Technical Memorandum

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PROJECT TITLE:	Study Concerning Vehicles Operating under Intermodal Shipping Container Permit
SUBJECT:	Study in Response to Senate Bill 1524
DATE:	September 1st, 2022

This Technical Memorandum was prepared in collaboration between the Texas Department of Transportation (TxDOT), the Texas Department of Motor Vehicles (TxDMV), the University of Texas at Austin (UT Austin) and the University of Texas at San Antonio (UTSA) in response to Senate Bill 1524 of the 85th Texas Legislative Session

Senate Bill 1524 (SB1524)

This study was conducted to evaluate the impact of permits issued under the provisions of Senate Bill 1524 (SB1524) of the 85th Texas Legislative Session and implemented under Texas Transportation Code, Chapter 623: Permits for Oversize or Overweight Vehicles. SB1524 relates to the movement of vehicles transporting an intermodal shipping container. An intermodal shipping container is defined as an enclosed, standardized, reusable container that: (i) is used to pack, ship, move, or transport cargo, (ii) is designed to be carried on a semitrailer and loaded onto or unloaded from a ship or vessel for international transportation or a rail system for international transportation, and (iii) when combined with vehicles transporting the container, has a gross weight or axle weight that exceeds the limits allowed by law to be transported over a state highway or county or municipal road.

The bill authorized the Texas Department of Motor Vehicles (TxDMV) to issue a $6,000 annual permit authorizing the movement of a sealed intermodal shipping container moving in international transportation by a truck-tractor and semitrailer combination that fit one of the two following configurations:

- A truck-tractor and semitrailer combination with six total axles that is equipped with a roll stability support safety system and truck blind spot systems and operates with a gross weight of the combination not exceeding 93,000 pounds and that meets the following criteria:
    - The distance between the front axle of the truck-tractor and the last axle of the semitrailer is approximately 647 inches,
    - The truck-tractor is configured as follows: one single axle that does not exceed 13,000 pounds; one two-axle group that does not exceed 37,000 pounds, in which no axle in the group exceeds 18,500 pounds; and the distance between the individual axles on the two-axle group of the truck-tractor is not less than 51 inches and not more than 52 inches, and
    - The semitrailer is configured as follows: one three-axle group that does not exceed 49,195 pounds, in which no axle in the group exceeds 16,400 pounds; and the distance between the individual axles in the three-axle group of the semitrailer is 60 inches.
- A truck-tractor and semitrailer combination with seven total axles that is equipped with a roll stability support safety system and truck blind spot systems and operates with a gross weight of the combination not exceeding 100,000 pounds and that meets the following criteria:
    - The distance between the front axle of the truck-tractor and the last axle of the semitrailer is approximately 612 inches,
    - The truck-tractor is configured as follows: one single axle that does not exceed 15,000 pounds; one three-axle group that does not exceed 44,500 pounds, in which no axle in the group exceeds 14,900 pounds; and the distance between the individual axles on the three-axle group of the truck-tractor is not less than 51 inches and not more than 52 inches, and
    - The semitrailer is configured as follows: one three-axle group that does not exceed 46,200 pounds, in which no axle in the group exceeds 15,400 pounds; and the distance between the individual axles in the three-axle group of the semitrailer is 60 inches.

The transportation of a sealed intermodal shipping container under a permit issued under this bill must begin, or end, at a port authority or port of entry that is located in a county contiguous to the Gulf of Mexico or a bay or inlet opening into the gulf and may not exceed 30 miles from the port authority or port of entry (Figure 1).

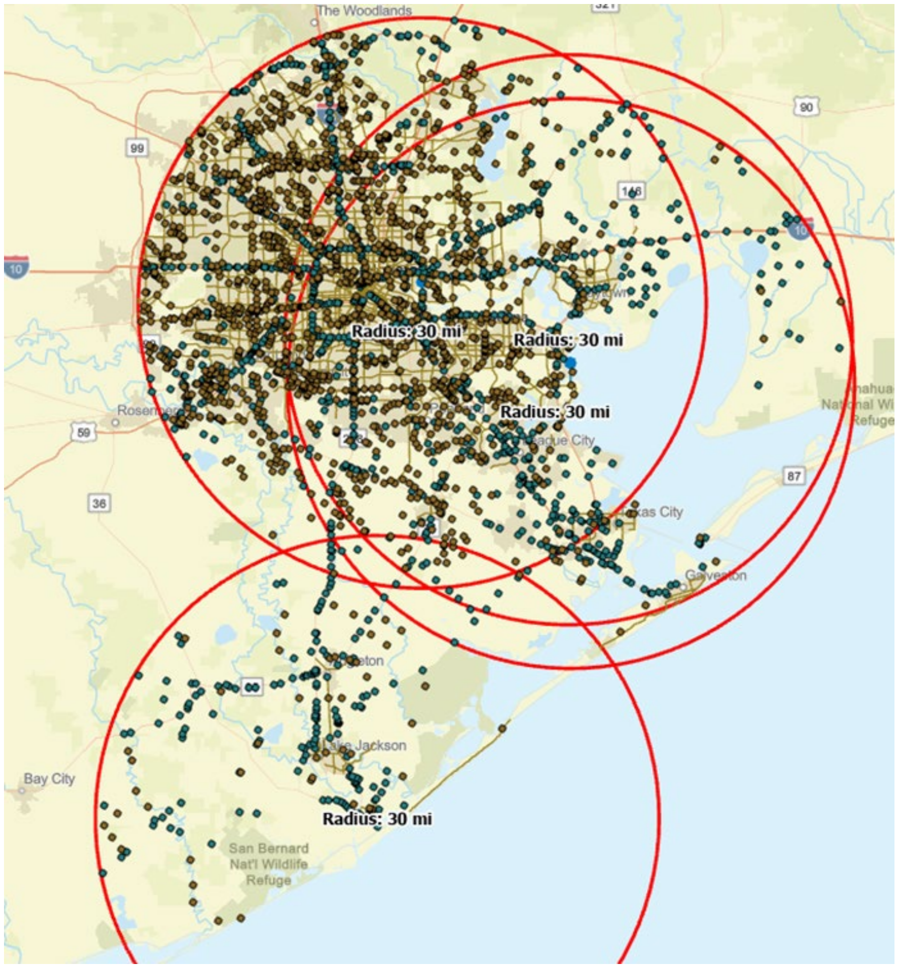

Figure 1: SB1524 Bridge and Road Network Used in the Consumption Analysis

A permit issued under this bill does not authorize the operation of a truck-tractor and semitrailer combination on the national system of interstate and defense highways (or more simply Interstate Highways) or load-restricted roads or bridges, including a road or bridge for which a maximum weight and load limit has been established and posted by the Texas Department of Transportation (TxDOT). It should be noted that the network included in the study area shown in Figure 1 includes state and local roads and on- and off-system bridges including interstate bridges. The interstate bridges were not considered in the bridge consumption calculations as per SB1524 restrictions.

Analysis Procedure for State and Local Roads

The pavement consumption analysis was based on the methodology developed under the 2012 Rider 36 Study (Prozzi et al, 2012) and updated during the 2022 House Bill 2223 (HB2223) Study. Consumption is expressed in relative terms to the consumption of the pavement by a standard axle, using the term Equivalent Consumption Factor (ECF). Traditionally, the standard axle is an 18,000-lbs single axle. A given pavement structure that reaches a pre-defined failure criterion under a given axle load and configuration is defined as having equivalent consumption (or equivalent performance) to a different loading condition when it results in the same level of distress in the same time period. Multiple distress criteria, such as pavement surface rutting, fatigue, transverse and longitudinal cracking, ride quality, faulting, and punchouts, were applied in calculating the ECFs. The ECFs were calculated as follows:

ECF = GEF x ALF

Where GEF is the "Group Equivalency Factor" for a given axle group, and ALF is the "Axle Load Factor" for a given axle load. The GEF is defined as the ratio between the life of a pavement under a single axle to the life of pavement under a group of axles (i.e., tandem or tridem). This factor considers only the number of axles and inter-axle spacing and expresses the number of single axles that would cause the same damage to the pavement as the group. By this definition, the GEF of a single axle is one. The ALF is defined as the ratio between the life of pavement under a single axle of 18,000 lbs. and the life of pavement under a single axle of a different load. By this definition, the ALF of a single axle of 18,000 lbs. is one.

The concept of ECF was first introduced during the Rider 36 Study in 2012 as an enhancement and update on the "Load Equivalency Factor" (LEF) developed in the early 1960s as part of the analysis of the results of the AASHO Road Test. The fundamental principle behind equivalent consumption involves the assumption of equivalencies between different axle loads and configurations that result in the same level of pavement distress, pavement performance, or pavement consumption. In establishing such equivalencies, the standard 18,000 lbs. single axle was used as a frame of reference. This configuration is referred to as one Equivalent Single Axle Load of one ESAL. For this study, ECFs were determined for different axle configurations and loads over a spectrum of pavement structures encountered within a 30-mile radius of the four Gulf ports addressed in the bill (Figure 1). These pavement structures include: asphalt concrete pavements (ACP), surface treated pavements (STP), plain-jointed concrete pavements (JCP), and continuously reinforced concrete pavement (CRCP).

As part of the present study, three failure criteria were evaluated for each of the four pavement types. Each pavement is designed to reach terminal distress values under given traffic and environmental conditions only by the end of its design period, which is typically 20 or 30 years for flexible and rigid pavements, respectively. However, due to inherent differences in the failure mechanisms, it is impossible to reach all terminal distress levels simultaneously at the end of the design period. Thus, it is necessary to determine the traffic volume that would result in a terminal distress value for each of the failure criteria separately and then obtain a weighted average.

Once the traffic volumes are determined, the next step involves analyzing each pavement structure for a range of different axle loads and configurations and determining the traffic required to reach each failure criterion. Note that axles with an ECF of less than one will take longer than 20 (or 30) years to reach the failure criteria; while axles associated with an ECF of more than one will take less than 20 (or 30) years to reach the same failure condition.

It is also important to note that in this process, one would develop separate ECFs based on each distress criteria mentioned above. However, from a practical point of view, a given axle configuration and load should have a single ECF. Thus, it is important to establish both a weighing mechanism to be applied to the individual ECFs of each distress and a combined and unique ECF for the axle load and configuration. The weighing mechanism should consider fundamental engineering principles such as the prevailing distress mechanism, climate conditions and pavement type.

The inherent variability of ECFs is another key concern. For example, an ECF calculated using the rutting criteria could result in a lower standard error (that is, lower uncertainty) as compared to an ECF obtained using the cracking or roughness criteria, which are predicted with the highest uncertainty. Thus, the authors of this study recommend that ECFs with lower variability receive a relatively higher weight in these instances. In analyzing the corridors subject of this bill, the ECFs utilized correspond to the 84th percentile value that was obtained as the average value plus one standard deviation.

Impact on State and Local Roads

Given the gross vehicle weight (GVW) limits and the axle configurations and loads, as described in SB1524, several load distributions are possible. A review of weigh-in-motion (WIM) data for highways and roads located in the study area identified a single WIM station nearby. The WIM station was located in College Station, 70 miles from the specific study area, so the WIM data was considered not representative for this study. From the point of view of pavement consumption, a sensitivity analysis was conducted and four different possible load distributions capture the extreme cases. These load distributions are presented in Tables 1 and 2 with the respective associated Equivalent Consumption Factors (ECFs) for each of the four pavement types evaluated.

Table 1: Equivalent Consumption Factors for the 93,000 lbs. Six-Axle Vehicle

Axle loads in pounds			EDFs			
Single	**Tandem**	**Tridem**	**ACP**	**CRC**	**JCP**	**STP**
13,000	37,000	43,000	3.94	3.53	3.26	3.77
13,000	30,805	49,195	3.51	3.41	3.13	3.39
11,000	37,000	45,000	4.06	3.51	3.29	3.91
11,000	32,805	49,195	3.73	3.42	3.19	3.61

Table 2: Equivalent Consumption Factors for the 100,000 lbs. Seven-Axle Vehicle

Axle loads in pounds			EDFs			
Single	**Tridem**	**Tridem**	**ACP**	**CRC**	**JCP**	**STP**
15,000	44,500	40,500	2.83	3.24	2.66	2.68
15,000	38,800	46,200	2.91	3.26	2.71	2.76
11,000	44,500	44,500	2.94	3.16	2.63	2.81
11,000	42,800	46,200	2.97	3.17	2.65	2.83

Tables 1 and 2 indicate that there is some variability in ECFs depending on the pavement type and how the gross vehicle weight is distributed amongst the three axle groups of each vehicle. Each vehicle under this permit will have its own weight distribution and it will use a particular route within the 30-miles zone, therefore, each vehicle will be associated with a particular ECF. For this reason, and in order to obtain a representative value, the ECF corresponding to the 84th percentile was used to assess the pavement-associated cost. The resulting ECFs are 3.82 and 3.10 for the six- and seven-axle vehicles, respectively.

During the recent HB2223 Study, it was determined that a state-average unit cost for pavement consumption (expressed in August 2022 dollars) was 5.1 cents per ESAL per mile. Thus, the average consumption cost for the six- and seven-axle vehicles are $0.19 and $0.16, respectively.

Analysis Procedure for On- and Off-System Bridges

The bridge analysis objective is to estimate the bridge consumption costs of the two container chassis configurations specified by SB1524 and summarized by Figure 2. These two configurations are capped at 93,000 and 100,000 pounds of Gross Vehicle Weight (GVW) and have further axle load limits and spacing specified in the Bill.

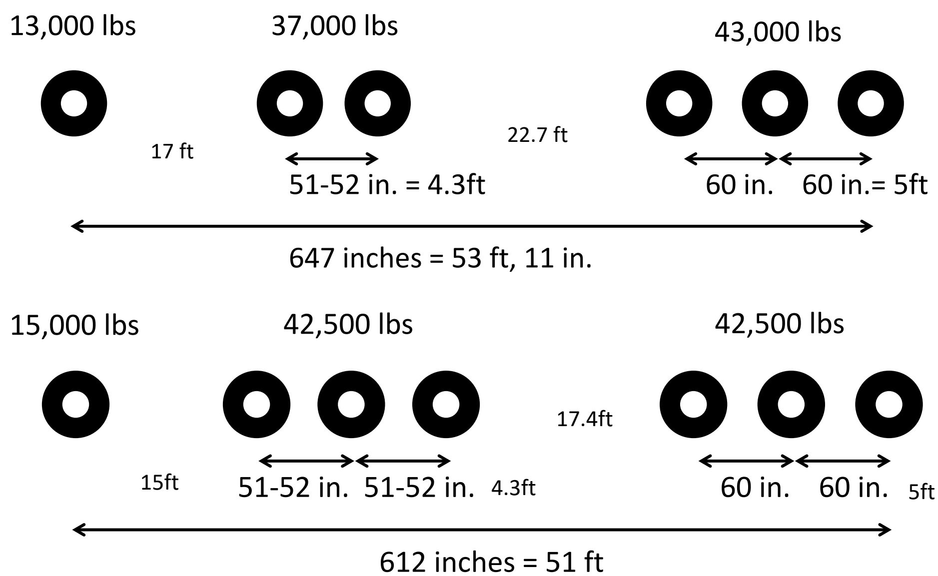

Figure 2: SB1524 Vehicle Configurations for the Bridge Consumption Analysis.

The approach calculates bridge consumption costs per mile, to support the requirements stated in the SB1524. The methodology treats each passage of each representative vehicle configuration (axle loads and spacings) as a fractional consumption of the bridge's design life. In its methodology, the University of Texas at San Antonio (UTSA) team consider costs due to consumption of the bridge life. The methodology is documented in several reports for similar bridge consumption cost determination projects (Prozzi et al, 2012).

In addition, SB1524 restricts these container chassis configurations to a 30-mile radius with the following statement *"must begin or end at a port authority or port of entry that is located in a county contiguous to the Gulf of Mexico may not exceed 30 miles from the port authority or port of entry and must be on a highway or road described by Section 623.405(b)".* The road network available for these configurations is further restricted by excluding Interstate Highways and load posted bridges. Figure 1 summarizes these Bill restrictions in terms of bridges and the road network involved in the bridge consumption analysis. This bridge and road network encompasses 5,137 center miles of roads and 2,608 bridges including a mix of state and local bridges and road segments.

Impact on On- and Off-System Bridges

The bridge consumption analysis is divided between state-managed bridges (On-System) and local-managed bridges (Off-System) due to the requirements of the analytical procedures and data availability. The results of the Bridge Consumption Analysis are summarized by Tables 3 and 4 for the 93,000-pound and 100,000-pound GVW configurations depicted in Figure 2.

The Off-System bridge consumption per mile is higher than the On-System bridge consumption due to several factors such as lower bridge load ratings for Off-System bridges and the also the nature of the road network available for the SB1524 container chassis configurations. Out of the 2,608 bridges considered in this bridge consumption analysis, 1,814 bridges are Off-System bridges.

Table 3: Bridge Consumption for the Six-Axle Vehicle (93,000 lbs)

Run	Consumption Cost ($)	Total Miles	Dollar/mile
Off	412	2,350	$ 0.18
On	433	2,787	$ 0.16
Total	845	5,137	$ 0.16

Table 4: Bridge Consumption for the Seven-Axle Vehicle (100,000 lbs)

Run	Consumption Cost ($)	Total Miles	Dollar/mile
Off	698	2,350	$ 0.30
On	625	2,787	$ 0.22
Total	1,323	5,137	$ 0.26

Crash Analysis

The information contained in Table 5 represents reportable data collected from Texas Peace Officer's Crash Reports (CR-3) received and processed by the Texas Department of Transportation (TxDOT) as of the report date. A reportable motor vehicle traffic crash is defined as: *"Any crash involving a motor vehicle in transport that occurs or originates on a traffic way, results in injury to or death of any person, or damage to the property of any one person to the apparent extent of $1,000."*

Federal highway safety laws require the state to create this crash database for use in obtaining federal safety improvement funds. Section 409 of Title 23 of the United States Code, forbids the discovery and admission into evidence of reports, data, or other information compiled or collected for activities required pursuant to Federal highway safety programs, or for the purpose of developing any highway safety construction improvement project, which may be implemented utilizing federal-aid highway funds, in tort litigation arising from occurrences at the locations addressed in such documents or data. Information that is not available to a party in civil litigation may be confidential under state law, pursuant to Texas Government Code Section 552.111.

For Motor Vehicle Crash Data Report definitions, please go to: http://www.txdot.gov/inside-txdot/forms-publications/drivers-vehicles/publications/annual-summary.html and view or download the Annual Motor Vehicle Crash Data Report Definitions report (TxDOT, 2020).

Table 5: Motor Vehicle Traffic Crashes involving Permitted Vehicles

Crash Year	Fatal Crashes	Suspected Serious Injury Crashes	Suspected Minor Injury Crashes	Possible Injury Crashes	Non-Injury Crashes	Unknown Injury Crashes	Total Crashes
2018	0	0	0	0	1	0	1
2019	0	0	0	0	1	0	1
2020	0	0	1	1	1	0	3
2021	0	0	0	1	0	0	1
2022 YTD	0	0	0	0	2	0	2

Infrastructure Consumption Analysis

From January 26, 2018 to the time of preparation of this report, 1,028 permits have been issued under the provisions of SB1524, an average of 223 permits per year. An analysis of license plate numbers, unit numbers and VINs, revealed that these permits involved approximately 400 different vehicles. Because no information was available regarding the mileage each of these vehicles travel in one year, a phone survey was conducted by personnel from the Texas Department of Transportation. This phone survey indicated a significant variability in vehicle-miles-travelled (VMT). Table 6 shows the results of the survey and the average VMT based on this sample.

Table 6: Sample of VMT by Vehicles under this permit

Respondent	Miles/Year	Equipment/Company
1	4,000-10,000	Freightliner, Day Cab, equipped with an additional drop axle and a blind spot monitoring system
2	144	40 ft containers, Day Cab
3	360	No additional information was provided
4	1,040	40 ft containers, Tri axle
5	2,555	No additional information was provided
6	9	No additional information was provided
7	30,000	No additional information was provided
8	156,000	24/40 Tri axle
9	1,404	40 ft containers, stabilized chassis with 4 axles
Average	**22,057**	

The informal survey had high variability in responses from the companies, therefore it was decided to conduct a sensitivity analysis to determine whether the $6,000 permit fee is commensurable with the consumption cost. The sensitivity analysis shows the correlation between the VMT and the total consumption of roadway and bridges. The results of the sensitivity analyses are presented in Tables 6 and 7 for the six- and seven axle configurations, respectively. The tables show that the current fee is adequate to cover an annual mileage of 17,143 and 14,286 for the six- and seven-axle vehicle, respectively.

Table 7: Infrastructure Consumption Cost for the 6-Axle Vehicle as a function of VMT

VMT Assumption	Pavement	Bridge	Total
10	$ 2	$ 2	$ 4
100	$ 19	$ 16	$ 35
1,000	$ 190	$ 160	$ 350
10,000	$ 1,900	$ 1,600	$ 3,500
15,000	$ 2,850	$ 2,400	$ 5,250
17,143	**$ 3,257**	**$ 2,743**	**$ 6,000**
20,000	$ 3,800	$ 3,200	$ 7,000
50,000	$ 9,500	$ 8,000	$ 17,500
100,000	$ 19,000	$ 16,000	$ 35,000
150,000	$ 28,500	$ 24,000	$ 52,500

Table 8: Infrastructure Consumption Cost for the 7-Axle Vehicle as a function of VMT

VMT Assumption	Pavement	Bridge	Total
10	$ 2	$ 3	$ 4
100	$ 16	$ 26	$ 42
1,000	$ 160	$ 260	$ 420
10,000	$ 1,600	$ 2,600	$ 4,200
14,286	**$ 2,286**	**$ 3,714**	**$ 6,000**
20,000	$ 3,200	$ 5,200	$ 8,400
50,000	$ 8,000	$ 13,000	$ 21,000
100,000	$ 16,000	$ 26,000	$ 42,000
150,000	$ 24,000	$ 39,000	$ 63,000

Conclusions

In preparation of this report, a team of researchers from the University of Texas at Austin and the University of Texas at San Antonio gathered and evaluated relevant data provided by the Texas Department of Transportation and the Texas Department of Motor Vehicles as well as data contained in the Crash Records Information System (CRIS). To reach the conclusions of this study the following data were analyzed:

- Gross vehicle weights, axle configurations and weights of vehicles operating under this permit that were involved in a motor vehicle crash,
- Types of vehicles operating under this permit,
- Annual traffic volumes and variations, and
- Weigh-in-motion data for highways and roads located in the study area.

Using this information and a methodology developed under Rider 36 Study and recently updated during the HB2223 Study, the team of researchers, in collaboration with personnel from TxDOT and TxDMV, performed a series of analyses to determine and quantify the impacts to and consumption of state and local bridges, and the impacts to and consumption of state and local roads.

While the HB2223 Study did not specifically address local roads and bridges, the study estimated consumption for a wide range of facilities designed from 100,000 to 200,000,000 ESALs. The average consumption rates from the HB2223 Study were applied here to estimate the average pavement consumption for the study area. However, the bridge consumption calculation for the SB1524 analysis encompasses the network summarized by Figure 1.

Infrastructure consumption is linearly related to the vehicle-miles-travelled (VMT), which could vary from as little as 9 annual miles to as much as 156,000 annual miles. The sensitivity analyses conducted in this study indicated that the current fee structure is adequate if the six- and seven-axle vehicles travel annually a maximum of 17,143 and 14,286 miles, respectively. If the annual mileage that these vehicles travel fully loaded is in excess of these figures, the current annual fee does not recover the consumption cost.

References

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