, Salam and Monismith [24] suggested that the power could be 3.8 through their fatigue tests on asphalt concrete specimens. The Asphalt Institute recommended using 3.291 [24]. In terms of rutting performance, however, it is hypothesized that smaller power values are more appropriate. For instance, Archilla and Madanat [26] found that the power for single axles is 2.98, while it is 3.89 for tandem axles. Research conducted at the Canterbury Accelerated Pavement Testing Indoor Facility (CAPTIF), using a compaction-wear model, suggested that the exponent value of the power law varied from around 1.0 to 3.4 [27]. Other studies justify power values ranging from smaller than unity to almost 10. One aspect is certain: there is no unique power because pavements consist of many materials that are affected by multiple failure mechanisms. Therefore, for the sake of generality, this study considers a series of representative power values to examine load-pavement impact based on axle load spectra.

The load-pavement impact based on axle load spectra can be obtained by totaling the contributions from all the loads x_r in the distribution; this is often denoted as load spectra factor (LSF):

$$LSF = \sum_{r=1}^{R} \left(\frac{x_r}{L_s} \right)^m q_r t = \frac{\sum_{r=1}^{R} x_r^m q_r t}{L_s^m} \tag{4.5}$$

where *R* = total number of load bins, with bin width *t* = 1 kip for single axle and 2 kip for tandem; q_r = normalized frequency of axle load in the *r*th bin of a given load spectrum; and L_s = standard axle load (kip).

It can be seen that LSF is actually the *m*-th sample moment statistic [28] divided by the constant $L_s{}^m$. Provided the continuous distribution function for each axle type is obtained through the data fit, as described earlier in this section, it is more convenient and equally valid to express the axle load-pavement impact in terms of the population moment directly from the pdf. The summation part in Equation 4.5 can be replaced by its continuous counterpart in the form of integral as follows:

$$LSF = \int \left(\frac{x}{L_s} \right)^m f(x) dx \tag{4.6}$$

$$LSF = \frac{\int x^m f(x) dx}{L_s^m} = \frac{E\left(X^m\right)}{L_s^m} = \frac{M^m}{C} \tag{4.7}$$

where x = axle load weight (kip); $f(x)$ = axle load fit function for a given axle type; ${L_s}^m$ = constant, C; and M^m = m-th moment of a given pdf.

Thus, using the axle load spectrum fit function *f(x)* as given in Equation 4.3, axle load-pavement impact can be equivalently estimated by applying Equation 4.7 through the moment statistic.

Moment for the Lognormal Distribution

As shown in Equation 4.7, the moment of the axle load spectrum function is the statistic governing the estimation of load-pavement impact. Note that the moment order (also power *m*) is generalized in this particular research to include not only integer but also non-integer cases, e.g., 3.8 in Salam and Monismith [25]. In this sense, the advantage of adopting lognormal distribution is demonstrated once again. The follow-up discussion will show that both integer and non-integer moments exist for lognormal distribution and, conveniently, close-forms are available. Other popular distributions, such as the normal distribution, however, may find trouble in "non-integer" moments since its moment generation function (MGF) only applies in the integer conditions [27]. The generalized *m*-th moment for a random variable *X* with lognormal distribution can be derived as:

$$M^m = E\left(X^m\right) = \int x^m \frac{1}{\sqrt{2\pi} x \zeta} \exp\left(-\frac{1}{2} \left(\frac{Ln(x) - \lambda}{\zeta} \right)^2 \right) dx = \exp\left(m\lambda + \frac{m^2}{2} \zeta^2 \right) \tag{4.8}$$

where λ and ζ are as in Equation 4.2.

With load spectrum fitted by mixing *K* lognormal distributions, the load-pavement impact by an axle type with given load spectrum, LSF can easily be obtained as:

$$LSF = \sum_{k=1}^{K} W_k \exp\left(m\lambda_k + \frac{m^2}{2} \zeta_k{}^2 \right) \Big/ L_s^m \qquad (4.9)$$

where W_k, λ_k, and ζ_k are as in Equation 4.3; *m* is the power.

Equation 4.9 shows that load-pavement impact based on axle load spectra under varying power conditions can be estimated provided the spectra fit functions are available. Thus, the proposed approach provides an efficient and effective way to evaluate a specific axle load spectrum as well as quantitatively compare the load spectra obtained from different WIM sites.

PROOF OF CONCEPT

The data from all 20 WIM sites in Texas were used to examine the methodology described in the previous section. Due to the different axle types and their different configurations and impact on pavement performance, single axles are further divided into steering axles (with single wheels) and single axles with dual wheels, referred to hereafter as steering and single axles, respectively. Considering that tridems and quads have a minimal effect on estimated performance (as compared with singles and tandems) for all WIM sites investigated, these two axle types were not included in this study. The study can, however, be extended to any number of axle types in a straightforward manner.

Results indicate that, from a statistical and physical perspective, the mixed lognormal distributions perform well in describing axle load distributions from all WIM stations. Table 4 presents the parameters of the multi-modal mixed lognormal distributions for steering, single, and tandem axles with the data shown in Figure 16.

Table 4. Mixed Lognormal Distribution Parameters for Load Spectra Fitted Functions.

Axle Type	Parameters								
	W_1	W_2	W_3	λ_1	λ_2	λ_3	ζ_1	ζ_2	ζ_3
Steering	0.238	0.762	–†	1.59	2.43	–	0.178	0.096	–
Single	0.477	0.383	0.140	1.53	2.44	2.83	0.241	0.338	0.104
Tandem	0.433	0.296	0.270	2.71	3.26	3.49	0.335	0.189	0.065

†: Parameters not available because only bi-modal distribution is applied.

All three axle load spectra exhibit a pattern with two pronounced main peaks. Consequently, the mix of two lognormal distributions is used for capturing these two peaks. If the two peaks are far apart, a third piece of lognormal distribution is added to reduce the data fit error. As a result, two pieces of lognormal distribution are adopted for steering axles and three pieces are adopted for the other two axle types. Figure 16 depicts the fitted curves as solid lines. Applying the mixed lognormal distribution fit functions reveals that axle load spectra characteristics are well captured.

The central location of each of the two main peaks (modes) is captured by the parameters mean, λ_k, and standard deviation, ζ_k. Numerically in kips, each mode is approximately equal to $\exp\{\lambda_k - \zeta_k^2\}$. In the case of tandem axles, the two locations are approximately 13.5 and 32.5 kips for two main peaks, respectively (see Figure 16 c). In the same way, other modes can also be estimated. It should be noted that these statistics have a physical meaning. The two main peaks are typically associated with the average weight of unloaded and fully loaded conditions, respectively. These peaks could be estimated on a regular basis and can be used for WIM auto-calibration procedures. Table 5 presents the characteristics of the fitted functions in terms of fit precision.

Table 5. Axle Load Spectra Fitted Function Precision and Pavement Impact.

Axle Type	Data Fit	LSF (Relative Error)*						
	R^2	Moment Order						
		1	1.5	2	2.5	3	3.5	4
Steering	0.977	0.55 (0.05%)	0.42 (0.09%)	0.33 (-0.06%)	0.26 (-0.60%)	0.21 (-1.75%)	0.17 (-3.85%)	0.14 (-7.31%)
Single	0.998	0.51 (1.65%)	0.41 (2.50%)	0.34 (3.40%)	0.31 (4.32%)	0.28 (5.19%)	0.27 (5.96%)	0.26 (6.54%)
Tandem	0.995	0.69 (0.51%)	0.60 (0.83%)	0.54 (1.15%)	0.49 (1.48%)	0.46 (1.78%)	0.43 (2.03%)	0.41 (2.19%)

*LSF, Load Spectra Factor, denotes the load-pavement impact obtained from the observed axle load spectra; Relative error (as is shown in the parenthesis in percentage) is the relative difference of load-impact factor between fit function and observed axle load spectra.

Because it is commonly used as a data fit criterion, R^2 is calculated for different axle types. The second column of Table 5 shows that all of the R^2 values are close to 1, which suggests that the estimated mixed lognormal distributions fit the observed axle load spectra well. In addition, the Kolmogorov-Smirnov test of the empirical cumulative distribution function was used to verify this visual observation. The results of these tests support the hypothesis used in this study. More importantly, in addition to pure data fit, the fit precision in terms of load-pavement impact is investigated in detail. Table 5 presents these fit errors in columns 3 through 9, in parentheses. The fit error is defined as the relative difference between *LSF* estimated from the fit (continuous) function and that from the observed (discrete) axle load spectrum for each moment order (power) considered. *LSFs* for the three axle types from the observed load spectra are listed under each power.

With regard to the power (moment order), the indication was that its value varies with different types of pavement distress. In this study, researchers evaluate the following powers as representatives: 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0, with lower values typically representing the rutting equivalence and higher values the cracking or serviceability condition.

With regard to the *LSF*, Table 5 illustrates that the lower the power, the closer the magnitudes of the three axles' *LSF* (e.g., 1.0, 0.9, and 1.1 for power = 1); whereas, for higher powers, the *LSF* of tandems is significantly larger than that of single and steering axles. Hence, it is implied that for the cases studied, the contributions of the three axle types to rutting are comparable, while the largest contribution to fatigue is produced by tandems, followed by single and steering axles.

Regarding the fit errors in terms of load-pavement impact, Table 5 shows that these errors are low and reasonably acceptable in the context of pavement design, i.e., the largest error is 7.3 percent. This result suggests that well-established mixed lognormal distributions are appropriate to represent axle load spectra to be used in pavement design. It is also shown that with the increase of power value, the fit error in terms of load-pavement impact increases in magnitude. This increase would imply that fatigue damage represented by load-pavement impact is more sensitive to the fit function precision than is rutting damage.

It is important to note that higher values of R^2 do not necessarily lead to better precision in terms of load-pavement impact. In this case study, the steering axle load spectrum has the smaller R^2 but also has the lower fit errors for the lower powers. Additionally, the fit errors for single axle load spectrum in all power conditions are higher than their counterparts for tandem axles (although the former exhibits larger R^2).

CHAPTER SUMMARY FINDINGS

This chapter presents the motivation for the statistical characterization of axle load spectra based on WIM data using the mixed lognormal distributions as "the best" option. This methodology will be applied in the next chapter for detailed evaluation of traffic data from Texas and Mexico. The statistical distributions of axle load for three typical axle types (steering axle, single axle [with dual wheels], and tandem axle) were established and analyzed. Researchers found that mixed lognormal distribution fits the observed data well, with R^2 close to unity. The numerous advantages of adopting mixed lognormal distribution include:

- The distribution reflects the fact that axle loads are non-negative.
- The distributional characteristics and statistical meaning of axle load spectra are effectively captured.
- Close-form expressions for the moment statistics are available.
- By mixing several distributions, the location of each peak can be easily estimated through its corresponding parameters of mean and standard deviation, which have physical meaning.

Researchers thoroughly examined load-pavement impact based on axle load spectra. Findings indicate that load-pavement impact can be expressed as a moment related statistic of the axle load probability density function (axle load spectrum). In addition to the popularly used fourth power law, a range of possible power values can represent the relation between axle loading and typical pavement stresses, such as rutting and fatigue cracking. Based on axle load spectra and for lower powers (more relevant to rutting), it was found that the contributions to total load-pavement impact of the three typical axle types are comparable. On the other hand, for higher powers (more relevant to fatigue cracking), the load-pavement impacts are contributed largely by tandems, followed by single axles, and then steering axles.

The precision in terms of load-pavement impact is also obtained. The results suggest that mixed lognormal distributions are most likely to be "the best" distribution family to represent observed axle load spectra. R^2 does not clearly reflect the precision in terms of load-pavement impact.

CHAPTER 5:
TRAFFIC CHARACTERIZATION AND COMPARISON BETWEEN TEXAS AND MEXICO

TRAFFIC CLASSIFICATION

Based on the methodology presented in the previous chapter, traffic loading data collected from two WIM stations in Texas and from eight WIM stations in Mexico are described and evaluated. Traffic loading characterization is established and a comparison between the characteristics in each country is thoroughly examined based on the available data from the same time period (year 2001). To facilitate comparison, the chapter first presents traffic classification schemes adopted in this study for the U.S. data and the data from Mexico. Based on these classification schemes, vehicle type composition is also obtained from samples in Texas and Mexico. In addition, different vehicle weight and axle load legal limit regulations in Texas and Mexico are compared. In the methodology section, a series of relevant statistics reveals traffic load characteristics in Texas and Mexico.

FHWA's Traffic Monitoring Guide categorizes U.S. vehicles into 13 classes considering the number and configuration of the axles. Figure 17 shows these classes [20]. The TMG defines Classes 4 to 13 as trucks. In this study, the traffic data obtained in Texas were classified using the TMG scheme. However, Mexico adopts a different classification scheme. Based on available data from Mexico, only five truck classes are included: C2, C3, T3S2, T3S3, and T3S2R4. Figure 18 shows the classification scheme used in Mexico. After comparing the TMG and Mexican classification schemes, four Mexican vehicle classes were adopted in this study: C2, C3, T3S2, and T3S3, which correspond to Class 5, Class 6, one type from Class 9, and one type from Class 10 in the United States, respectively. For the sake of clarity, the notations for the four common Mexican and U.S. classes are considered interchangeable in the remainder of this report. In addition, note that Mexican truck class T3S2R4 is not allowed in Texas.

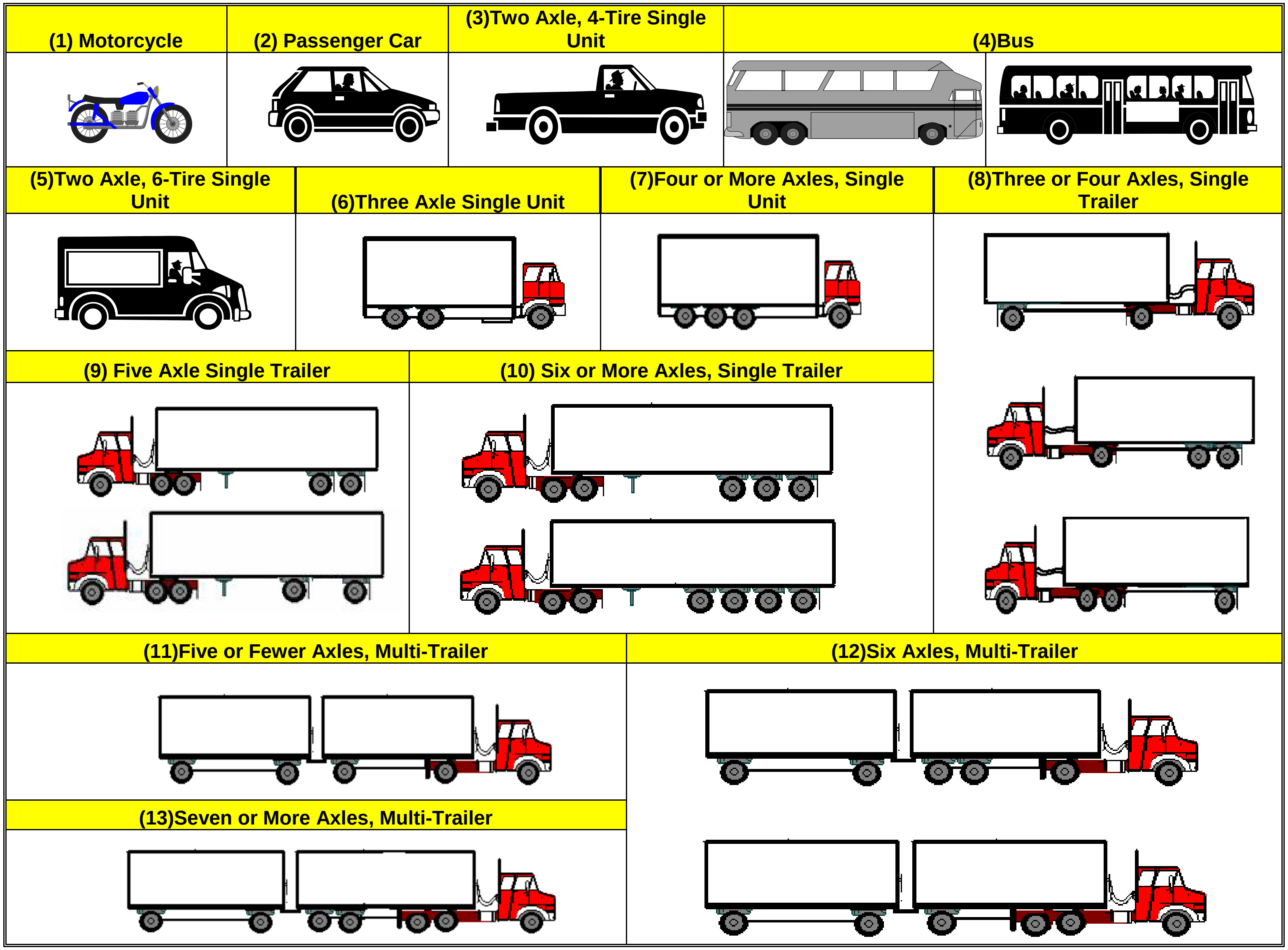


Figure 17. Traffic Classification Scheme by TMG2001.

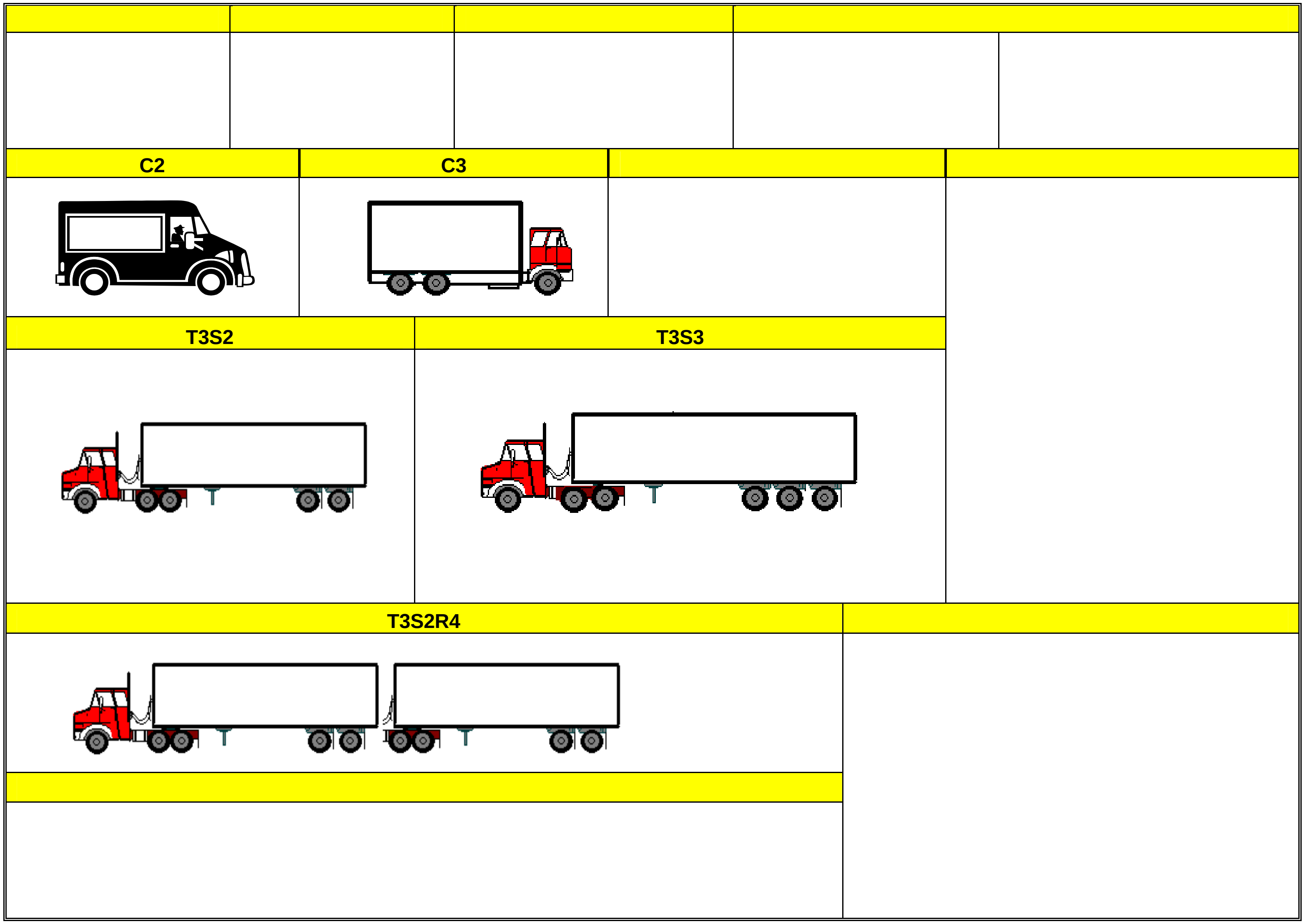


Figure 18. Truck Classes in Mexico and Adopted in the Study.

TRAFFIC COMPOSITION

For comparative purposes, Figure 19 and Figure 20 present traffic volume percentages among the common classes, C2, C3, T3S2, and T3S3. Traffic volumes represent all samples across different WIM stations in Texas (two WIM stations) and Mexico (eight WIM stations), respectively. It is shown that on both sides, among the four truck classes, T3S2 (the five-axle 18-wheeler) accounts for the largest traffic volume, followed by C2, T3S2, and T3S3. In addition, the most noticeable difference is the fact that a significantly greater number of six-axle trucks (T3S3) are used in Mexico than in Texas (for the WIM stations analyzed): 0.4 percent in Texas and 12.6 percent in Mexico.

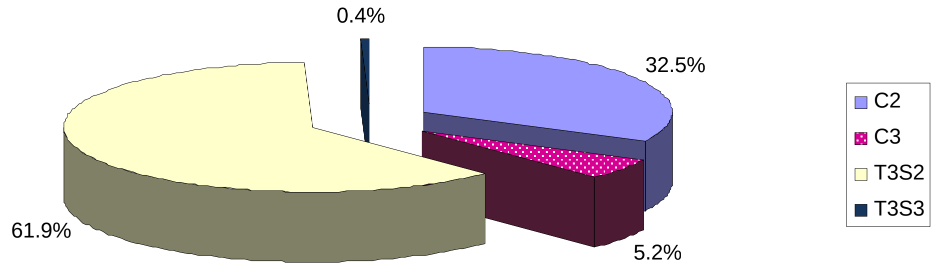


Figure 19. Traffic Volume Percentages among Four Common Truck Classes in Texas.

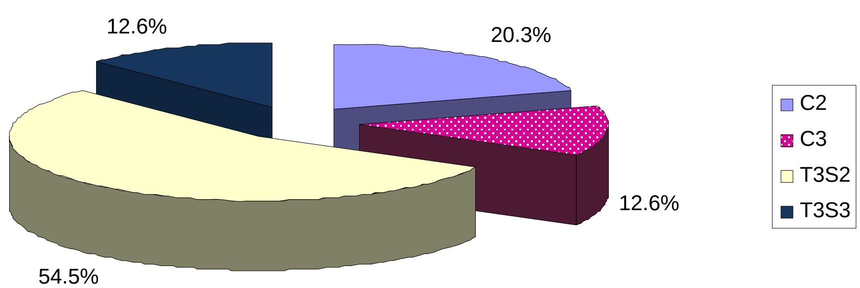


Figure 20. Traffic Volume Percentages among Four Common Truck Classes in Mexico.

VEHICLE WEIGHT AND AXLE LOAD LEGAL LIMIT

From a system management perspective, traffic loading has always been a major concern because of the significant impact of axle loads on the deterioration of the road infrastructure. A series of measures has thus been adopted to protect the highway infrastructure from deteriorating. For example, federal interest in preserving the Interstate Highway system dates back to the 1950s with the enforcement of vehicle size and weight, resulting in the development of a series of standards [29]. Currently, the federal axle load limits on the Interstate Highway system are:

- single axle: 20,000 pounds,
- tandem axle: 34,000 pounds,
- tridem axle: 42,000 pounds, and
- gross vehicle weight (GVW): 80,000 pounds [29, 30].

Each state may adopt its own commercial vehicle weight standards, but Texas has adopted the Federal regulation [30]. In comparison, the Mexican truck axle weight limits on "high type" roadways, based on 1995 norms are listed as follows (when different, proposed 2008 values are given in brackets):

- single axle w/single wheels: 14,330 pounds,
- single axle w/dual wheels: 24,250 pounds,
- tandem axle: 42,990 pounds (39,680 pounds after 2008),
- tridem axle: 51,800 pounds (49,600 pounds after 2008), and
- gross vehicle weight (GVW) for single unit: 106,920 pounds (105,820 after 2008) .

It is thus evident that, with the exception of the weight limit for a single axle with single wheels (usually the steering axle), the typical non-steering axles in Mexico have a higher legal load limit compared to trucks in the United States (percentage differences are given in Table 6). This has resulted in the popular misconception of the negative impact on the Texas transportation infrastructure should those Mexican trucks operate on the Texas highway system. It should be noted that, should Mexican trucks be allowed to operate over the Texas road network, they will have to comply with local legal axle loads. What is most important is the type of truck that Mexican-based companies will bring into Texas because local maximum axle loads will be enforced. Thus, an in-depth analysis of axle load characteristics becomes relevant. It should be noted that, under current Texas regulation, Mexican trucks T3S3 and T3S2R4 would be friendlier to the pavement than the popular 18-wheeler (T3S2).

Table 6. Comparison of Legal Limits between the United States and Mexico.

Axle/Weight Type	Difference in Mexico over the U.S. (%)
Single axle w/ single wheels	-28.4
Single axle w/ dual wheels	+21.3
Tandem	+16.7
Tridem	+18.1
GVW	+32.3

AXLE LOAD CHARACTERISTICS

Axle Load Characteristics in Texas

Based on traffic data collected at two WIM stations (D516 and D522) in Texas, axle load distributions (or spectra) for each axle type on different vehicle classes were obtained for each axle type of the most significant classes. Station D516 is located near San Antonio on Interstate Highway 35, while station D522 is located near McAllen on U.S. Highway 281. Based on the axle load spectra, a series of statistics of interest including sample means (reflecting transport weight) and other relevant moment statistics (as described in Chapter 4) for the individual axle types and vehicle classes were then calculated.

WIM Station D516 (IH-35)

Axle load distributions for each axle type are illustrated in Figures 21 to 24. Each figure represents load distributions of one axle type from the different vehicle classes in this discussion. It is shown that axle load distributions vary significantly among axle types as well as vehicle classes. Based on the established axle load distributions, researchers adopted the following relevant statistics:

- Mean axle load for each axle type of each vehicle class (AVE), as shown in Equation 5.1. This statistic captures the average magnitude of weight carried by each axle.
- Load Spectra Factor (LSF), as is shown in Equation 5.2. This statistic estimates load associated damage on pavement.

It is well established in pavement engineering that the damage caused by an axle load to a typical asphalt pavement increases exponentially with the axle load weight. This empirical relationship is often referred to as the power-law, and the concept can be extended to describe load-pavement impact in terms of axle load distribution. It has been established that load-pavement impact based on axle load distribution or spectra can be expressed as a moment-related statistic [32, 33]. Alternatively, LSF is equivalent to average ESALs for each type of axle. Mathematically, these summary statistics are expressed as:

$$AVE = \sum_i x_i f_i \tag{5.1}$$

$$LSF = \sum_i \left(\frac{x_i}{L_s} \right)^m f_i \tag{5.2}$$

where

i = the ith weight interval of axle load distribution;

x_i = load weight corresponding to the ith interval (kip);

L_s = standard axle load (kip), 18 kip, 33 kip, and 47 kip for single, tandem, and tridem axles, respectively;

m = moment statistic or power order, usually ranging from 1 to 4; and

f_i = normalized frequency of axle load corresponding to the ith interval.

Based on Equations 5.1 and 5.2, the results of the relevant statistics are obtained and illustrated in Table 7. Without loss of generality, this chapter adopts four typical moments (i.e., power orders) to calculate LSF. The lower values of orders are typically associated with pavement damage in terms of surface deformation or rutting, while the higher values relate to pavement damage in terms of fatigue cracking or serviceability [23, 34].

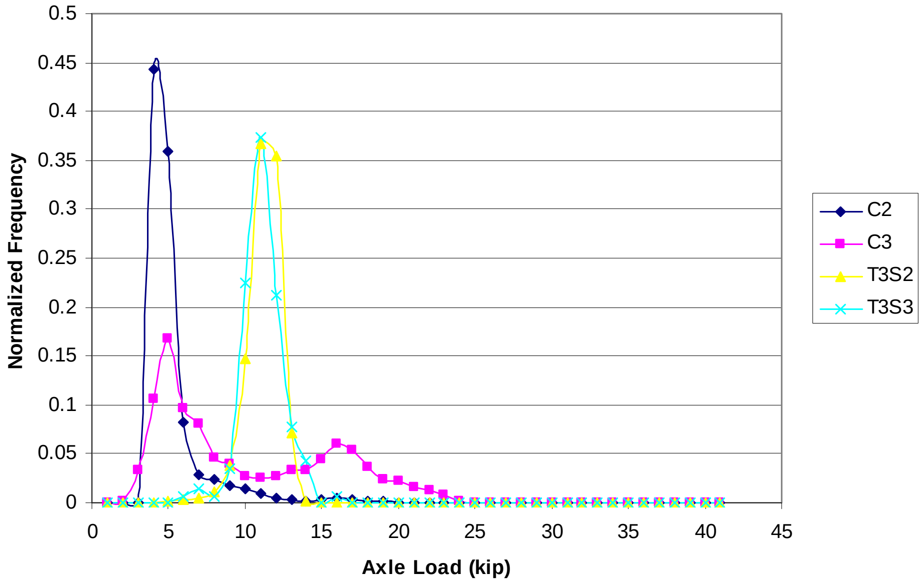


Figure 21. Axle Load Distributions for Steering Axles at WIM Station D516 in Texas.

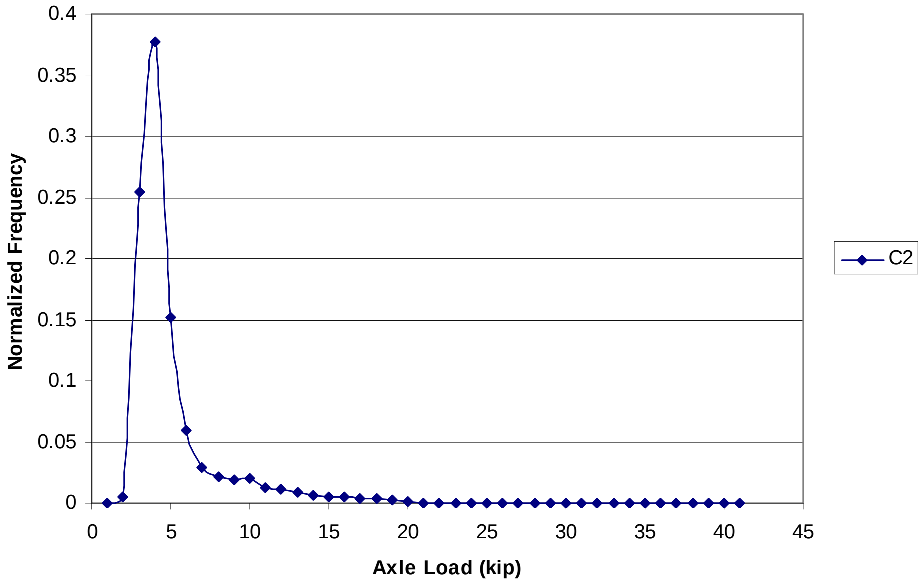


Figure 22. Axle Load Distribution for Single Axle at WIM Station D516 in Texas.

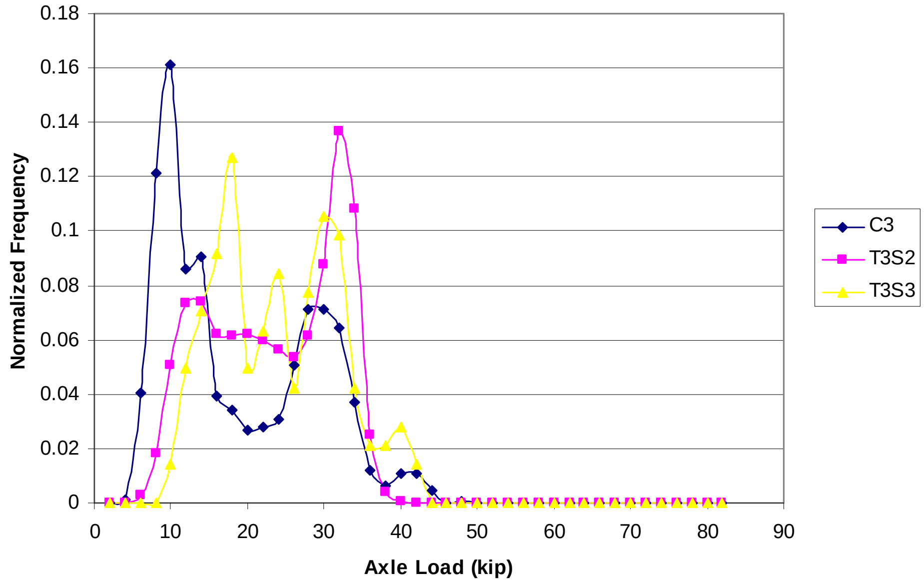


Figure 23. Axle Load Distributions for Tandem Axles at WIM Station D516 in Texas.

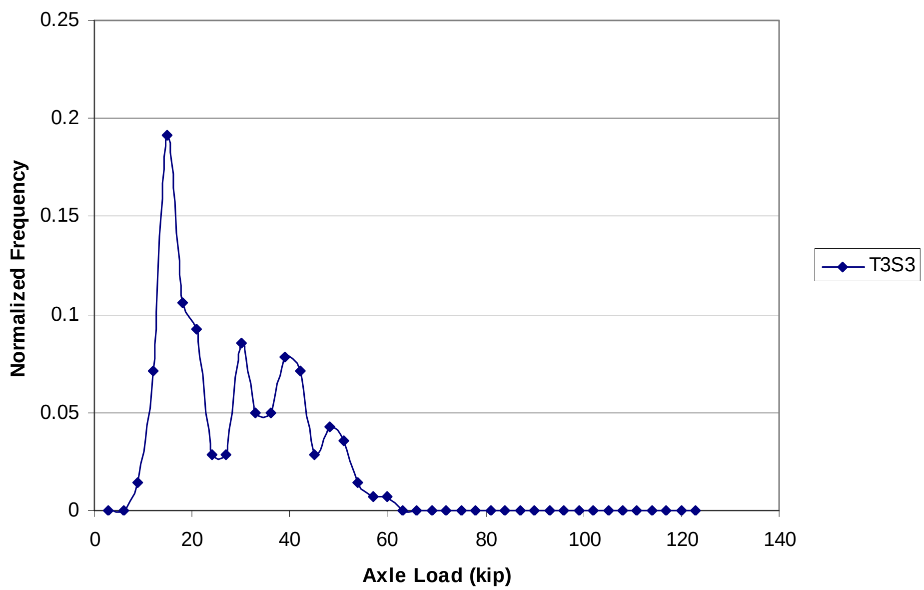


Figure 24. Axle Load Distribution for Tridem Axle at WIM Station D516 in Texas.

Table 7. Axle Load Statistics at WIM Station D516 in Texas.

Axle Type			Steering				Single	Tandem			Tridem
Vehicle Class			C2	C3	T3S2	T3S3	C2	C3	T3S2	T3S3	T3S3
Mean (kip)			5.19	9.97	11.2	11.1	5.03	18.8	23.5	24.2	27.8
LSF	Power Order	4	0.02	0.33	0.16	0.16	0.04	0.33	0.45	0.49	0.32
		3	0.04	0.35	0.25	0.25	0.05	0.35	0.50	0.52	0.35
		2	0.10	0.40	0.39	0.39	0.10	0.42	0.57	0.59	0.43
		1	0.29	0.55	0.62	0.62	0.28	0.57	0.71	0.73	0.59

WIM Station D522 (US 281)

Axle load distributions and characteristics at WIM Station D522 in Texas are studied with the same procedure used for WIM Station D516. Figures 25 to 28 provide the results; Table 8 presents the summary statistics. It is interesting to note that axle load distributions and the relevant statistics are very different between these two stations, which highlight the validity of this approach.

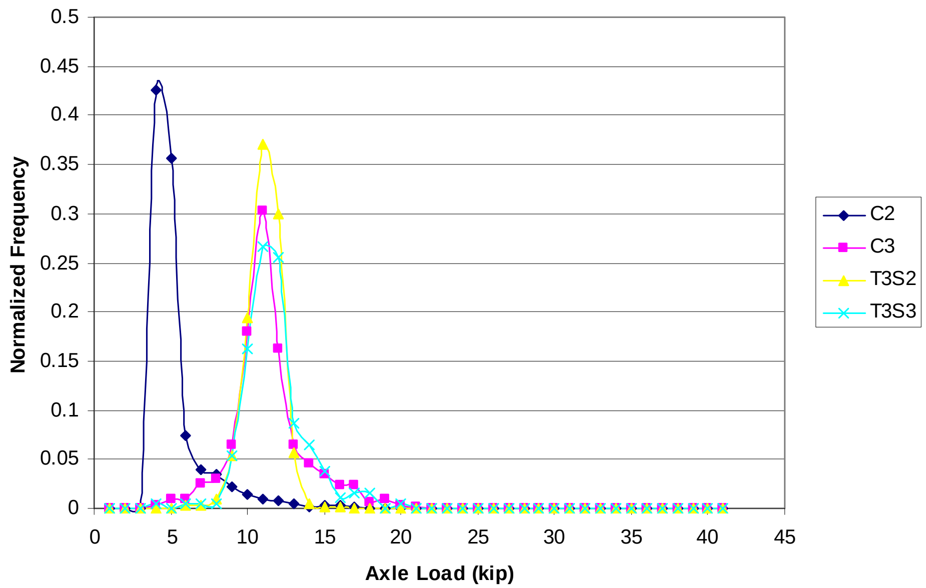


Figure 25. Axle Load Distributions for Steering Axles at WIM Station D522 in Texas.

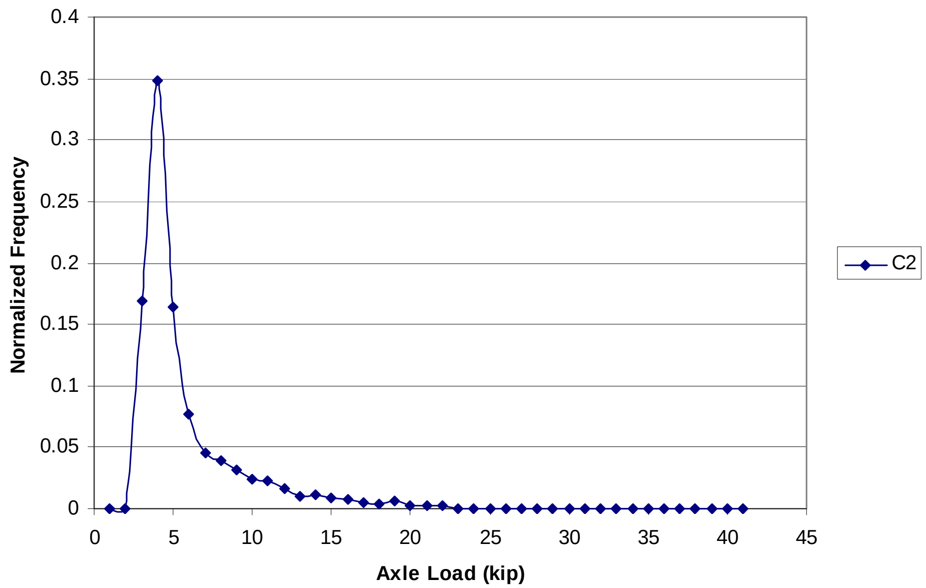


Figure 26. Axle Load Distribution for Single Axle at WIM Station D522 in Texas.

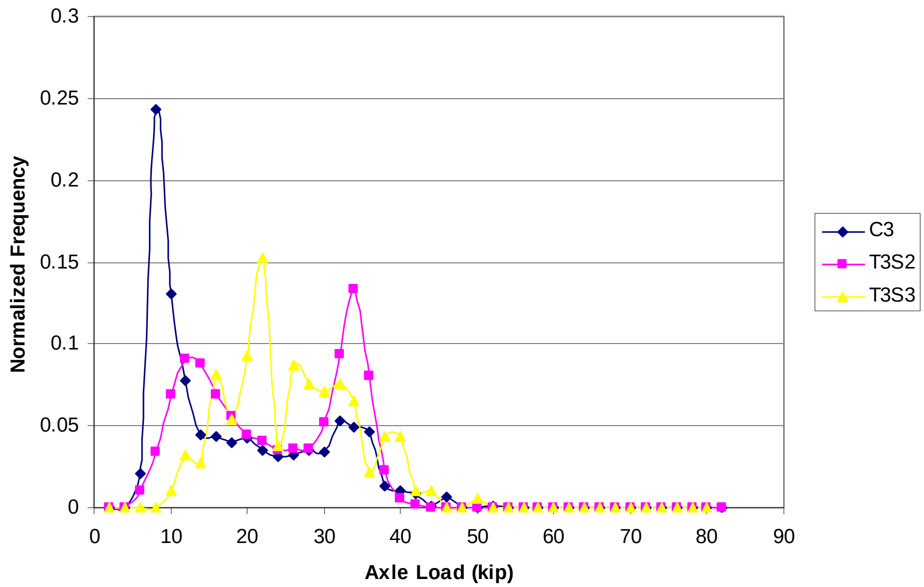


Figure 27. Axle Load Distributions for Tandem Axles at WIM Station D522 in Texas.

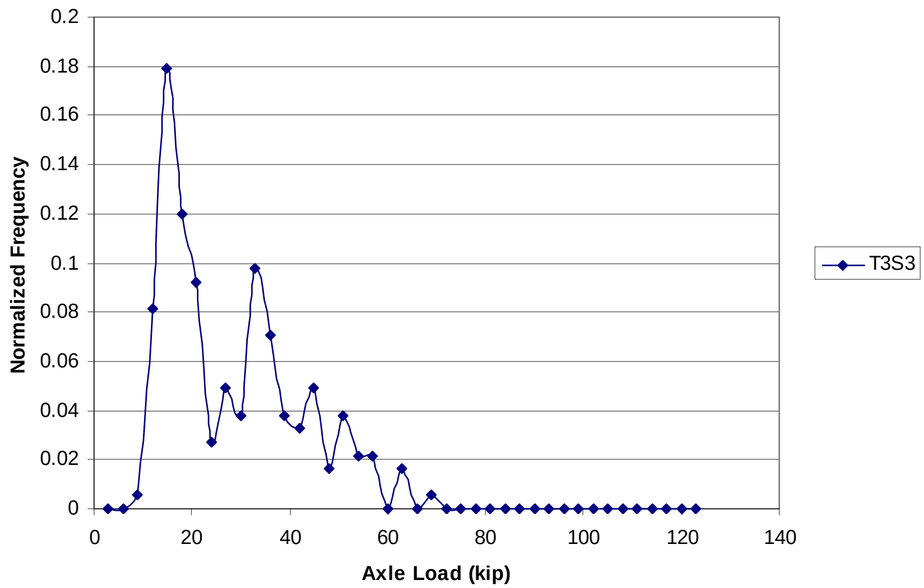


Figure 28. Axle Load Distribution for Tridem Axle at WIM Station D522 in Texas.

Table 8. Axle Load Statistics at WIM Station D522 in Texas.

Axle Type			Steering				Single	Tandem			Tridem
Vehicle Class			C2	C3	T3S2	T3S3	C2	C3	T3S2	T3S3	T3S3
Mean (kip)			5.24	11.4	11.1	11.7	5.80	18.3	23.2	25.8	28.3
LSF	Power Order	4	0.02	0.21	0.15	0.22	0.07	0.36	0.51	0.62	0.38
		3	0.04	0.29	0.24	0.30	0.09	0.37	0.53	0.62	0.39
		2	0.10	0.42	0.38	0.44	0.14	0.41	0.58	0.67	0.45
		1	0.29	0.63	0.62	0.65	0.32	0.56	0.70	0.78	0.60

Axle Load Characteristics in Mexico

Following the same analysis procedure that was used to evaluate the traffic data from Texas, axle load distributions and statistical characteristics were obtained based on data from eight WIM stations in Mexico. The data were provided by the Instituto Mexicano del Transporte (IMT) in June 2007. Without the collaboration of the IMT, this analysis would not have been possible. Since the research team was not involved in the data collection, it is not possible to fully verify the accuracy of the WIM data except through general trends. For example, steering axle weights on combination trucks usually fall within repeatable ranges. Based on such trends, these data appear to be reasonably accurate.

It is important to note that the data from Mexico are collected by means of a temporary WIM system that travels throughout Mexico and collects samples over several days at a given station, and then it is moved to the next location. This program, initiated in 1996, continues to date. For the purpose of this research, WIM data collected in 2001 at the following locations were used:

Sta. Number	Station Name	Highway Name	Mileage (km)
E123	Coyame	Chihuahua-Ojinaga	141+000
E124	Fitosanitaria	Janos-Agua Prieta	152+000
E125	Cereso	Moctezuma-Agua Prieta	192+000
E126	Entorque Moctezuma	Agua Prieta-Imuris	2+300
E127	Lienzo Charro	Sonoita-Puerto Penasco	7+200
E128	Sonoita	Sanata Ana-Sonoita	251+000
E129	Las Adelitas	Sonoita- Mexicali	187+000
E130	El Faro	Mexicali-San Felipe	38+000

Axle load distributions of five truck classes (C2, C3, T3S2, T3S3, and T3S2R4) corresponding to two WIM stations (E126 and E129) were selected as representatives for illustration purposes, as shown in Figures 29 to 36. In addition, Tables 9 to 16 provide relevant statistics for axle load distributions for all stations. A comprehensive database containing all data was delivered as part of this research project and is contained in Product 1.

WIM Station E126 (Agua Prieta – Imuris Highway, km. 2+300)

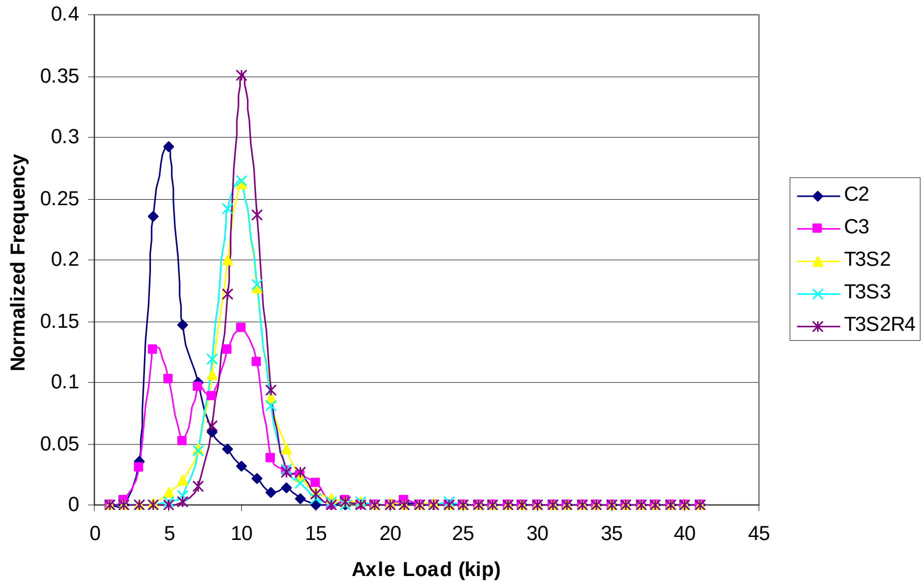


Figure 29. Axle Load Distributions for Steering Axles at WIM Station E126 in Mexico.

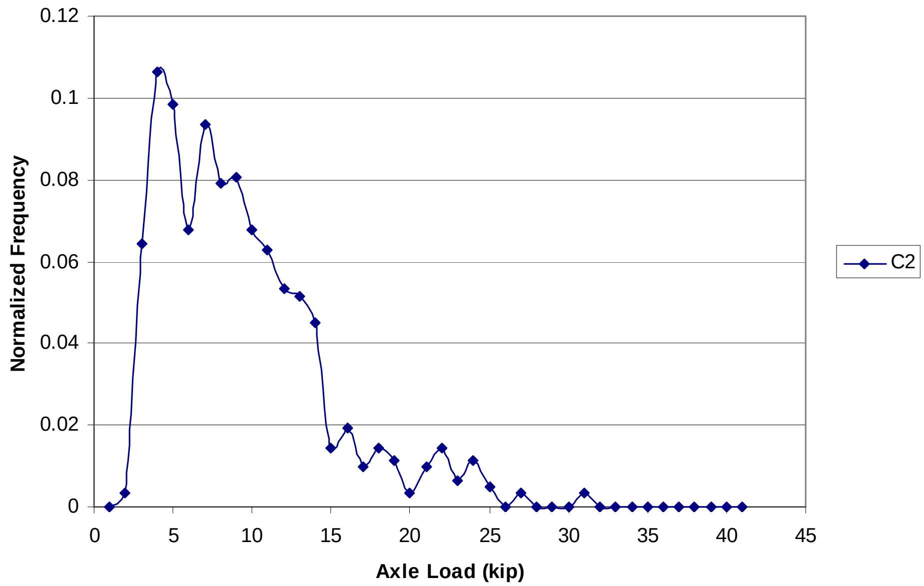


Figure 30. Axle Load Distribution for Single Axle at WIM Station E126 in Mexico.

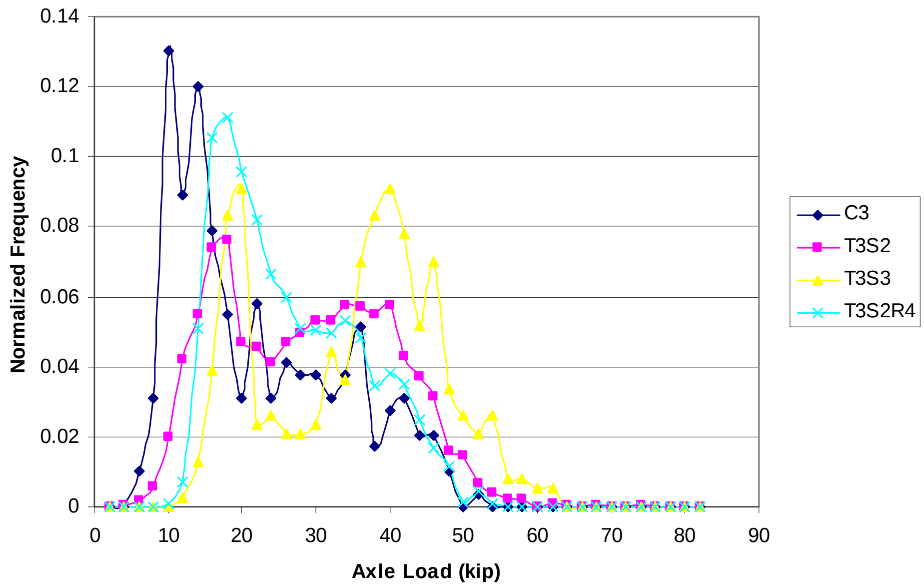


Figure 31. Axle Load Distributions for Tandem Axles at WIM Station E126 in Mexico.

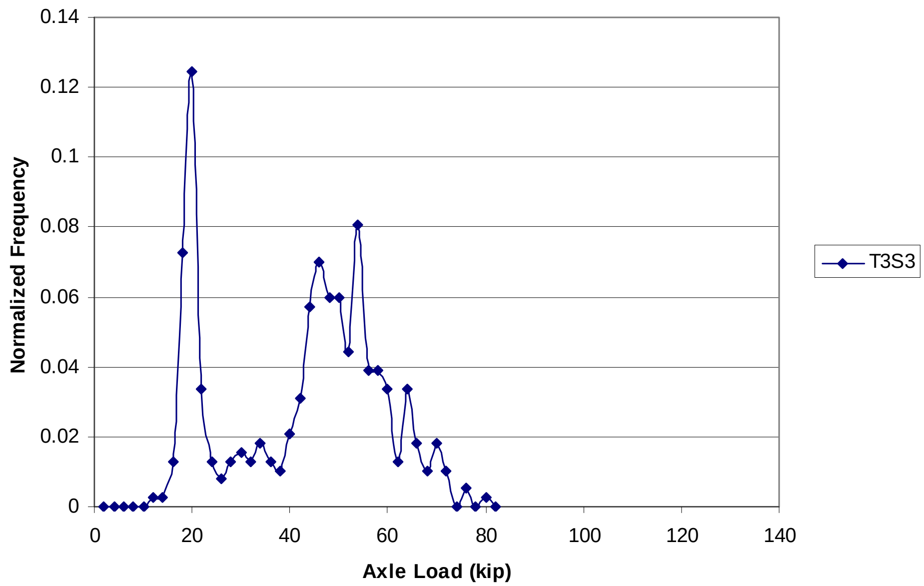


Figure 32. Axle Load Distribution for Tridem Axle at WIM Station E126 in Mexico.

WIM Station E129 (Sonoita-Mexicali Highway, km. 187)

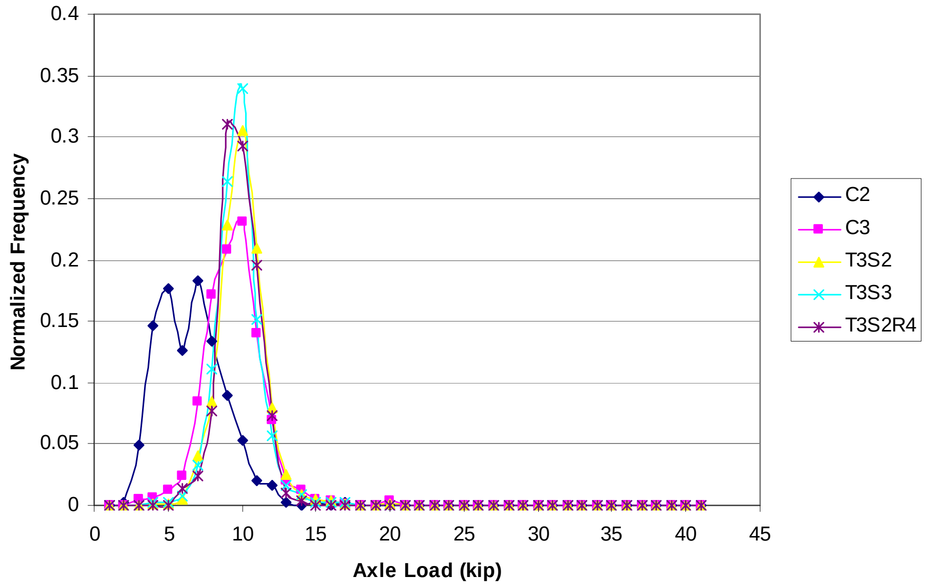


Figure 33. Axle Load Distributions for Steering Axles at WIM Station E129 in Mexico.

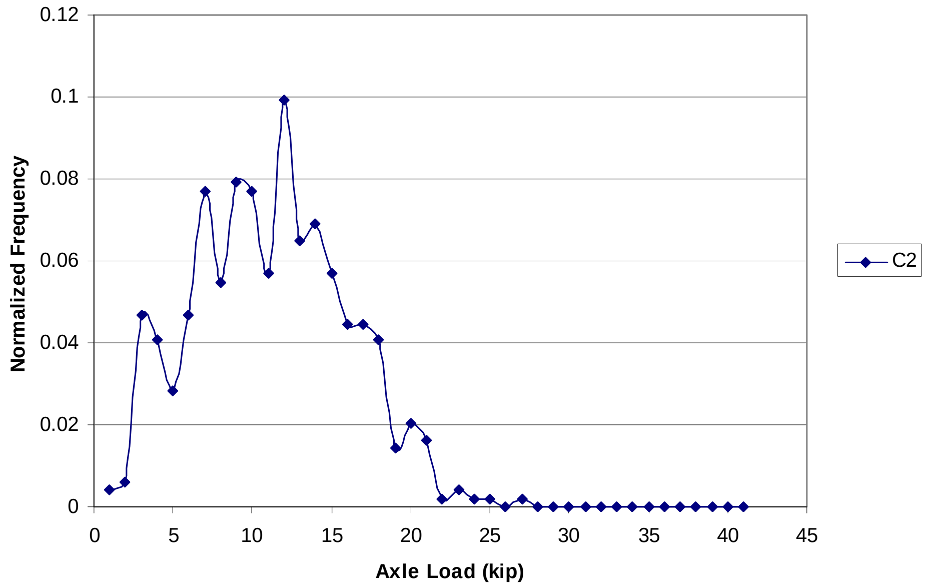


Figure 34. Axle Load Distribution for Single Axle at WIM Station E129 in Mexico.

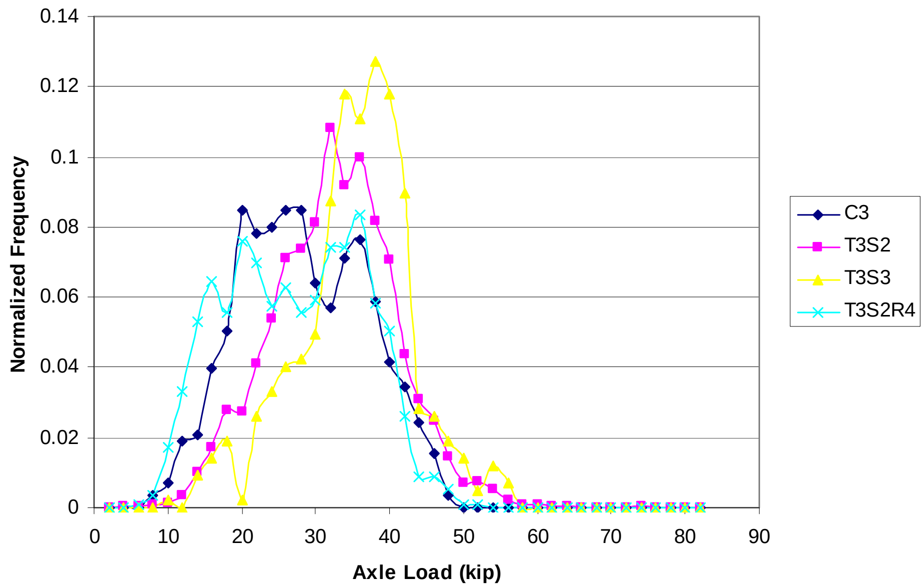


Figure 35. Axle Load Distributions for Tandem Axles at WIM Station E129 in Mexico.

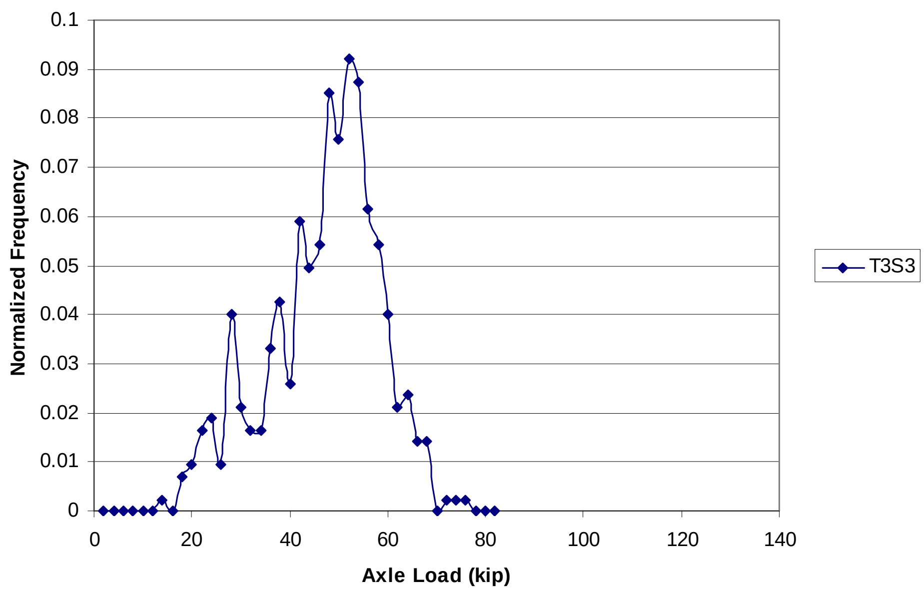


Figure 36. Axle Load Distributions for Tridem Axle at WIM Station E129 in Mexico.

Based on axle load distributions presented in Figures 29 to 36, a series of relevant statistics associated with pavement damage was obtained for all available WIM sections in Mexico. These statistics are presented in Tables 9 to 16.

Table 9. Axle Load Statistics at WIM Station E123 in Mexico.

Axle Type			Steering					Single	Tandem				Tridem
Vehicle Class			C2	C3	T3S2	T3S3	T3S2R4	C2	C3	T3S2	T3S3	T3S2R4	T3S3
Mean (kip)			5.90	9.02	8.40	10.20	N/A	8.94	27.02	24.42	30.93	N/A	38.13
LSF	Power Order	4	0.03	0.08	0.06	0.16	N/A	0.21	0.68	0.52	1.67	N/A	1.46
		3	0.06	0.15	0.11	0.23	N/A	0.24	0.68	0.55	1.25	N/A	1.06
		2	0.12	0.26	0.22	0.35	N/A	0.32	0.73	0.61	1.02	N/A	0.85
		1	0.33	0.50	0.47	0.57	N/A	0.50	0.82	0.74	0.94	N/A	0.81

Table 10. Axle Load Statistics at WIM Station E124 in Mexico.

Axle Type			Steering					Single	Tandem				Tridem
Vehicle Class			C2	C3	T3S2	T3S3	T3S2R4	C2	C3	T3S2	T3S3	T3S2R4	T3S3
Mean (kip)			6.65	10.07	10.41	10.48	10.50	11.27	30.16	33.59	35.46	28.99	48.31
LSF	Power Order	4	0.03	0.13	0.13	0.13	0.13	0.31	1.07	1.48	1.77	1.00	1.55
		3	0.06	0.20	0.21	0.21	0.21	0.36	0.97	1.26	1.44	0.90	1.29
		2	0.15	0.33	0.34	0.35	0.35	0.45	0.91	1.11	1.22	0.86	1.13
		1	0.37	0.56	0.58	0.58	0.58	0.63	0.91	1.02	1.07	0.88	1.03

Table 11. Axle Load Statistics at WIM Station E125 in Mexico.

Axle Type			Steering					Single	Tandem				Tridem
Vehicle Class			C2	C3	T3S2	T3S3	T3S2R4	C2	C3	T3S2	T3S3	T3S2R4	T3S3
Mean (kip)			5.77	7.12	9.87	9.53	10.74	8.32	19.56	28.02	29.95	25.76	36.60
LSF	Power Order	4	0.03	0.07	0.12	0.09	0.13	0.24	0.67	1.41	1.49	0.72	0.96
		3	0.05	0.10	0.19	0.16	0.22	0.24	0.53	1.07	1.16	0.68	0.83
		2	0.12	0.19	0.32	0.29	0.36	0.29	0.49	0.89	0.97	0.69	0.76
		1	0.32	0.40	0.55	0.53	0.60	0.46	0.59	0.85	0.91	0.78	0.78

Table 12. Axle Load Statistics at WIM Station E126 in Mexico.

Axle Type			Steering					Single	Tandem				Tridem
Vehicle Class			C2	C3	T3S2	T3S3	T3S2R4	C2	C3	T3S2	T3S3	T3S2R4	T3S3
Mean (kip)			5.96	8.20	10.04	9.94	10.32	9.33	22.17	28.70	34.79	26.52	42.41
LSF	Power Order	4	0.03	0.09	0.12	0.12	0.12	0.29	0.62	1.17	2.09	0.79	1.25
		3	0.06	0.14	0.19	0.19	0.20	0.30	0.57	0.98	1.57	0.73	1.05
		2	0.13	0.24	0.32	0.31	0.34	0.35	0.57	0.88	1.24	0.73	0.93
		1	0.33	0.46	0.56	0.55	0.57	0.52	0.67	0.87	1.05	0.80	0.90

Table 13. Axle Load Statistics at WIM Station E127 in Mexico.

Axle Type			Steering					Single	Tandem				Tridem
Vehicle Class			C2	C3	T3S2	T3S3	T3S2R4	C2	C3	T3S2	T3S3	T3S2R4	T3S3
Mean (kip)			6.81	8.21	9.36	7.71	8.28	10.30	22.24	26.20	26.29	21.22	33.57
LSF	Power Order	4	0.03	0.07	0.09	0.04	0.05	0.23	0.44	0.68	0.48	0.32	0.32
		3	0.07	0.12	0.16	0.08	0.11	0.29	0.46	0.66	0.56	0.37	0.40
		2	0.16	0.22	0.28	0.19	0.22	0.38	0.53	0.70	0.66	0.47	0.53
		1	0.38	0.46	0.52	0.43	0.46	0.57	0.67	0.79	0.80	0.64	0.71

Table 14. Axle Load Statistics at WIM Station E128 in Mexico.

Axle Type			Steering					Single	Tandem				Tridem
Vehicle Class			C2	C3	T3S2	T3S3	T3S2R4	C2	C3	T3S2	T3S3	T3S2R4	T3S3
Mean (kip)			7.17	9.68	10.11	9.93	10.09	11.64	30.24	33.75	34.53	28.47	46.72
LSF	Power Order	4	0.05	0.10	0.11	0.10	0.11	0.36	1.01	1.35	1.48	0.82	1.21
		3	0.09	0.17	0.19	0.18	0.19	0.40	0.93	1.20	1.28	0.80	1.10
		2	0.18	0.30	0.32	0.31	0.32	0.48	0.90	1.09	1.14	0.80	1.03
		1	0.40	0.54	0.56	0.55	0.56	0.65	0.92	1.02	1.05	0.86	0.99

Table 15. Axle Load Statistics at WIM Station E129 in Mexico.

Axle Type			Steering					Single	Tandem				Tridem
Vehicle Class			C2	C3	T3S2	T3S3	T3S2R4	C2	C3	T3S2	T3S3	T3S2R4	T3S3
Mean (kip)			6.56	9.44	10.00	9.75	9.79	11.19	28.30	32.50	35.29	27.14	46.94
LSF	Power Order	4	0.03	0.10	0.11	0.10	0.10	0.34	0.85	1.33	1.69	0.79	1.33
		3	0.07	0.16	0.19	0.17	0.17	0.38	0.80	1.14	1.40	0.75	1.17
		2	0.15	0.29	0.32	0.30	0.30	0.46	0.80	1.03	1.20	0.75	1.06
		1	0.36	0.52	0.56	0.54	0.54	0.62	0.86	0.98	1.07	0.82	1.00

Table 16. Axle Load Statistics at WIM Station E130 in Mexico.

Axle Type			Steering					Single	Tandem				Tridem
Vehicle Class			C2	C3	T3S2	T3S3	T3S2R4	C2	C3	T3S2	T3S3	T3S2R4	T3S3
Mean (kip)			6.87	9.05	9.05	8.70	8.50	10.28	24.99	26.98	25.41	21.00	35.41
LSF	Power Order	4	0.05	0.08	0.08	0.08	0.06	0.30	0.58	0.71	0.64	0.20	0.58
		3	0.09	0.15	0.14	0.14	0.12	0.33	0.58	0.70	0.63	0.29	0.58
		2	0.17	0.27	0.26	0.25	0.23	0.40	0.64	0.73	0.66	0.42	0.63
		1	0.38	0.50	0.50	0.48	0.47	0.57	0.76	0.82	0.77	0.64	0.75

TRAFFIC LOAD CHARACTERISTICS COMPARISON BETWEEN TEXAS AND MEXICO

Differences in freight flow, economic activities, and regulations on legal axle load limits between Texas and Mexico are among the key factors attributed to different axle loading characteristics in Texas and Mexico, as the previous figures and tables clearly demonstrate. In particular, axle loading characteristics between the two countries differ in the following aspects:

- axle load distribution form,
- percentage overload,
- mean transported weight by each individual axle, and
- load-associated pavement damage.

A detailed comparison of load characteristics in accordance with these four aspects is discussed in the subsequent sections. Note that in order to minimize the effect of small sample size bias and geographical difference on traffic data, all available traffic data from all sections are pooled to obtain one sample for Texas and one for Mexico, respectively.

Axle Load Distribution Forms Comparison between Texas and Mexico

Figures 37 to 45 illustrate axle load distributions for each individual axle on each class of vehicle for the Texas and Mexico data, respectively. For steering axle, except truck class C3, all axle load distributions feature only one mode (one peak in the figure). Steering axle load distribution for C3 truck shows three peaks (tri-modal) in Texas and two peaks (bi-modal) in Mexico. For single axles, all axle loads from C2 trucks in Texas and Mexico have one mode, with that in Mexico being more evenly distributed. For tandem axles, all axle load distributions on different truck classes in Texas feature multiple modes, with the distributions of truck classes C3 and T3S2 showing bi-modal distributions. Axle load distributions in Mexico have multiple modes, one mode, and two modes for classes C3, T3S2, and T3S3, respectively. Furthermore, for non-steering axles (single, tandem, and tridem axles), the number of load distribution modes is an indication of how much cargo is transported by different vehicle classes and how well utilized the truck capacities are. For example, tandem axle load distributions featuring two significant modes imply that the left-side mode includes those axles with their capacity almost not utilized, while the right-side mode includes those axles with their capacity almost fully utilized.

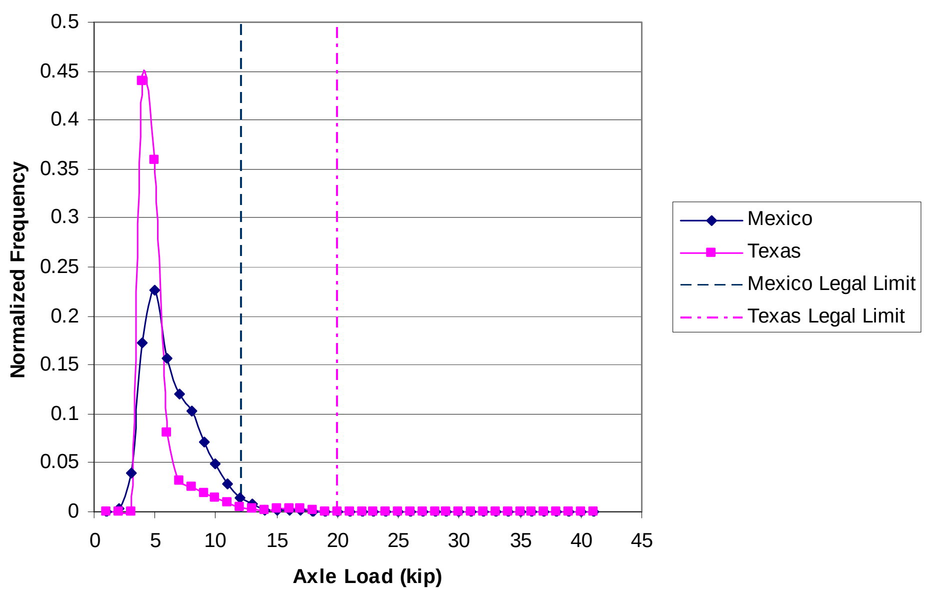


Figure 37. Truck Class C2 Steering Axle Load Distributions Comparison.

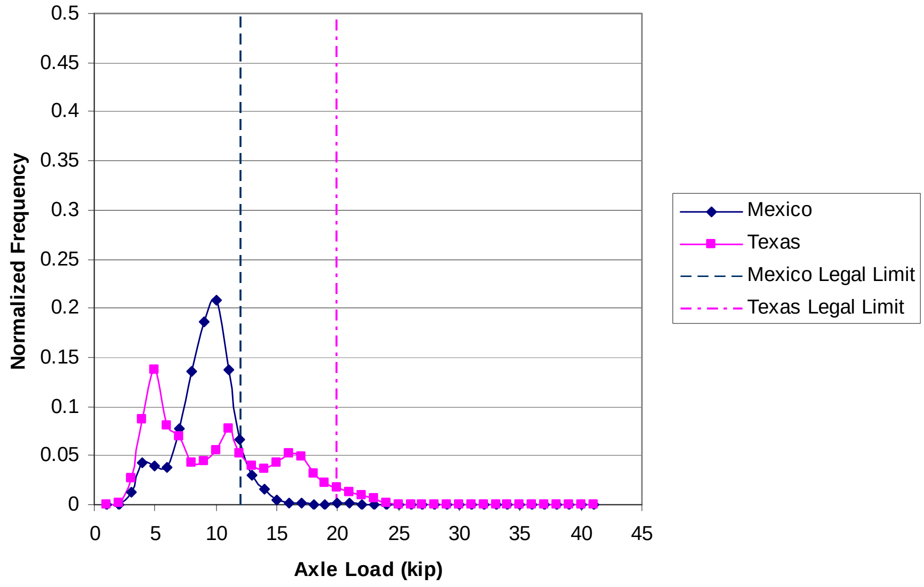


Figure 38. Truck Class C3 Steering Axle Load Distributions Comparison.

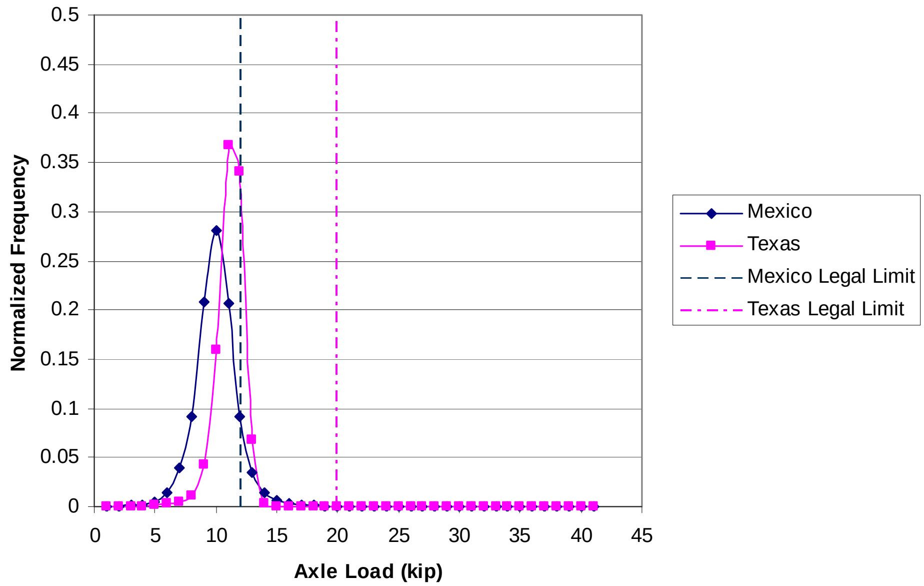


Figure 39. Truck Class T3S2 Steering Axle Load Distributions Comparison.

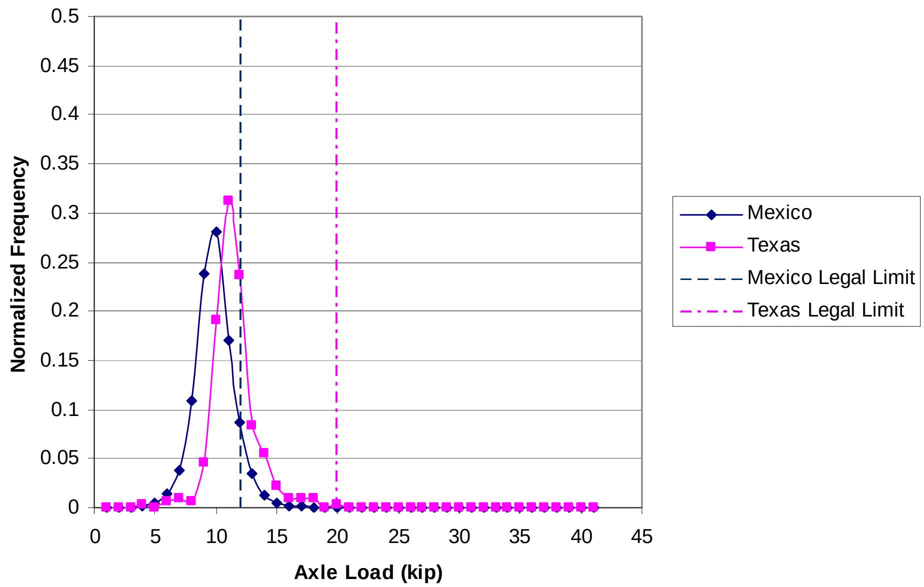


Figure 40. Truck Class T3S3 Steering Axle Load Distributions.

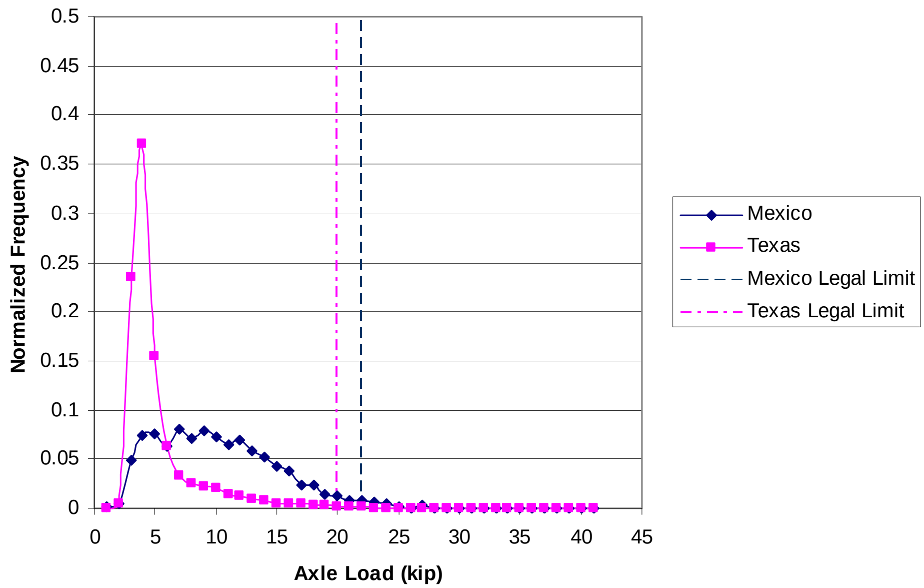


Figure 41. Truck Class C2 Single Axle Load Distributions Comparison.

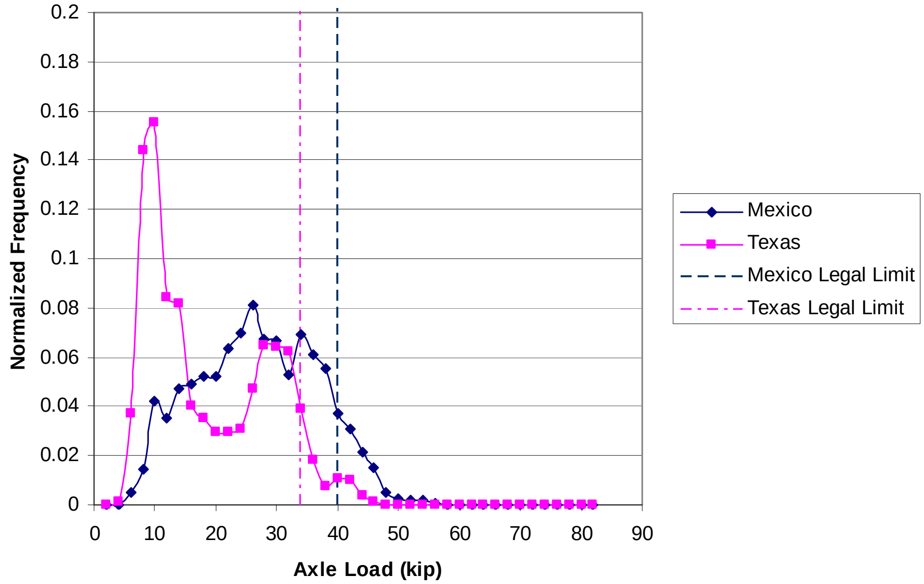


Figure 42. Truck Class C3 Tandem Axle Load Distributions Comparison.

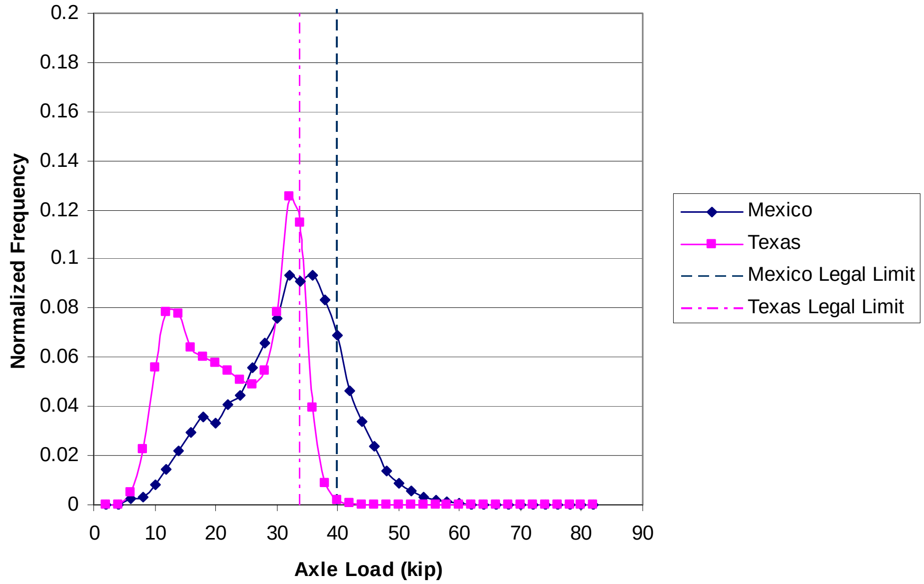


Figure 43. Truck Class T3S2 Tandem Axle Load Distributions Comparison.

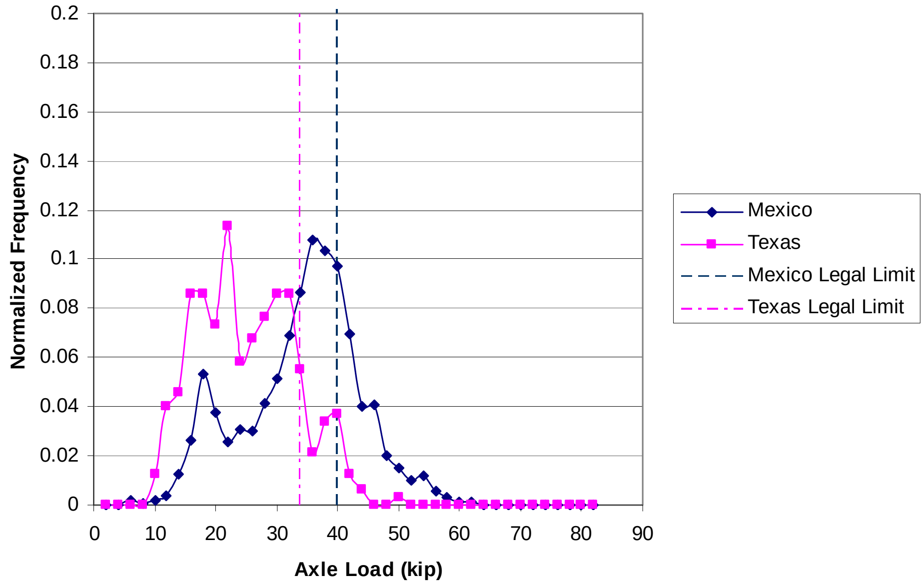


Figure 44. Truck Class T3S3 Tandem Axle Load Distributions Comparison.

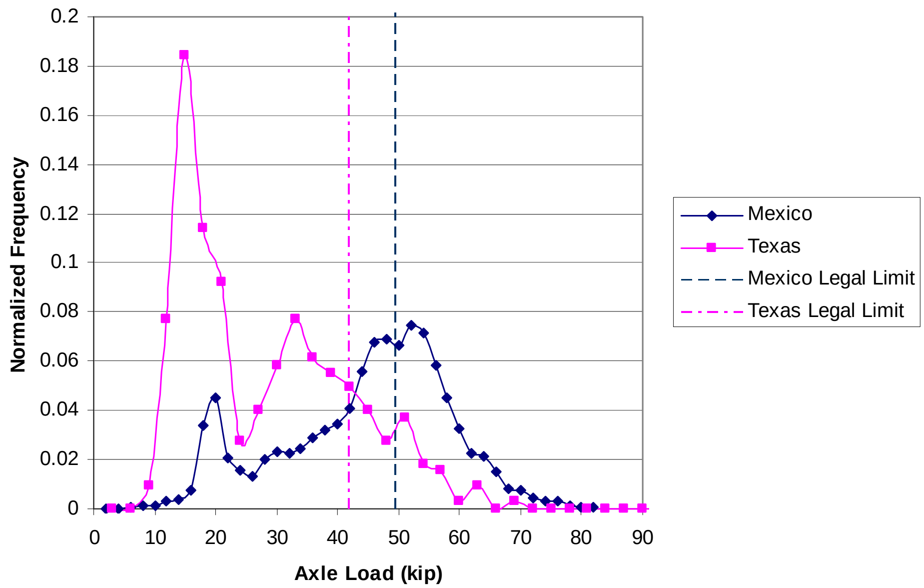


Figure 45. Truck Class T3S3 Tridem Axle Load Distributions Comparison.

Overload Percentage Comparison between Texas and Mexico

This section provides an analysis of the percentage of overloading in the traffic samples obtained from Texas and Mexico. Table 17 shows these percentages expressed in percentage of overloaded axles for different vehicle classes based on the sample data. Note that overloading is calculated without including any allowable tolerances or accounting for WIM measurement errors; therefore, actual overloading (as determined by static scales) may actually be lower than the values obtained from this sample.

Results indicate that overloading takes place in both Texas and Mexico, and the percentages of over-limit axles could be high for specific axle and vehicle types. For example, over-limit axles account for as much as 20.3 percent and 43.6 percent for tridem axles in Texas and Mexico, respectively. Second, for all axle types, overloading seems to be a slightly bigger issue in Mexico than in Texas. However, if tolerances are taken into account, overloading seems to be an issue limited to multiple axle configurations, i.e., tandem and tridem axles. Third, as the number of axles of various types increases, the percentage of over-limit axles increases.

Table 17. Sample Percentages of Axles Exceeding Legal Limits in Mexico and Texas.

Axle Type	Vehicle Classes							
	C2		C3		T3S2		T3S3	
	Texas	Mexico	Texas	Mexico	Texas	Mexico	Texas	Mexico
Steering	0.01	1.49	3.16	5.19	0.00	5.50	0.00	5.21
Single	0.27	1.76	-	-	-	-	-	-
Tandem	-	-	5.28	7.88	5.14	13.9	11.3	21.8
Tridem	-	-	-	-	-	-	20.3	43.6

Comparison of Axle Load Distribution Statistics

Tables 18 and 19 provide a series of pavement damage related statistics for all types of axles of all classes of trucks in Texas and Mexico, respectively. It can be seen that all summary statistics vary among axle types because of their different transport capacities and also vary among vehicle classes because of their different transport functions. For steering axles, the mean load and LSF for a given truck class is larger in Texas than in Mexico, which can be attributed to the higher legal steering load limit in the United States than in Mexico. The opposite is true for single, tandem, and tridem axles; higher mean axle loads and LSFs can be found in Mexico due to the higher legal load limits.

Table 18. Axle Load Statistics Based on Data from WIM Stations in Texas.

Axle Type			Steering				Single	Tandem			Tridem
Vehicle Class			C2	C3	T3S2	T3S3	C2	C3	T3S2	T3S3	T3S3
Mean (kip)			5.20	10.23	11.17	11.46	5.20	18.72	23.43	25.10	28.11
LSF	Power Order	4	0.02	0.31	0.16	0.19	0.04	0.33	0.47	0.56	0.35
		3	0.04	0.34	0.25	0.28	0.06	0.36	0.50	0.58	0.38
		2	0.10	0.41	0.39	0.42	0.11	0.41	0.57	0.64	0.44
		1	0.29	0.57	0.62	0.64	0.29	0.57	0.71	0.76	0.60

Table 19. Axle Load Statistics Based on Data from WIM Stations in Mexico.

Axle Type			Steering					Single	Tandem				Tridem
Vehicle Class			C2	C3	T3S2	T3S3	T3S2R4	C2	C3	T3S2	T3S3	T3S2 R4	T3S3
Mean (kip)			6.40	9.11	10.00	9.89	10.17	10.14	26.80	31.58	34.11	27.54	44.66
LSF	Power Order	4	0.03	0.10	0.11	0.11	0.12	0.30	0.82	1.27	1.68	0.84	1.26
		3	0.07	0.16	0.19	0.18	0.19	0.32	0.76	1.10	1.36	0.78	1.09
		2	0.14	0.27	0.32	0.31	0.33	0.39	0.75	1.00	1.15	0.78	0.99
		1	0.36	0.51	0.56	0.55	0.56	0.56	0.81	0.96	1.03	0.83	0.95

Based on axle load distribution statistics and axle configurations for different vehicles, weight statistics for the individual vehicles can also be calculated. For example, for the dominant vehicle type, the T3S2, its mean weight is equal to the mean weight of steering for class T3S2 (Table 19) plus the mean weight of a tandem multiplied by 2. The LSFs can be calculated for the various powers (i.e., 1 to 4) in the same manner. Using this calculation method, Table 20 presents the calculated class-based load statistics. In general, LSFs are larger in Mexico than in Texas due to the higher axle load limits that are applied in Mexico. However, it is important to note that as Mexican trucks enter the United States they have to comply with local load limits and, consequently, the LSF will reduce to values on par with those prevailing in Texas. Should Mexican trucks operate in Texas in accordance with the same truck class distribution as they do in Mexico, the damage per truck (LSF) will be lower because, for the same cargo, T3S3 is friendlier to the pavement than T3S2, and T3S2R4 is friendlier to the pavement than two T3S2 trucks. This is further explained in the next paragraphs.

Table 20. Class-Based Load Statistics Comparison between Texas and Mexico.

			Vehicle Classes									
Vehicle Class			C2		C3		T3S2		T3S3		T3S2R4	
Location			Texas	Mexico	Texas	Mexico	Texas	Mexico	Texas	Mexico	Texas	Mexico
Mean (kip)			10.4	16.5	28.9	35.9	58.0	73.2	64.7	88.6	-	120
LSF	Power Order	4	0.07	0.33	0.64	0.91	1.09	2.66	1.11	3.04	-	3.48
		3	0.10	0.39	0.69	0.92	1.25	2.39	1.23	2.63	-	3.32
		2	0.21	0.54	0.82	1.03	1.54	2.31	1.49	2.45	-	3.43
		1	0.58	0.92	1.14	1.32	2.04	2.47	2.00	2.53	-	3.90

As shown in Figures 17 and 18, comparing Mexico and Texas vehicle classification schemes, truck class T3S2R4 in Mexico is not allowed in Texas. This type of vehicle accounts for around 7.9 percent of the five typical truck classes in Mexico (see Figure 46). If the cargo on T3S2R4 needs to be transported into Texas, it should be transferred to other types of trucks that are allowed in Texas. To address this, Figure 47 proposes a hypothetical scenario that suggests that the same amount of cargo carried by a T3S2R4 truck can be equivalently carried by two T3S2 trucks. As a result, compared with T3S2R4, one more steering axle (from tractor) should be accounted for in calculating this vehicle's load-associated damage on the highway infrastructure. In this case the equivalent damage of one T3S2R4 would range from 2.04 to 3.46, while the damage caused by two T3S2 trucks would range from 2.20 to 4.08. It should be noted that these equivalent damage estimates are based on pavement damage and do not take into account the potential effect on bridges and other structures.

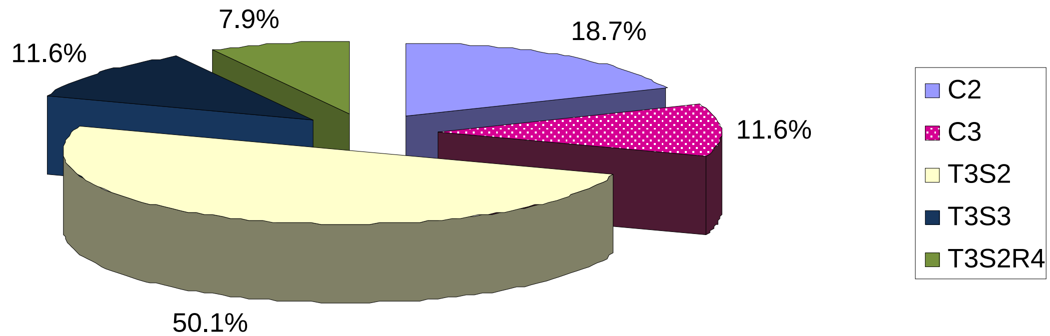


Figure 46. Traffic Volume Percentages among Five Truck Classes in Mexico.

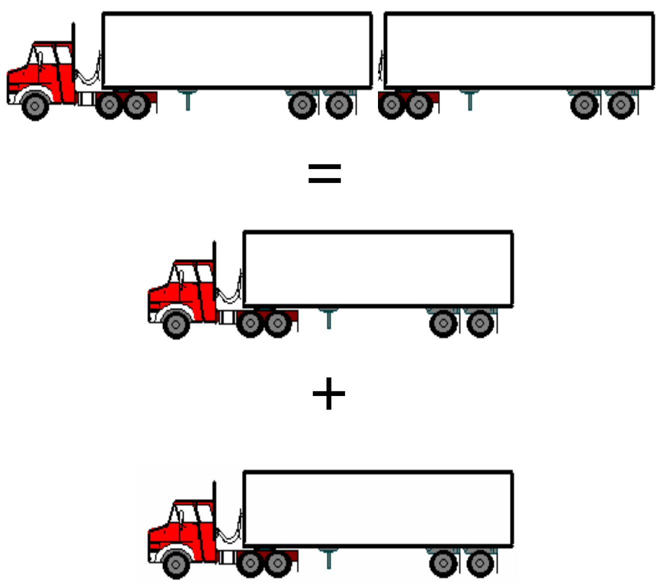


Figure 47. Hypothetical Scenario to Convert a T3S2R4 to Two T3S2 Trucks.

Another important benefit to the pavement infrastructure could be the result of an increased proportion of six-axle trucks (T3S3). Since the maximum gross vehicle weight allowed in Texas is 80,000 lb, a fully loaded T3S2 would cause more damage to the pavement than a fully loaded T3S3. It is not anticipated that T3S3 vehicles at 80,000 lb will become widespread in Texas since the additional axle weight (compared to T3S2) would reduce the allowable payload, all other factors equal. However, benefits will accrue from six-axle trucks that adhere to the 80,000 lb limit. The extent of this benefit will depend on a number of factors including the particular characteristics of the highway and the region. This important aspect should be quantified because it implies potentially significant savings in maintenance and rehabilitation. This quantification, however, is beyond the scope of this research project.

CHAPTER SUMMARY FINDINGS

This chapter investigates truck traffic load characteristics in Texas and Mexico based on sample data collected from WIM stations on both sides of the border. Traffic load characteristics in terms of different statistics based on axle load distributions for typical trucks were estimated. The load characteristics differ significantly between Texas and Mexico due to their different regulations (legal load limit) and socioeconomic conditions. The major findings are summarized as follows.

- Except for steering axles, all axle load distributions have higher mean weight in Mexico than in the United States (Texas) due to the different regulations prevailing in each country.
- Regarding over-limit axle loads, except for steering axles, the load distributions generally exhibit higher over-limit axle percentages in Mexico than in Texas.
- For typical payload-carrying axles (e.g., tandem and tridem axles), the mean weight in Mexico is around 35 percent to 60 percent heavier than in Texas.
- For four typical truck classes common to both Texas and Mexico, the mean vehicle weight in Mexico is heavier than in Texas by an order of about 24 percent to 60 percent.
- As Mexican trucks are allowed in Texas, they have to comply with the local axle load limits. In this case and assuming that the class distribution remains similar, the damage per truck to the road infrastructure could be reduced, primarily due to the increased use of six-axle trucks.

CHAPTER 6: CONCLUSIONS

The USDOT pilot program allows a small number of Mexican trucking companies to operate beyond the commercial zones to anywhere in the United States. It is believed that if proved successful this pilot program will eventually result in the opening of the border to all approved and certified OP-1 permit holders. TxDOT Research Project 0-5339 surveyed a sample of Mexican truck carriers that have applied to operate beyond the commercial zones, as well as investigated some of the issues surrounding the different truck configuration and permissible axle loads in Mexico and the United States. The most important findings, as documented in Chapter 3, revealed that:

- 31 percent of the Mexican companies interviewed have their headquarters in the United States,
- the majority of respondents (around 65 percent) were smaller Mexican trucking companies operating 10 or fewer trucks and/or trailers, including seven responses that indicated they currently use vans/pickups to transport commodities,
- almost half of the companies interviewed (18 respondents) anticipated 10 trips or fewer per week across the border and most respondents (55 percent of the responses) indicated a U.S. border state when asked about the major U.S. destinations for the commodities that the company will be transporting to the United States,
- almost half the respondents (16 companies) have truck fleets that are five or fewer years old and most respondents were planning on using their existing fleet to operate into the United States once the border opens, and
- the most common (57 percent) truck configuration is the T3-S2 (5 axles with 18 tires). This is also by far the most popular long distance haul vehicle used in the United States. A relatively higher invalid and non-response rate was observed for the questions relating to tire types and tire inflation pressures, but in general the tire types used are the same tire types that are used in the United States and the provided tire inflation pressures would meet U.S. standards. These types of survey responses can be very useful in performing analyses about the infrastructure impacts of Mexican trucking companies on the Texas road infrastructure once the border opens.

The other important dimension to this study was evaluation of the potential impacts on the pavement infrastructure if subjected to different axle loads and configurations. To this effect, sample WIM data from Texas and Mexico were collected, processed, and analyzed. This analysis used the concept of LSF, which is an extension to the commonly known LEF that is applied for the determination of ESALs. The LSF-based method offers a series of advantages when compared with the LEF-based method because it is more general and applies to a wider range of conditions. It was found that load-pavement impact can be expressed as a moment related statistic of the axle load probability density function (axle load spectrum). The results suggested that mixed lognormal distributions are most likely to be "the best" distribution family to represent observed axle load spectra.

The comparative analysis showed that the load characteristics differ significantly between Texas and Mexico due to their different regulations (legal load limit) and socioeconomic conditions. Due to higher legal load limits in Mexico, average axle loads and gross vehicle weights are higher. However, as Mexican trucks are allowed into Texas, they have to comply with the local axle load limits. In this case and assuming that the class distribution remains similar, the damage per truck to the road infrastructure could be reduced, primarily due to the increased use of six-axle trucks. An issue that remains to be resolved is the damage equivalency between five- and six-axle trucks.

Tremendous uncertainty and thus speculation exists about the impacts of the Mexican trucking companies on the Texas infrastructure and the U.S. economy. This is evident from the lack of support to open the border. This research showed that although Mexican trucks traversing Texas infrastructure will have to comply with the local axle load limits, some truck configurations currently not popular in Texas – although legal – could become more common, such as the six-axle truck. This could actually benefit the Texas road network since 80,000 lb on a six-axle truck is less damaging to the pavement than the same load on a five-axle truck. The extent of this benefit – if it materializes – is currently unknown and variable and should be determined for local pavement types and environmental conditions. In addition, Mexican and U.S.-based companies tend to load their fleets differently, resulting in different axle load spectra. The "form" of these axle load spectra directly relates to the rate of road infrastructure damage. There is thus a need to both characterize the Mexican truck companies that traverse the Texas infrastructure (i.e., those participating in the pilot program) and those that will traverse the Texas infrastructure (i.e., those that have applied for the OP-1 permit) in terms of company size, number of cross-border trips, equipment type, and loading practices, and to determine the resulting infrastructure impacts of these truck loads. The research team thus recommends that TxDOT fund subsequent research to survey the Mexican trucking companies that are participating in the USDOT pilot program, as well as those that have applied for the OP-1 permit. Based on this information (actual data from those Mexican trucking companies included in the pilot program) and the survey responses of those that anticipate operating across the border, researchers can characterize Mexican trucking companies and calculate the impacts of these Mexican truck companies on Texas' infrastructure.

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APPENDIX: DATA NEEDED

In the first year of this research study – between January and June of 2006 – the CTR research team interviewed 14 individuals from seven TxDOT divisions and three districts to identify the NAFTA truck related data and information required by TxDOT for transportation planning and infrastructure management. For the purpose of this study, a NAFTA truck was defined as a commercial vehicle coming from or going to Mexico. The major findings of this effort were reported in Technical Report 0-5339-1 entitled "Integration and Consolidation of Border Freight Transportation Data for Planning Applications and Characterization of NAFTA Truck Loads for Aiding in Transportation Infrastructure Management: First Year." However, the research team recommended that additional interviews be conducted to obtain input from the Transportation Planning and Programming Division[6] and additional district staff. Also, the research team wanted to see if the responses changed when the interviewees are provided with a list of NAFTA truck data variables that are collected and could be made available for transportation planning purposes. This Appendix summarizes the major findings of this second round of interviews.

SURVEY METHODOLOGY

The Project Monitoring Committee (PMC) provided the research team with a list of additional TxDOT Division and District staff to interview about the uses and needs for NAFTA truck data. The research team subsequently conducted telephone interviews with individuals from the following divisions and districts:

- Transportation Planning and Programming Division (Austin),
- Bridge Division (Austin),
- Pharr District (Transportation Planning and Programming, Maintenance, Construction),
- San Antonio District (Transportation Planning and Programming, Maintenance, Construction), and

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[6] At the direction of the PMC, the research team did not interview staff from the Transportation Planning and Programming (TPP) Division and major Metropolitan Planning Organizations (MPOs), as most of the key personnel interested and involved with truck travel data were interviewed in 2003 as part of TxDOT Research Project 0-4713. However, when the results of the first round of interviews were presented to the PMC, the need to interview TPP staff specifically about their needs and use of NAFTA truck data became obvious.

- Laredo District (Transportation Planning and Programming, Design, Maintenance, Construction).

Telephone interviews were conducted to minimize respondent burden. The questionnaire that was used for the survey is included at the end of this Appendix. Table A.1 summarizes the number of responses received by TxDOT job function or title.

Table A.1. Number of Responses by TxDOT Job Function/Title.

Job Function/Title	Number of Responses
Bridge Inspection Branch Manager	1
District: Construction Director	2
District: Maintenance Director	1
Travel Survey Program Manager	1
Engineering Tech IV	1
Program Manager	1
Transportation Analysis Branch Manager	1
District – Transportation Planning & Development (TP&D)	2
District: Advanced Planning Director	1

INTERVIEW FINDINGS

Use of NAFTA Truck Information

Table A.2 summarizes the interview responses for the questions about whether interviewees use NAFTA truck information and what specific NAFTA truck data they use. As is evident from Table A.2 (and similar to the results obtained during the first round of interviews), most of the TxDOT staff interviewed do not use NAFTA data. The only exceptions were one respondent from the Laredo District and one respondent from the Transportation Planning and Programming (TPP) Division in Austin. The Laredo District uses NAFTA data concerning the following on a regular basis (i.e., once per month):

- trip purpose,
- truck crossing volume,
- truck origin,
- truck destination, and
- truck type.

The respondent from the TPP Division has used the following NAFTA truck data once or twice per year:

- trip purpose,
- commodity,
- truck crossing volume,
- truck origin,
- truck destination,
- U.S. port of entry,
- routing,
- shipment weight,
- shipment value, and
- mode of transportation.

None of the interviewees indicated that they use any additional NAFTA truck data variables.

Table A.2. NAFTA Truck Data Used by TxDOT Staff Interviewed.

Respondent	NAFTA Data Use		NAFTA Truck Data Variables										
	No	Yes	Trip Purpose	Commodity	Truck Crossing Volume	Origin	Destination	US Port of Entry	Routing	Shipment Weight	Shipment Value	Mode of Transport	Truck Type
Bridge Division	✓												
Laredo District_1	✓												
Laredo District_2		✓	✓		✓	✓	✓						✓
San Antonio District_1	✓												
San Antonio District_2	✓												
TPP_1	✓												
TPP_2													
TPP_3	✓												
TPP_4	✓												
TPP_5		✓	✓*	✓		✓	✓	✓	✓	✓	✓	✓	

Typically, the data used by TPP are collected during specific studies undertaken primarily by consultants. The Laredo District obtains NAFTA related truck information from TPP (traffic volumes), Texas A&M University (number of truck crossings), and the Laredo Development Foundation.

NAFTA Truck Data Collected by TxDOT

Three respondents from TPP indicated that they collect NAFTA truck data. One respondent indicated that NAFTA truck data are typically collected as part of specific consultancy studies (as mentioned earlier). Another respondent from TPP indicated that NAFTA truck data on weight, cargo, origin, and destination are collected. The other respondent from TPP remarked that WIM data are being collected at each of the Border Safety Inspection Facilities from each truck entering the United States from Mexico. However, TxDOT only collects these data and passes them on within 24 hours to the Texas Department of Public Safety (DPS). None of the other respondents indicated that they collect any NAFTA truck data (see Table A.3).

Table A.3. NAFTA Truck Data Collected by TxDOT.

Respondent	Collect NAFTA Data		NAFTA Truck Data Variables							
	No	Yes	Shipment Weight	Commodity	Origin	Destination	Trip Purpose	U.S. Port of Entry	Routing	Shipment Value
Bridge Division	✓									
Laredo District_1	✓									
Laredo District_2	✓♦									
San Antonio District_1	✓									
San Antonio District_2	✓									
TPP_1		✓	✓	✓	✓	✓				
TPP_2		✓*								
TPP_3	✓									
TPP_4	✓									
TPP_5		✓**	✓	✓	✓	✓	✓	✓	✓	✓
Pharr District	✓									
San Antonio District_3	✓									

* TxDOT collects WIM data for all trucks entering the U.S. from Mexico at each of the eight Border Safety Inspection Facilities (BSIFs). However, TxDOT does not retain it for more than 24 hours before it is passed on to DPS.

** Primarily special studies done by consultants

♦ Obtain volume data from TPP, remaining NAFTA truck data obtained from Texas A&M University National Border Indicators program

STRENGTHS AND WEAKNESSES OF CURRENT NAFTA TRUCK INFORMATION

The only strength that was listed by the respondents was that the data collected by TPP's Travel Survey Program do identify whether a truck is moving cargo destined for or originating in Mexico, i.e., a NAFTA truck. Many of the respondents expressed concerns about the available NAFTA truck information. Table A.4 summarizes the weaknesses that were recorded during the interviews.

Table A.4. Weaknesses of Available NAFTA Truck Information.

Weaknesses
1. Data collected by TPP's Travel Survey Program identify cargo origin, but destinations tend to be multiple
2. "Do not know what a NAFTA truck is"
3. Data not readily available – have to access multiple sources to obtain data
4. Not clear how to distinguish drayage and long-haul truck movements – not good information on drayage operations
5. No clear understanding of terminal hours and thus understanding of temporal distributions
6. Not clear what percentage of total trucks is NAFTA trucks
7. Origin/Destination data are weak. Need more disaggregate origin and destination data (by zone) to address bottlenecks

NEED FOR NAFTA TRUCK INFORMATION

All respondents were asked whether they have a need for NAFTA truck data other than what they were already using. Table A.5 summarizes the information gleaned from those interviewed when asked what NAFTA truck data variables they need or would want to have access to. From Table A.5, it is evident that the Bridge Division, Laredo District, and San Antonio District indicated the largest need for NAFTA truck data.

The Bridge Division representative is the only TxDOT staff person that participated in both rounds of surveys. During the first round of surveys, the Bridge Division indicated that they need the following NAFTA truck information annually: number of trucks, truck weight, axle weight, and axle spacings. During the second round of surveys – when each respondent was presented with a list of available NAFTA truck data variables – the Bridge Division representative indicated the need to have access to the following additional NAFTA truck data variables: truck (tractor) license issuing state, trailer license issuing state, truck types, equipment (trailer) length, origin, destination, U.S. port of entry, routing, and shipment weight.

Representatives from the TPP Division did not indicate a need for additional NAFTA truck data besides what they are already using.

Table A.5. NAFTA Truck Data Needed by TxDOT Staff Interviewed.

NAFTA Truck Data Variables	Respondent					
	Bridge	LD_1*	LD-2	SA_2	Pharr**	SA_3 ***
Truck (Tractor) License Issuing State	✓			✓		
Tractor VIN		✓				
Tractor Registration				✓		
Trailer License Issuing State	✓			✓		
Gross Weight	✓	✓		✓		
Group Weight (Axle Weight and Axle Spacings)	✓			✓		
Truck Types	✓			✓		
Hazardous Materials Indicator		✓		✓		
Equipment (Trailer) Length	✓	✓		✓		
Height		✓				
Driver HazMAT Authorization				✓		
Truck Crossing Volume	✓			✓		
Commodity				✓		
Origin	✓		✓	✓		
Destination	✓	✓	✓	✓		
U.S. Port of Entry	✓		✓	✓		
Routing	✓		✓			
Shipment Weight	✓					
Hazardous Materials Code				✓		

LD: Laredo District
SA: San Antonio District
* This respondent did not need any NAFTA truck data, but indicated that the Director of Maintenance needs the following NAFTA truck data when issuing oversize/overweight permits.
** This respondent has used NAFTA truck data in the past to define truck routes.
*** This respondent mentioned that the MPO is the one who might be interested in NAFTA truck data.

CONCLUDING REMARKS

The survey findings during the second round of interviews were to a large extent similar to the findings during the first round of interviews. Some respondents definitely expressed a need for comprehensive, current, and accurate NAFTA data. According to the Laredo respondent, NAFTA data and specifically truck volumes entering Texas are very important for all projects proposed for innovative financing. Although fewer than half of the respondents indicated a need for additional NAFTA truck data, most respondents were more concerned about the quality and detail of available data than in collecting additional NAFTA truck data.

NAFTA Truck Data Survey

Thank you for helping with this survey about the uses and needs of NAFTA truck data by the Texas Department of Transportation. You are part of a carefully selected sample that has been asked to assist with this survey, and we appreciate your time. Your answers will help us understand how NAFTA truck information is utilized in Texas. As with all surveys we conduct, your responses are confidential. Should you have any difficulties in responding or have questions about our project please contact Jolanda Prozzi by email (jpprozzi@mail.utexas.edu) or by phone (512-232-3079).

NAFTA Truck Data Survey

These questions are asked to understand how NAFTA truck information is used within the Texas Department of Transportation and to gain your perspective on the current data available to you. For our purposes, a NAFTA truck is a truck (empty or loaded) that moves cargo destined for or originating in Mexico. The survey first asks about data you currently use followed by data you need but don't have.

1. Do you use NAFTA truck information?

☐ Yes ☐ No

If yes, which of the following NAFTA truck data variables do you currently use?

NAFTA Truck Data Variables	Do Not Use	Use
Carrier Information		
Carrier Name	☐	☐
SCAC #	☐	☐
USDOT #	☐	☐
TxDOT #	☐	☐
Insurance Information	☐	☐
Nationality of Owner	☐	☐
Conveyance		
Truck (Tractor) License Plate #	☐	☐
Issuing State	☐	☐
Tractor VIN	☐	☐
Tractor Make	☐	☐
Tractor Model/Year	☐	☐
Tractor Registration	☐	☐
Tractor Fuel Tax	☐	☐
Trailer License P1 #	☐	☐
Issuing State	☐	☐
Trailer Identification	☐	☐
Trailer Registration	☐	☐
Gross Weight	☐	☐
Group Weight (Axle Weight and Axle Spacings)	☐	☐
Truck Type	☐	☐

Fuel Type	☐	☐
Transponder	☐	☐
Hazardous Materials Indicator	☐	☐
Conveyance Empty Indicator	☐	☐
Equipment (Trailer) Length	☐	☐
Driver Information		
Name	☐	☐
Date of Birth	☐	☐
Contact Information	☐	☐
CDL #	☐	☐
CDL Country of Issuance	☐	☐
CDL State of Issuance	☐	☐
Citizenship	☐	☐
Employment/ Criminal History	☐	☐
HazMat Authorization	☐	☐
Trip Characteristics		
Trip Purpose	☐	☐
Truck Crossing Volume	☐	☐
Commodity	☐	☐
Origin	☐	☐
Destination	☐	☐
U.S. Port of Entry	☐	☐
Routing	☐	☐
Shipment Weight	☐	☐
Shipment Value	☐	☐
Containerized Shipment	☐	☐
Mode of Transport	☐	☐
Hazardous Materials Code	☐	☐

2. Do you use any additional NAFTA truck data variables?

☐ Yes ☐ No

If yes, please list any additional NAFTA truck data variables that you use.

3. Of those NAFTA truck data variables that you do use, what is the frequency of your use?

NAFTA Truck Data Variables	Less than once a year	1 or 2 times a year	3 or 4 times a year	Once a month	More than once a month
Carrier Information					
Carrier Name	☐	☐	☐	☐	☐
SCAC #	☐	☐	☐	☐	☐
USDOT #	☐	☐	☐	☐	☐
TxDOT #	☐	☐	☐	☐	☐
Insurance Information	☐	☐	☐	☐	☐
Nationality of Owner	☐	☐	☐	☐	☐
Conveyance	☐	☐	☐	☐	☐
Truck (Tractor) License Plate #	☐	☐	☐	☐	☐

Issuing State	☐	☐	☐	☐	☐
Tractor VIN	☐	☐	☐	☐	☐
Tractor Make	☐	☐	☐	☐	☐
Tractor Model/Year	☐	☐	☐	☐	☐
Tractor Registration	☐	☐	☐	☐	☐
Tractor Fuel Tax	☐	☐	☐	☐	☐
Trailer License P1 #	☐	☐	☐	☐	☐
Issuing State	☐	☐	☐	☐	☐
Trailer Identification	☐	☐	☐	☐	☐
Trailer Registration	☐	☐	☐	☐	☐
Gross Weight	☐	☐	☐	☐	☐
Group Weight (Axle Weight and Axle Spacings)	☐	☐	☐	☐	☐
Truck Type	☐	☐	☐	☐	☐
Fuel Type	☐	☐	☐	☐	☐
Transponder	☐	☐	☐	☐	☐
Hazardous Materials Indicator	☐	☐	☐	☐	☐
Conveyance Empty Indicator	☐	☐	☐	☐	☐
Equipment (Trailer) Length	☐	☐	☐	☐	☐
Driver Information					
Name	☐	☐	☐	☐	☐
Date of Birth	☐	☐	☐	☐	☐
Contact Information	☐	☐	☐	☐	☐
CDL #	☐	☐	☐	☐	☐
CDL Country of Issuance	☐	☐	☐	☐	☐
CDL State of Issuance	☐	☐	☐	☐	☐
Citizenship	☐	☐	☐	☐	☐
Employment/ Criminal History	☐	☐	☐	☐	☐
HazMat Authorization	☐	☐	☐	☐	☐
Trip Characteristics					
Trip Purpose	☐	☐	☐	☐	☐
Truck Crossing Volume	☐	☐	☐	☐	☐
Commodity	☐	☐	☐	☐	☐
Origin	☐	☐	☐	☐	☐

Destination	☐	☐	☐	☐	☐
U.S. Port of Entry	☐	☐	☐	☐	☐
Routing	☐	☐	☐	☐	☐
Shipment Weight	☐	☐	☐	☐	☐
Shipment Value	☐	☐	☐	☐	☐
Containerized Shipment	☐	☐	☐	☐	☐
Mode of Transport	☐	☐	☐	☐	☐
Hazardous Materials Code	☐	☐	☐	☐	☐

4. Where do you get the NAFTA truck data that you use?

5. Do you collect any NAFTA truck data?

☐ Yes ☐ No

If yes, what NAFTA truck data do you collect?

6. In your opinion, what are the strengths and weaknesses of the current NAFTA truck information available to you?

7. Do you have a need for NAFTA truck data other than what you are already using?

☐ Yes ☐ No

If yes, which of the following NAFTA truck data variables do you need?

NAFTA Truck Data Variables	Do Not Need	Need
Carrier Information		
Carrier Name	☐	☐
SCAC #	☐	☐
USDOT #	☐	☐
TxDOT #	☐	☐
Insurance Information	☐	☐
Nationality of Owner	☐	☐
Conveyance		
Truck (Tractor) License Plate #	☐	☐
Issuing State	☐	☐
Tractor VIN	☐	☐
Tractor Make	☐	☐
Tractor Model/Year	☐	☐
Tractor Registration	☐	☐
Tractor Fuel Tax	☐	☐
Trailer License P1 #	☐	☐
Issuing State	☐	☐
Trailer Identification	☐	☐

Trailer Registration	☐	☐
Gross Weight	☐	☐
Group Weight (Axle Weight and Axle Spacings)	☐	☐
Truck Types	☐	☐
Fuel Type	☐	☐
Transponder	☐	☐
Hazardous Materials Indicator	☐	☐
Conveyance Empty Indicator	☐	☐
Equipment (Trailer) Length	☐	☐
Driver Information		
Name	☐	☐
Date of Birth	☐	☐
Contact Information	☐	☐
CDL #	☐	☐
CDL Country of Issuance	☐	☐
CDL State of Issuance	☐	☐
Citizenship	☐	☐
Employment/ Criminal History	☐	☐
HazMat Authorization	☐	☐
Trip Characteristics		
Trip Purpose	☐	☐
Truck Crossing Volume	☐	☐
Commodity	☐	☐
Origin	☐	☐
Destination	☐	☐
U.S. Port of Entry	☐	☐
Routing	☐	☐
Shipment Weight	☐	☐
Shipment Value	☐	☐
Containerized Shipment	☐	☐
Mode of Transport	☐	☐
Hazardous Materials Code	☐	☐

8. What is your job function/title?

Thank you for your assistance with this questionnaire. If you have any questions about this questionnaire or the project, please contact

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or
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