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Estimating Texas-Mexico North American Free Trade Agreement Truck Volumes

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North American Free Trade Agreement (NAFTA) truck traffic continues to grow on the international trade highway corridors linking the United States to Mexico. This situation presents planning challenges to accommodate NAFTA truck traffic along these highways and at U.S.-Mexican border ports of entry. Because transportation data are lacking, the numbers of trucks, particularly those carrying NAFTA trade to and from Mexico, are difficult to estimate. Two data sources available for estimating the number of trucks crossing the border are the counts of trucks crossing the bridges and the U.S. international trade data. Two methods of estimation, each using one of these data sets, are developed and described. Two separate truck flows derived from the models are explained and compared using a standardized truck type (equivalent trade truck) to represent truck flows. Interestingly, both methods provide useful outcomes.

The total trade between the United States and Mexico continues to grow strongly and is expected to exceed $200 billion in 2000. Highway issues, both along trade corridors and at border crossings, continue to attract attention from federal and state planners. For example, the congestion along Interstate Highway 35 north of San Antonio in Central Texas is frequently attributed to the growth in North American Free Trade Agreement (NAFTA) truck traffic along that corridor segment. Yet the accurate measurement of truck volumes associated with international trade remains a challenge. Data collected at the bridges by U.S. Customs and data on U.S. international trade are not structured specifically to answer questions about such truck volumes. The problem is complicated further because much truck border activity is not directly related to over-the-highway international trade trips. McCray did earlier work on NAFTA truck trade flows and associated highway corridors (*1*). Although estimating trade flows from truck volumes remains challenging, an understanding must be developed of the effect of NAFTA truck volumes on trade highway corridors and port infrastructure (*2, 3*). This is particularly true given the attention now being directed at both federal and state levels to identify and possibly fund NAFTA truck corridors.

BACKGROUND

In 1998, the U.S. Department of Transportation Southwest Region University Transportation Centers Program sponsored an investigation of U.S.-Mexican trade corridors, particularly those used mainly by trade trucks. The study objective was to develop a Global Information System (GIS)-based U.S.-Mexico corridor map of NAFTA truck flows based on available data sources using TransCAD GIS software. The trade estimation used a two-stage approach, which is fully described in the study report (*4*). As the focus of this study, truck volumes leaving the border were first estimated and then calibrated using weigh-in-motion (WIM) data, which was the focus of a previous study (*5*). The initial study used the concept of a standardized, loaded NAFTA truck, which is used for truck volumes in this analysis.

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ALTERNATE METHODS TO ESTIMATE LOADED NAFTA TRUCKS

Two methods for determining standardized, loaded truck volumes were evaluated. The first method concentrated on truck numbers derived from the border bridge systems and U.S. Customs, after adjusting for various factors. The second method used U.S. international trade data and commodity densities, truckload weights, and truckload volumes to determine truck flows. This study analyzes truck flows at a port-of-entry (POE) level; therefore the methods developed aggregate flows at bridge or border crossing levels into POE levels, although the methods can also be applied at a bridge or crossing level when required.

Bridge Truck Volume Method

This method is based on the bridge counts available from bridge authorities and U.S. Customs. At the U.S.-Mexican border, various economic activities influence truck volumes, including those associated with drayage practices (i.e., international trailers are drayed across the border by local trucking firms), intermodal movements of empty and full trailers, freight consolidation at warehouses, and activities that supply and consume products and services at border cities. Each factor has a different effect on NAFTA truck volumes. Drayage practices, involving tractors that often cross the border loaded and return empty, tend to grossly overstate the likely number of trade trucks on NAFTA highway trade corridors. Intermodal movements from border ports to U.S. nonborder cities, especially trailers on flat cars (TOFC), cross the bridges but do not use the trade corridors leading away from the border, also contributing to overstating the bridge crossing counts as a measure of NAFTA truck traffic on U.S. corridors. Freight consolidation reduces the number of loads on the trade corridors compared with loads crossing the bridges. WIM data for border-crossing and highway corridors can be used to estimate this consolidation (*6*). Finally, border cities also receive some truck freight that is consumed locally and therefore does not affect NAFTA corridors.

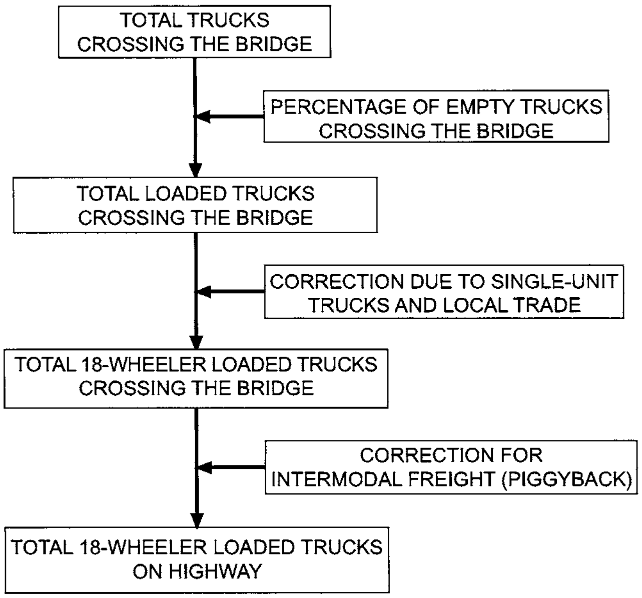

FIGURE 1 Estimation of NAFTA trucks using bridge truck counts.

Truck Volumes on Bridges

The steps in this method are shown in Figure 1. The assumptions underlying this method, as applied to this border segment, are given in Table 1. These data can be obtained for southbound flows into Mexico from U.S. bridge authorities that collect tolls and for northbound flows from U.S. Customs. Data could also be provided by WIM or truck count and classification sites if a collection process existed at POEs. More data were available for northbound loaded trucks; southbound loaded trucks were reported only at the ports of Laredo and Eagle Pass. For all other ports, the percentage of southbound loaded trucks was assumed from the available southbound flows.

Loaded Trucks Crossing Bridges

The number of loaded trucks must be estimated by applying a factor for empty trucks to the total number of trucks. Data for empty and loaded trucks crossing bridges were obtained for this study but may not be available consistently. Also, data availability may change as new facilities are built and new processes are implemented at border POEs. For example, new transportation data are a requirement on export manifests beginning August 1, 2000 (*7*).

Equivalent Trade Trucks

This study chose to standardize the various truck types carrying international trade into equivalent 36 287-kg (80,000-lb), five-axle, 14.6-m (48-ft) semitrailer trucks (3S2), termed equivalent trade trucks (ETT). This truck type was selected on the basis of results from an analysis of truck types and weight statistics that clearly indicated the 3S2 dominated other vehicles types on NAFTA corridors (*6*). Also, national statistics show that for long-haul trips, semitrailer trucks dominate other classes because of their higher efficiency (*8*). The weight of an ETT will depend on the commodity being transported. In particular, the total truck weight will be less than 36 287 kg if the commodity transported cubes out (see the Truckload Volume and Weight section).

Because both semitrailer trucks and single-unit trucks transport trade, single-unit trucks must be transformed into an equivalent number of ETT units. The equivalence between a single-unit truck and an ETT must be based on weight or volume capacity per truck. Truck weight limits are 14 515 kg (32,000 lb) and 28 865 kg (46,000 lb) for two- and three-axle trucks, respectively, whereas the gross limit is 36 287 kg (80,000 lb) for 3S2 trucks, giving a ratio between 2.5 and 1.7. The ratio between single-unit and combination truckloads for different commodities varies between 1.7 and 2.2, if hazardous materials commodities are not considered (*9*). A correction must also be applied for local traffic because some truck transport is supplying producers and consumers in each border city and is not related to NAFTA trade. As shown in an origin-destination survey at border ports, origins or destinations not related to international trade were less than 10 percent (*10*). This study assumes that some single-unit trucks carry local commerce, estimated at 33 percent in all ports except Laredo, which is assumed to be 25 percent because it has much larger trade movements relative to its size.

Correction for Intermodal Shipments

In ports where intermodal yards are present (truck-rail and truck-ship), some trailers that cross the border by truck may continue their journey by another mode, such as TOFC. The correction for intermodal movements is necessary, especially in Laredo and Eagle Pass, where there are significant TOFC movements.

Results

An estimated total of 2,070,226 NAFTA standardized ETT trucks crossed the Texas-Mexico border and traveled on Texas highways during 1997, as shown in Table 2. This represents an average of

TABLE 1 Main Assumptions in Estimating NAFTA Truck Volumes

I.	Percentage of empty trucks is similar for single-unit and combination trucks
II.	Nonpassing trade is considered not significant, which may overestimate the number of NAFTA trucks
III.	Annual volumes are estimated, seasonal peaks may occur
IV.	Equivalence between single-unit and combination trucks is based on truckload weight and volume capacity
V.	For long haul movements only combination trucks are estimated (3S2 type)
VI.	Percentage of empty trucks on a highway segment varies only with direction of travel and is the same for all ports
VII.	Local trade (border intercity trade) is captured using a percentage of single unit trucks

TABLE 2 Bridge Truck Volume Method Results

Port of Entry	Bridge Count Method		
	Northbound	Southbound	Total
Laredo	494,602	561,325	1,055,927
El Paso	226,462	178,290	404,752
Brownsville	112,487	104,404	216,891
Hidalgo	139,315	126,171	265,486
Eagle Pass	35,852	39,194	75,046
Del Rio	26,497	25,627	52,124
Total	1,035,215	1,035,011	2,070,226

7,660 ETT trucks per day. Laredo has the largest truck volume in Texas, with 47 and 53 percent, respectively, for northbound and southbound movements. El Paso is next in volume, with 22 percent of northbound trucks and 17 percent of southbound vehicles. Surprisingly, Hidalgo has the third-largest truck volume, with 14 and 12 percent of north and southbound vehicles, respectively, supplanting Brownsville as the leading POE in the Texas Valley. This truck volume reflects the growth of maquiladora operations in the Hidalgo-Reynosa area, adding manufactured commodities to the traditional agricultural trade moved across the border.

The variations in the number of trucks at Texas border POEs relate to trade volume and the characteristics of the different commodities being transported. Although this method is based on truck counts, the second method develops the numbers of trucks on the basis of U.S. international trade data.

Trade Commodity Density and Volume Method

This method is based on calculating truckload weight per commodity, using commodity densities. Representative commodity group densities are used, which, when multiplied by the truck capacity volume, give the commodity group truckload. Other researchers have used a similar approach to determine truck volumes on key highway corridors (*11*).

Each truck type there has a maximum volume and truckload weight. A critical density is reached when the commodity either weighs out or cubes out. A cubed-out commodity fills the volume of the trailer but does not reach the maximum weight. A weighed-out commodity reaches the weight limit but does not fill the truck's volume. Considering the total volume of the truck, a weighed-out commodity density therefore equals the critical density. This value is termed the maximum practical density per commodity and is used in this study to discriminate between the two types of loaded trucks.

Method

Figure 2 is a flowchart detailing the steps of the commodity group density method. The first step is to separate commodities of high density, which will weigh out from low-density commodities that will cube out. In the second step, the truck type best suited to the movement of the commodity group must be selected and the truckload volume and weight must be determined.

The third step is to aggregate the commodities and obtain a representative density for each group. It is important to note that when commodities are aggregated, the representative density is not an average of the densities, but a nonlinear function of the weight proportion of each commodity, density of each commodity, truck capacity volume, and truck maximum weight. Using the representative density by group (D_i), truck volume (V_i), and the total weight per group (W_i), the number of trucks per group is calculated (N_i).

Commodity Group Density

The commodity group i (C_i) comprises different commodities j (C_{ij}). For one commodity C_{ij} with density D_{ij}, the number of loaded trucks N_{ij} (with volume V) needed to carry the commodity weight W_{ij} is

$$N_{ij} = \frac{W_{ij}}{D_{ij} * V} \tag{1}$$

The total number of trucks (N) for all the commodities in commodity group C_i will be

$$N_i = \sum_j \frac{W_{ij}}{D_{ij} * V} \tag{2}$$

The average density (D_i) per commodity group C_i will be

$$D_i = \frac{W_i}{N_i * V} \tag{3}$$

where W_i is the total weight of commodity group C_i,

$$W_i = \sum_j W_{ij} \tag{4}$$

Replacing N_i from Equation 2 into Equation 3 results in

$$D_i = \frac{1}{\sum_j \frac{P_{ij}}{D_{ij}}} \tag{5}$$

where P_{ij} is the ratio of the weight of commodity j (W_{ij}) and total weight per commodity group i (W_i).

The total number of trucks is the sum of N_i, which gives the total number of loaded trucks, and a correction factor for empty trucks and must be applied to obtain the total number of trucks on the highway corridor. This method is based on two key assumptions—first, truckloads are represented as either weighing out or cubing out; second, a single commodity per truck is considered.

Various commodities with different densities are in each two-digit harmonized classification. However, for practical reasons, it is convenient, and within acceptable accuracy, to categorize commodities for this work at the two-digit harmonized level, such as electronics and chemicals, and to use this density to determine whether a truck would weight out or cube out.

Application of the Method

Trucks were estimated using U.S. international trade data and aggregating the data at the two-digit harmonized system (HS) commodity level, which is the same commodity detail used in the Transborder Surface Freight Database (TSFD) (*12*).

Densities. Densities by commodity were obtained from an NCHRP report (*13*). Density data are reported in kg/m^3 (lb/ft^3), with the

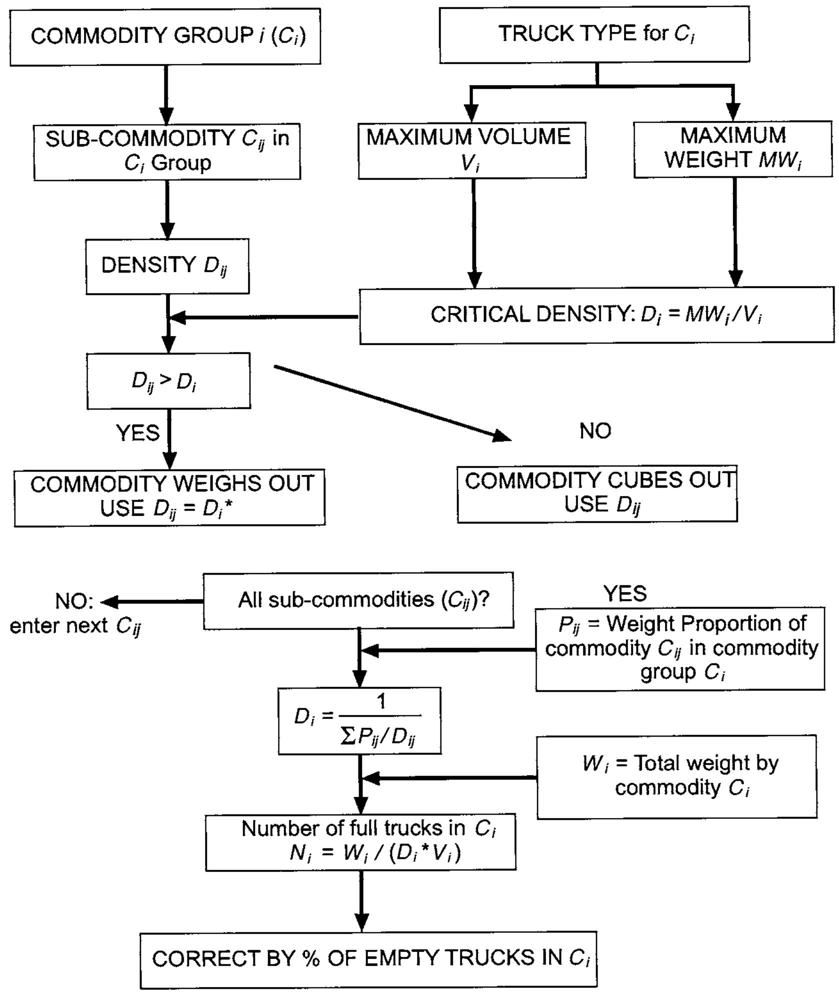

FIGURE 2 Truck weight estimation by commodity group.

same units used hereafter. Some important problems appear with the application of these data:

1. Commodity densities are given using the Standard Transportation Commodity Classification. Trade data are given in Standard International Trade Code (SITC) or HS commodity classifications, and the match is not perfect.
2. Density data were compiled mostly during the 1970s. For commodities that have not had changes in production methods or materials (e.g., agricultural or mineral products), the value is fairly accurate. However, for highly industrialized products such as electrical equipment, machinery, vehicles, and instruments, changes in density can be expected. As an example, the trend has been to reduce weight by replacing metal components with lighter plastic components. These products are very important in U.S.-Mexican trade, so underestimating volumes may be expected.
3. Many electronic and electric products were not included in the NCHRP report, and their densities have to be obtained from other sources (e.g., data provided by freight forwarders or brokers).

Truckload Volume and Weight. Using trailer data provided by the Laredo base of Schneider Inc., truck volumes in ETTs were estimated of 48 feet long by 259 cm (102 in.) high and 279 cm (110 in.) wide, giving a total of 106 m^3 (3,740 ft^3). Five percent of the volume was considered wasted, making the usable volume 101 m^3 (3,560 ft^3). The total weight limit per ETT is 36 287 kg (80,000 lb), with the weight of a tractor and an empty trailer ranging between 14 515 kg (32,000) and 16 329 kg (36,000 lb), based on WIM data (*6*). The payload is therefore 28 865 kg (46,000 lb), and the critical density derived from 28 865 kg and 101 m^3 is 206.6 kg/m^3 (12.9 lb/ft^3). This is a critical part of the estimation process and deserves closer attention in future research. Even for similar commodity groups, trailer loads and densities actually may vary between ports. Ideally, these load weights and densities would be identified by port and region to permit a more accurate estimate of truck volumes. Using the general method for all Texas ports probably overestimates truck volumes, which is why calibration using WIM and other data is so important.

Commodity Weight Data. Weights at the two-digit HS commodity level have been obtained using TSFD. The commodity value and weight correspond to all northbound movements, because the TSFD does not contain commodity details at port level. Five-digit SITC data were obtained by special order from the U.S. Department of Commerce (*14*). Using a concordance, these data were converted to two-digit HS data for each port. Transborder surface transportation data were obtained from the Bureau of Transportation Statistics and used to prepare a table of weight-to-value relationships. This weight-to-value table was used to produce the estimated weight of each two-digit commodity at each major U.S.-Mexican border port. Commodity modal split was calculated using TSFD data. Using these databases and estimated densities, the number of trucks per port can be estimated at the two-digit HS commodity level.

Results

This study reports the density values at the two-digit HS commodity level used to calculate the number of ETTs. The same values are given for loaded and empty trucks, because the average value per truck per commodity is useful in checking the accuracy of results. These tables are too voluminous to reproduce herein, but a section on total northbound movements is reproduced in Table 3. This table provides examples for 20 two-digit HS chapters, broken down by density, truckload weight, trade weight, truck number, and truckload value.

As expected, the truckload values vary widely with commodity group. Northbound, agricultural products have an average value of $13,300, increasing to $85,700 for instruments. Southbound, the range is from agricultural products at an average value of $16,700 to instruments at $102,900. Results by commodity group allow further calibration of the model and more basic knowledge about trade flows and modal choice. Truckload values might dramatically change in comparing northbound and southbound commodities, even in the same HS chapter. For example, HS Chapter 27 mainly concerns crude oil for northbound shipments, whereas refined-oil subproducts mainly comprise southbound shipments. This situation stresses the need for careful calibration—each port has peculiarities in commodities traded and drayage and maquiladora effects on truck volumes that the aggregated data sometimes cannot capture. Knowledge of trade port operations, and contacts with carriers, brokers, customs, and freight operators, is important to calibrate the models at port level. Table 4 presents the results of the trade commodity density and volume method.

The second method is close in aggregate to the first method. However, the first method can better estimate truck volumes if more data on density and volumes, by commodity group, are collected at the various POEs. Because trucks are loaded out to high levels in the second method—a process not always possible in reality—the current ETT method probably underestimates true truck volumes. However, because truckers strive to reach higher levels of productivity, through intelligent transportation systems and other means, actual truckloads may be expected to be similar to the truckloads used in this analysis.

TABLE 3 Selection of Northbound ETTs Based on Densities

HTS Chapter	Density lbs/ft^3	Truckload Weight	Trade Weight lbs	Truck Number	Truckload Value
01	10.5	37,380	300,237,533	8,032	22,093
02	17.0	44,000	7,390,456	168	47,158
03	12.0	42,720	110,142,960	2,578	162,825
04	8.0	28,480	11,466,484	403	18,990
05	9.0	32,040	19,340,385	604	34,676
06	8.5	30,260	30,817,934	1,018	23,318
07	11.5	40,940	4,912,160,194	119,984	11,212
08	11.2	39,872	2,626,642,810	65,877	8,337
09	9.6	34,176	297,506,686	8,705	51,175
10	20.0	44,000	14,552,564	331	8,190
11	11.2	39,872	21,407,258	537	6,195
12	8.1	28,836	88,720,460	3,077	12,272
13	12.3	43,788	16,345,947	373	38,493
14	7.0	24,920	53,648,368	2,153	15,283
15	11.7	41,652	17,340,464	416	23,125
16	15.0	44,000	28,979,298	659	53,622
17	10.3	36,668	150,936,192	4,116	22,328
18	10.6	37,736	27,230,509	722	37,274
19	8.5	30,260	269,032,139	8,891	15,336
20	10.9	38,804	526,042,301	13,556	15,612

TABLE 4 Trade Commodity Density and Volume Method Results

Port of Entry	Northbound	Southbound	Total
Laredo	468,910	671,034	1,139,944
El Paso	252,823	228,801	481,624
Brownsville	100,206	128,463	228,669
Hidalgo	116,969	89,343	206,313
Eagle Pass	40,474	39,827	80,301
Del Rio	26,517	27,066	53,583
Total	1,005,899	1,184,534	2,190,433

Comparison of the Two Methods

The results were reasonably close given the aggregated nature of the data. The total number of estimated trucks crossing in the six most important ports in Texas differs no more than 6 percent. Nonetheless, surprisingly, virtually the same figures can be obtained using two different paths with relatively aggregated data. Differences at some ports are more significant, which suggests that further work is necessary to calibrate results at the port level.

The two methods should not be seen as noncomplementary. On the contrary, each method contributes to a better understanding of the problem and provides a crosscheck and basis for further analysis and comparisons at the port level.

SUMMARY

Findings were presented from an evaluation of two methods to develop standardized truck volumes carrying NAFTA trade to and from Mexico. The first method, using border-crossing volumes, is the weakest theoretically, because numerous assumptions need to be made and the method relies on a wide variety of crucial, yet sometimes difficult to obtain, data. This method forces the practitioner or researcher to gain an understanding of the complex border-crossing process and avoid the temptation to apply uncalibrated recipes or formulas.

The method using densities and volumes shows promise and explains why results show that average value per truckload per port varies significantly. El Paso, for example, has a higher truckload value because of the high proportion of electrical products. No linear relationship exists between trade value per port and number of trucks, or between trade value and average truck weight, which suggests that trade value alone is not enough to compare port characteristics and indicate trade effects on infrastructure. This method would benefit from an updating of commodity densities and a homogenization of transportation and trade commodity classifications.

Commodity disaggregation provides more insight in the planning analysis. Key commodity groups can be identified, allowing more flexibility to analyze the effects of NAFTA trade and forecast future scenarios. The methods developed can be used successfully to estimate commodity truck volumes; however, a larger effort is still required to analyze, match, and use current trade statistics and calibrate results. Again, the accuracy and detail of available data greatly affect the quality of results. Finally, further analyses of trailer loads in relation to commodity densities and volumes that are crossing border ports will enable more accurate standardized ETT volumes to be determined. Such data are important because they can be incorporated into federal and state planning actions that address the maintenance, rehabilitation, and reconstruction of designated international trade corridors in the United States.

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