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Characteristics of Double and Triple Trailer Truck Combinations Operating in the United States

CHIEN-PEI YU and C. MICHAEL WALTON

ABSTRACT

The enactment of the Surface Transportation Assistance Act of 1982 may have signaled the beginning of more widespread use of double and triple trailer truck combinations in the United States. This enactment has provided a new incentive to the ongoing study of doubles and triples; past works focused on the economics, operations, use, and safety aspects. This work concentrates on the characteristics of doubles and triples found in the Truck Inventory and Use Survey (TIUS) and the Truck Weight Study (TWS). TIUS and TWS are the two major data bases of the nation's truck resources. The TIUS has a well-designed sampling strategy but has a rather small sample of doubles and triples. The TWS has a large sample size, but when compared with TIUS it does not have a well-designed sampling strategy. To assist further in the monitoring of the development of the nation's truck resources on highways, some modifications may need to be made in both data bases, particularly for the doubles and triples. Data obtained from TIUS and TWS on some aspects of the doubles and triples are analyzed and the results are presented.

The enactment of the Surface Transportation Assistance Act of 1982, and the various provisions relating to double and triple trailer truck combinations, will have a significant effect on the transportation sector in general and the motor carrier industry in particular. It may be the beginning of a new era of more widespread use of multitrailer truck combinations. One provision outlines a study to be performed of the feasibility of a designated Intercity Truck Route Network that will allow the operation of multiple trailer units up to 110 ft in overall length. This increased emphasis on the longer truck combinations has provided a new incentive to explore various characteristics and important features of these trucks.

The data on doubles and triples from the Truck Inventory and Use Survey (TIUS) (1) and the Truck Weight Study (TWS) (2) conducted by FHWA in cooperation with various state highway departments were used as the basis for the analysis presented in this paper. The analysis is not a comprehensive treatment of the subject; much more work could be done to characterize the double and triple trailer combinations from these two files.

TIUS DATA BASE: USE AND LIMITATIONS

The TIUS is performed by the U.S. Bureau of the Cen-

sus. Its primary purpose is to "collect and publish data on the physical and operational characteristics of the nation's truck resources." Passage of the Surface Transportation Assistance Act of 1982 has made the understanding of the operational characteristics of doubles and triples more urgent because there is a stated requirement for a study to monitor the establishment of a Designated Interstate Truck Route Network. The TIUS is one of the most comprehensive data sources on truck inventory and use. Twenty-nine items of information are required from the truck owner for each truck. Information is required on the engine type, products carried, mileage traveled, range of gross vehicle weight, type of maintenance performed, area of operation, base of operation, and so forth; this information is valuable from the viewpoint of administration, funding, and planning. However, TIUS is only conducted every 5 years, and the information it contains projects an overall picture of inventory and use instead of dealing with a specific topic.

For this reason, out of the 96,494 records in the 1977 TIUS, only 286 records were for doubles or triples; of these, 212 records were western doubles with a two-axle tractor (2-S1-2 in AASHTO code) and 70 were triples with a tandem axle tractor (3-S1-2 in AASHTO code). Only four records of turnpike doubles were found in the entire sample. Such a small collection of doubles and triples (0.2 percent of the entire sample) is due to the indiscriminate sample gathering policy of TIUS. Hence, the predominant truck type represented in the file is the small truck. The reliability of the sample would be much enhanced if the sample were larger; nevertheless, because this is the only TIUS sample available, the sample is used in the study of doubles and triples.

TIUS does not identify an entire truck combination in one single information item; instead each truck is identified separately by its tractor or trailer. A two-stage process must be used to capture a double or triple from the file. The researcher must check the tractor and then the trailer type of each record and match that against standard configurations to determine if the record is a double or a triple.

In presenting many of the characteristics of doubles and triples in this paper, the expansion factor used by Sydec is also used to extrapolate the characteristics of the samples so that it is representative of the entire population.

TWS: USE AND LIMITATIONS

Since 1966 the TWS has been reported annually or biennially by FHWA, which obtains data on truck weights and commodity movements in each state. The data, gathered either manually or through automated weigh-in-motion systems in the field, are coded on cards or stored on magnetic tapes and sent directly to FHWA. The data sampling scheme is determined by each state highway department. FHWA, while encouraging accuracy and reliability in the data obtained, only provides a guideline for each state; therefore, the accuracy and reliability of the data varies widely.

This is one of the drawbacks of TWS. Although a large amount of data is available, the sampling technique in each state as well as the reliability of the sample is not known. A large number of specimens are available, yet it is difficult to calculate the reliability or probability of the samples. The TIUS is almost at the opposite end of the spectrum. TIUS has a structured sampling program, yet it does not have many samples. It is interesting to look at the characteristics of doubles and triples from both ends of the spectrum, judge the results, and determine what should be done in the future to improve the data base, as well as to enhance the sampling technique.

SOME CHARACTERISTICS OF DOUBLES AND TRIPLES AS OBSERVED FROM TIUS

The previous section stated that there were 286 records of doubles and triples captured from the 1977 TIUS. The TIUS provides a large amount of data for each truck, and in this analysis these data were arranged in a variety of ways to provide insight to the characteristics of the larger truck units.

The following are examples of analyses performed on the TIUS data:

1. Gross vehicle weight distribution,
2. Annual mileage distribution,
3. Weight-to-horsepower ratio,
4. Primary products carried, and
5. Operator class.

Figures 1 (1) and 2 (1) show graphical illustrations only for the findings of the western doubles with a two-axle tractor (2-S1-2), although findings concerning other types of doubles and triples are mentioned. All sample sizes shown on the vertical axis reflect the actual size in the TIUS files multiplied by the expansion factor.

Gross Vehicle Weight Distribution

Gross vehicle weight (GVW) distribution is an important operating characteristic of the vehicle. Figure 1 illustrates that the majority of the two-axle tractor, western doubles have a GVW ranging between 60,000 and 80,000 lb based on TIUS data; 77.6 percent of the GVWs for the western doubles fall within this range.

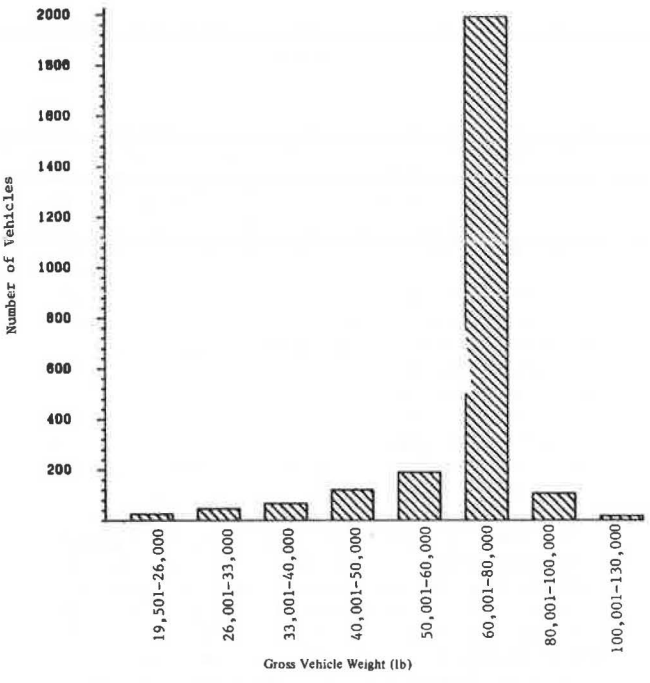


FIGURE 1 Gross vehicle weight distribution for western doubles with two-axle tractor *(1)*.

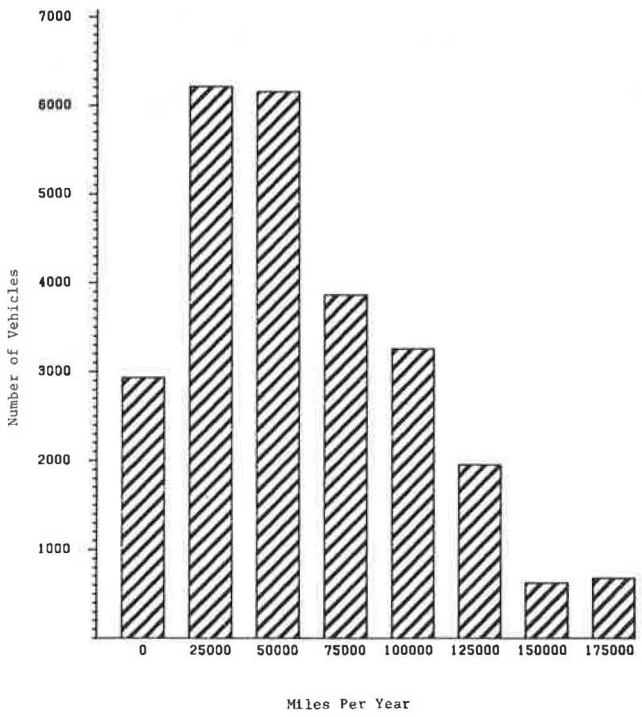


FIGURE 2 Annual mileage distribution for western doubles with two-axle tractor *(1)*.

Annual Mileage

Figure 2 shows that most western doubles have annual mileage between 25,000 and 100,000 miles. A statistical analysis indicated that for each of the vehicle types the mean and the standard deviation of the annual mileage were as follows:

Vehicle Type	Average Annual Mileage	Standard Deviation
Western double (two-axle tractor)	59,286	±41,686
Western double (three-axle tractor)	68,037	±50,855
Triple	47,952	±17,855

Weight-to-Horsepower Ratio

Weight-to-horsepower ratio is important in determining a truck's ability to negotiate a grade. The distribution for the TIUS samples is summarized in Table 1 (1). This should be compared with weight-to-horsepower data assumed in AASHTO design policies for climbing lane design; for example, previous performance data assumed a 400:1 ratio for large trucks. This suggests a higher performing capability for the doubles and triples or, to state it differently, these truck units should be able to travel most grades without difficulty. This assumes that the highway segment was designed to AASHTO standards.

TABLE 1 Weight-to-Horsepower Ratio for Doubles and Triples *(1)*

Weight-to-Horsepower Ratio	Western Double, Two-Axle Tractor (%)	Western Double, Three-Axle Tractor (%)	Triple, Three-Axle Tractor (%)
0:50	70.9	36.6	32.3
51:100	16.0	26.3	67.7
101:150	0.8	4.2	
151:200	0.7	4.2	
201:250	3.4	14.3	
251:300	6.4	6.4	
301:350	1.3	6.5	

Primary Products Carried

Table 2 (1) gives the primary products carried for doubles and triples as recorded in the TIUS files. It can be seen that 2-S1-2s were used mainly for carrying farm products, processed foods, building materials, and mixed cargoes; 3-S1-2s were used for products similar to those carried by 2-S1-2s, although less for farm products than for petroleum or petroleum products.

TABLE 2 Primary Products Carried by Doubles and Triples *(1)*

Primary Products Carried	2-S1-2[a] (%)	3-S1-2[b] (%)	3-S1-2-2[c] (%)
Farm products (crops, fruit)	30.5	8.6	87.5
Live animals	1.7	-	-
Mining products	0.7	2.0	6.3
Logs and other forest products	0.7	2.0	-
Processed foods	8.0	6.8	-
Textile mill products	0.3	-	-
Building materials	20.6	19.6	6.3
Household goods (moving)	-	3.1	-
Furniture or hardware	0.2	-	-
Paper products	1.4	-	-
Chemicals or related products	2.7	0.6	-
Petroleum or petroleum products	1.0	14.6	-
Primary metal products	-	1.3	-
Fabricated metal products	1.4	3.1	-
Machinery (except electrical)	0.3	1.9	-
Transportation equipment	0.8	-	-
Scrap, refuse, garbage	0.7	5.8	-
Mixed cargoes	28.4	31.0	-
Other	0.9	-	-

[a] Western double with two-axle tractor.
[b] Western double with three-axle tractor.
[c] Triple with three-axle tractor.

Operator Class

Table 3 (1) shows the operator class distribution for each of the three vehicle types; 2-S1-2 and 3-S1-2 were mostly operated by private operators, Interstate Commerce Commission (ICC) common carriers, and intrastate carriers. The sample for triples is too small for statistical analysis.

CHARACTERISTICS OF DOUBLES AND TRIPLES FROM TWS

Types of Doubles and Triples Represented

Altogether 58,279 records of trucks were classified

TABLE 3 Area of Operation for Doubles and Triples *(1)*

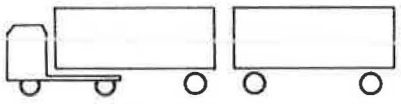
Area of Operation	Western Double, Two-Axle Tractor (%)	Western Double, Three-Axle Tractor (%)	Triple, Three-Axle Tractor (%)
Local	35.6	29.1	12.5
Over the road (one way less than 200 miles)	38.2	38.3	87.5
Over the road (one way 200 miles or more)	25.6	32.6	
Off the road	0.7		

as doubles and triples in FHWA TWS files from 1966 through 1980. Of these records, 99.3 percent were doubles, and the remainder were triples. There were 67 types of doubles in the file and 12 types of triples. Figures 3 and 4 show the major types of doubles and triples found in the TWS from 1966 to 1980. The average GVW, average wheelbase, and the sample size for each major type are also given.

The figures illustrate that the doubles with the more widespread use are the 2-S1-2 (83.2 percent) and 3-S1-2 (8.6 percent), which corresponds with the observation from the TIUS. The turnpike double (3-S2-4), which has received much attention, was represented by only 164 records, or 0.3 percent of the total records of doubles and triples. This suggests that although this vehicle type has strong economic potential, it is not widely used. Among the various triple trailer combinations, the most widely reported was the 2-S1-2-2, which had 260 records out of the total 391 records of triples (66.5 percent); the three-axle tractor triple (3-S1-2-2) ranks second with 83 records or 21.2 percent of all triples records. No records of the two-axle tractor triple were found in TWS. Perhaps this is due to the small sample size of triples provided by the TWS.

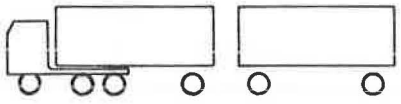
Weight of Doubles and Triples

Figure 5 shows the number of doubles weighed in each of the 48 contiguous states that conducted surveys in 1980 and their mean, minimum, and maximum weight.



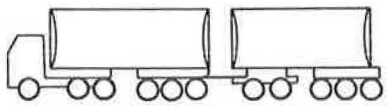
Western Double (Two-Axle Tractor)
(2-51-2)

Sample Size: 48,482 (84%)
Avg. Wheelbase: 59 Feet
Avg. Weight: 56,390 Lbs.



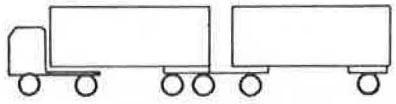
Western Double (Three-Axle Tractor)
(3-51-2)

Sample Size: 4,983 (8.6%)
Avg. Wheelbase: 60 Feet
Avg. Weight: 60,850 Lbs.



Michigan Double Tanker Truck
(3-53-5)

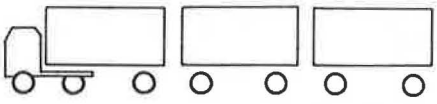
Sample Size: 819 (1.4%)
Avg. Wheelbase: 53 Feet
Avg. Weight: 94,360 Lbs.



Western Double (Tandem Axle Semi-Trailer)
(2-52-2)

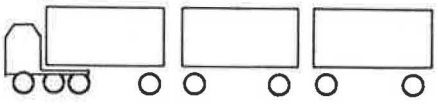
Sample Size: 689 (1.2%)
Avg. Wheelbase: 54 Feet
Avg. Weight: 56,890 Lbs.

FIGURE 3 Major types of doubles in the TWS file: 1966 to 1980.



Triple Trailer Combination (Two-Axle Tractor)
(2-51-2-2)

Sample Size: 260
Avg. Wheelbase: 89 Feet
Avg. Weight: 81,870 Lbs.



Tripler Trailer Combination (Three-Axle Tractor)
(3-51-2-2)

Sample Size: 83
Avg. Wheelbase: 91 Feet
Avg. Weight: 82,670 Lbs.

FIGURE 4 Major types of triples in the TWS file: 1966 to 1980.

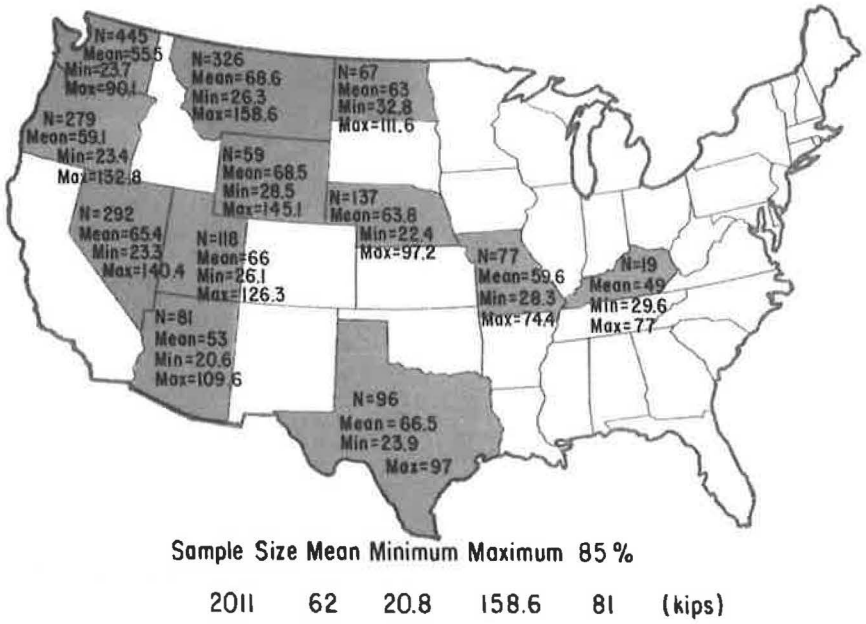


FIGURE 5 Sample size and weight range of doubles weighed in the 48 contiguous states in 1980.

Also the 1980 national summary is provided, including the 85th percentile of the weight of doubles. Figures 6 and 7 show the sample size and the weight ranges of turnpike doubles and triples weighed in 1980, respectively. A similar set of figures was prepared for doubles and triples for each year from 1966 to 1980. A review of the data suggests that the western doubles show more widespread use where they are permitted by law. The use of turnpike doubles is restricted to the western states, the state of Michigan, and designated turnpikes in the eastern states. The use of triples was almost entirely restricted to a few western states, except in 1974, where two triple combinations were also weighed in Michigan.

Share of Doubles and Triples in Traffic

Figure 8 shows the mean percentages of truck combi-

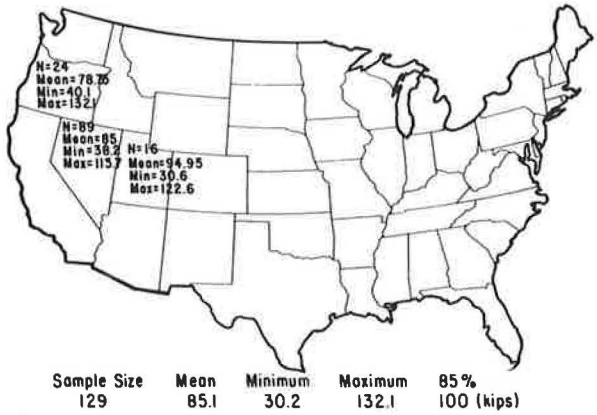


FIGURE 7 Sample size and weight range of triples weighed in the 48 contiguous states in 1980.

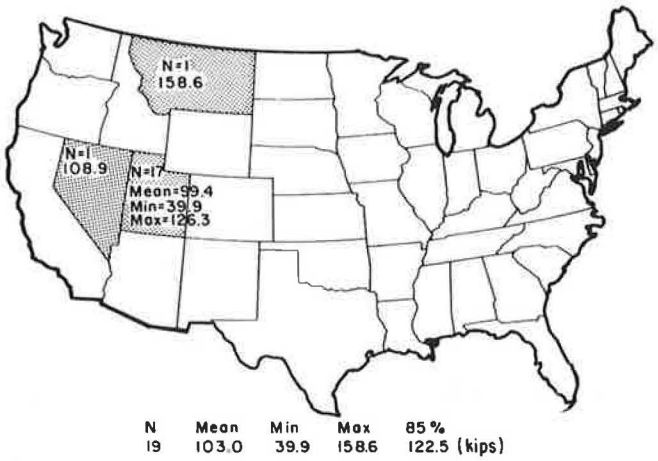


FIGURE 6 Sample size and weight range of turnpike doubles weighed in the 48 contiguous states in 1980.

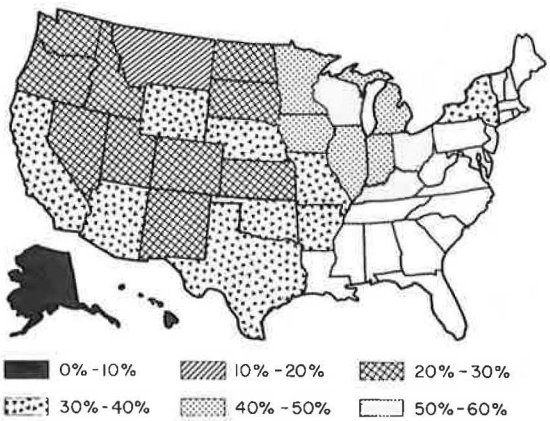


FIGURE 8 Mean percentage of combinations in truck traffic in the United States, 1966 to 1980.

nations in the truck traffic from 1966 to 1980. The illustration is based on the classification survey data reported by the states to FHWA. States that are blank are those that do not allow doubles or triples, that did not report any observations, or those with insignificant data. It is interesting to note that combinations make up a large percentage of the truck traffic in many states around or close to the Great Lakes, such as Ohio, Wisconsin, Kentucky, Michigan, Indiana, Illinois, Iowa, and Minnesota. Figure 9 shows from a slightly different perspective the average percentage of trucks in total traffic from 1966 to 1980. Results show that 13 states (i.e., Kentucky, Indiana, Wisconsin, North Dakota, Montana, Wyoming, Colorado, Texas, Oklahoma, Arkansas, Arizona, Oregon, and Alaska) have, on the average from 1966 to 1980, between 30 and 36 percent of trucks in total traffic. Figure 10 summarizes the data in Figures 8 and 9, showing the spread of combinations in relation to traffic in the United States from 1966 to 1980.

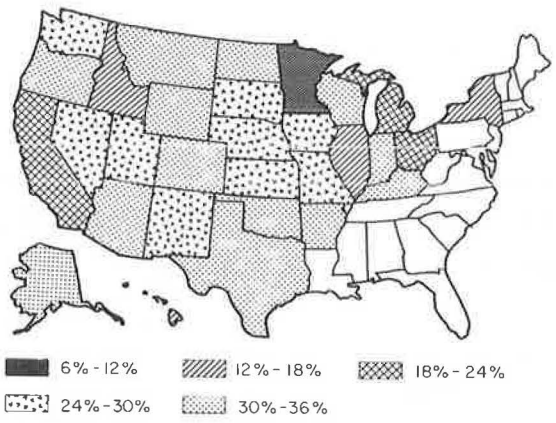


FIGURE 9 Mean percentage of trucks in total traffic in the United States, 1966 to 1980.

Steering Axle Weight

In size and weight studies, the interesting point is the steering axle weight of the truck. This parameter is significant from a number of perspectives. One, it is useful in establishing the practical maximum gross vehicle weight (PMGVW) a vehicle can carry, which is an important parameter in shifting procedure. Steering axle weight is also important from a safety and highway loading viewpoint. For convenience, the 67 types of doubles in the truck weight survey from 1966 through 1980 were grouped into three categories according to the lengths of their wheelbases. Those with a wheelbase of 65 ft or less are referred to as small doubles, those with a wheelbase between 65 and 85 ft as medium doubles, and those with a wheelbase greater than 85 ft as large doubles. The data show that the average steering axle weight for small and medium doubles from 1970 through 1980 is about 9,000 lb and that large doubles fall somewhere between 9,000 and 10,000 lb. The average steering axle weight for triples has been about 9,500 lb. The distribution of average steering axle weight for small doubles is shown in Figure 11.

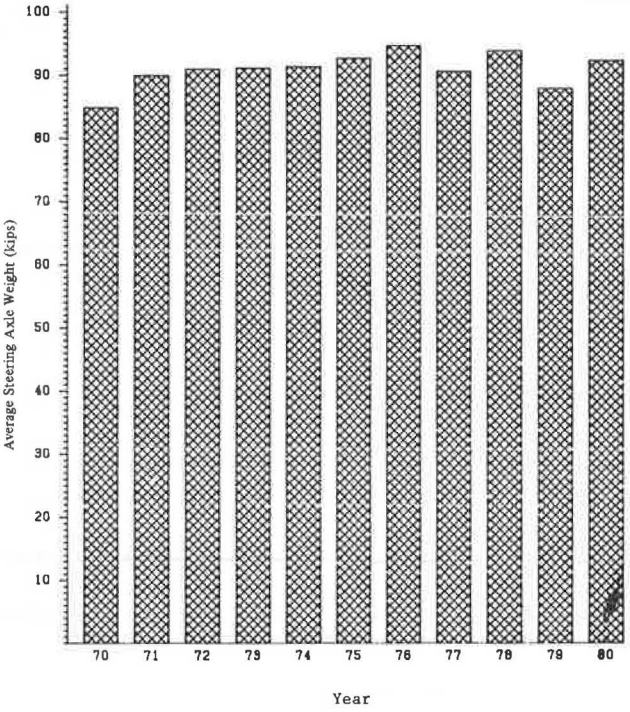


FIGURE 11 Mean steering axle weight for small doubles, 1970 to 1980.

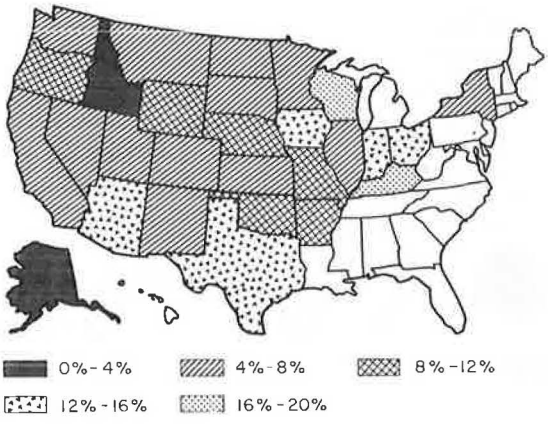


FIGURE 10 Mean percentage of combinations in total traffic, 1966 to 1980.

Gross Vehicle Weight

GVW distribution is important mainly from the points of view of highway loading, vehicle payload, and vehicle weight violation. Figures 12 and 13 show the GVW data for two-axle tractor, western doubles for the years 1967 and 1980, respectively. In Figure 12, the two peaks indicate that the empty weight is close to 30,000 lb, and the loaded weight is approximately 75,000 lb. Comparing Figure 12 with Figure 13, a rightward shift is noted in the national weight distribution; the left peak shifted to 35,000 lb while the right peak remains at 75,000 lb. A slightly greater percentage of overweight vehicles is also observed.

Figure 14 shows the GVW distribution of triples in 1980. A total number of 129 samples were collected in that year, indicating a significant increase in the reported use (or observations) of triples since 1970. The figure shows that many of

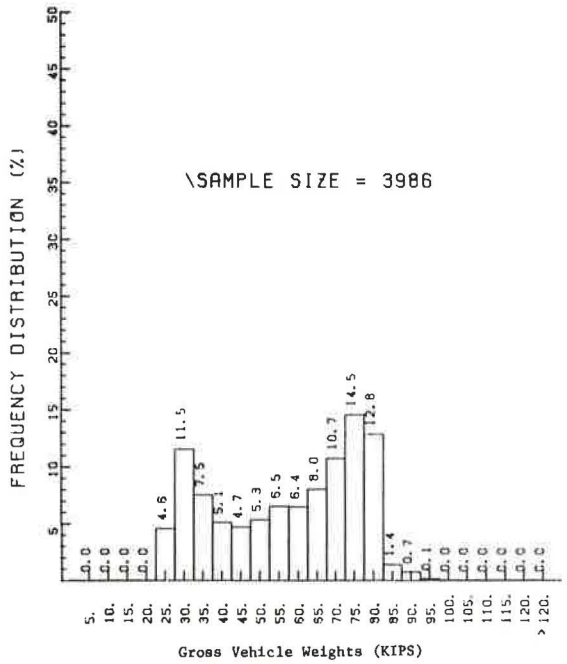


FIGURE 12 National gross vehicle weight distribution of western doubles in 1967.

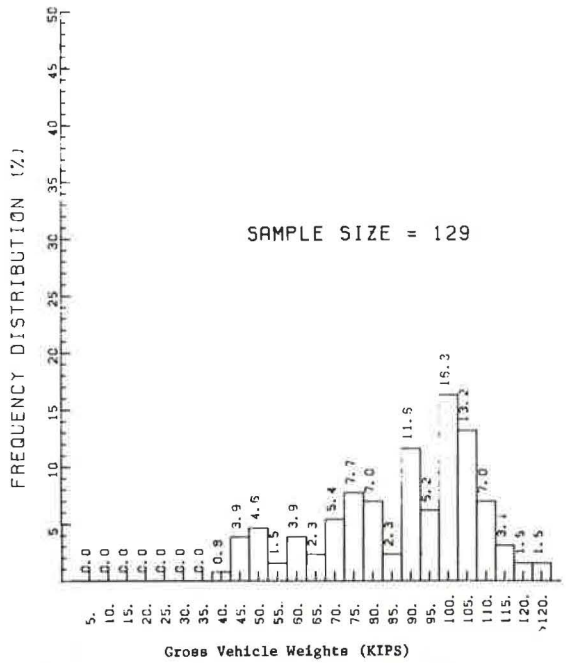


FIGURE 14 National gross vehicle weight distribution of triple trailer combinations in 1980.

the triple combinations are operating at weights greater than 80,000 lb; the largest group observed weighed more than 100,000 lb.

Weight Violations

Examples of violations by doubles and triples in Texas are used in this discussion. Figure 15 shows violations of single-axle weight limits from 1970 through 1980 for the two-axle western double. The figure provides a comparison of the number of western doubles weighed in Texas that were not in violation of the single-axle weight with those over the legal limit. The results suggest an increase in recorded small doubles operating in excess of the legal limit.

Empty Vehicle Trips

Another important fact obtainable from the files of doubles is how often a particular vehicle type runs empty on the highway. Figure 16 shows that the aver-

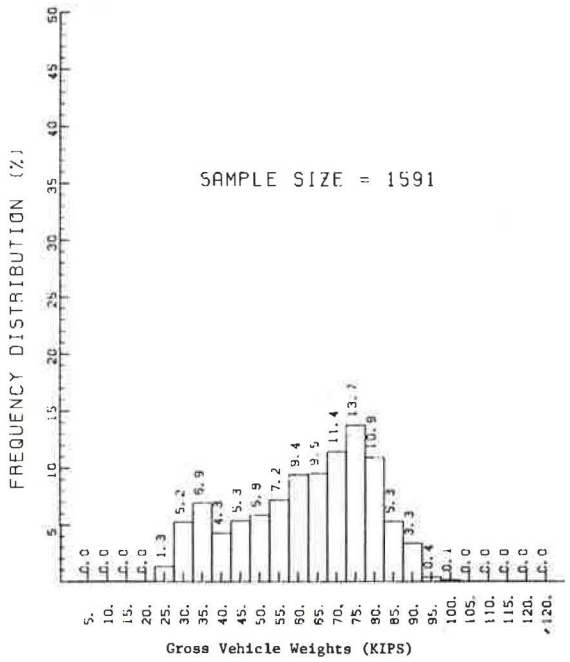


FIGURE 13 National gross vehicle weight distribution of western doubles in 1980.

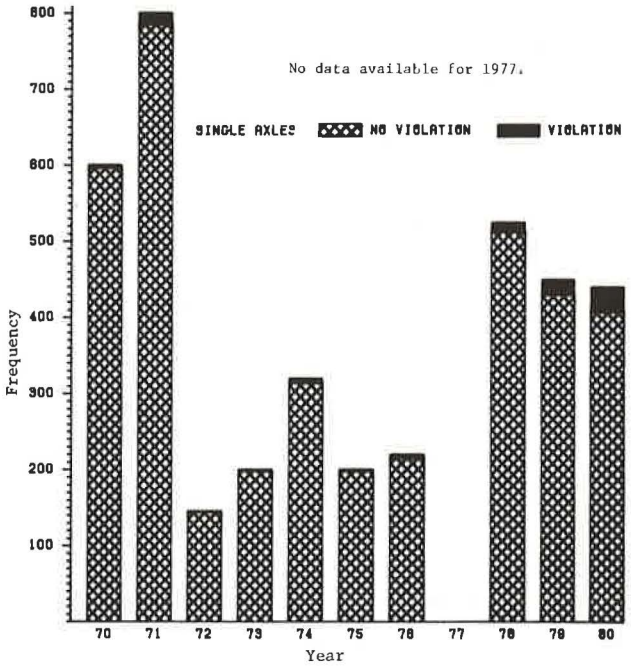


FIGURE 15 Frequency of single-axle weight violations for western doubles in Texas, 1970 to 1980.

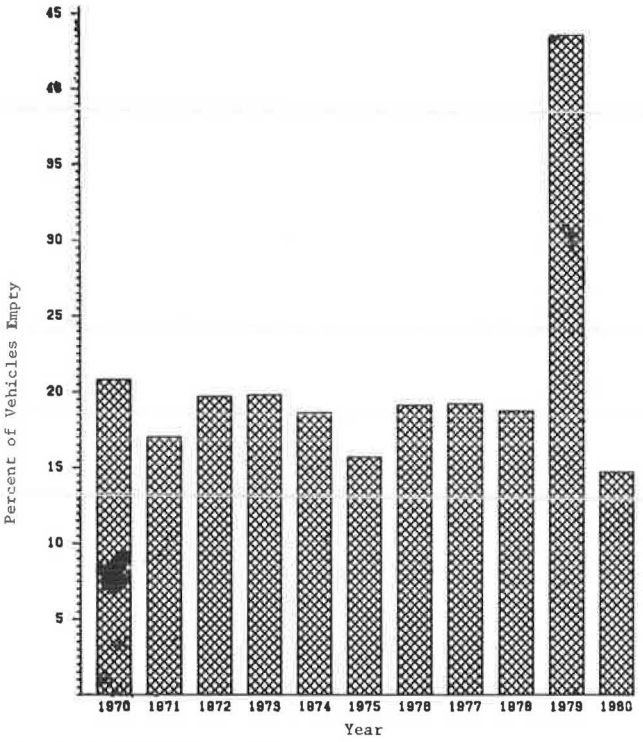


FIGURE 16 Percentage of vehicles empty, doubles, and triples in the United States, 1970 to 1980.

age percentage of doubles and triples from 1970 through 1980 that were recorded as operating empty ranges from 17 to 20 percent. The data for 1979 are anomalous, although the cause has not yet been found.

Commodities Carried

The question of what types of commodities are carried by these trucks is also an important one. It must be noted, however, that because dynamic weighing methods are used, much commodity-related information is no longer available from TWS and commodity information from TWS must be used judiciously. Therefore, only data from states where manual weighing and driver interviews are still conducted may be relied on. For the sample as a whole, the TIUS commodity information is more accurate than TWS, because TIUS has a more uniform sampling procedure. This does not nullify the usefulness of TWIS in providing commodity-related information; however, the data must be qualified, and the validity of the data should be accepted only from states where driver interviews are still included in the study.

SUMMARY AND CONCLUSIONS

Figures 1-16 have shown some of the important or interesting aspects of the operation of doubles and triples in the United States from 1966 to 1980 based on the two most available data sources on trucks: TWS and TIUS represent two ends of a sampling spectrum. The TIUS is conducted by the Bureau of the Census, has a well-planned sample design, and is aimed at getting a broad picture of the entire range of the nation's truck resources.

The TWS represents the other end of the spectrum. It has a very large sample, is conducted either annually or biennially, is conducted by each state highway department in cooperation with FHWA, and lacks a cohesive, well-planned sampling strategy. The sampling plans are often varied according to the budget of the state highway department.

The TIUS is answered by truck owners on their company premises, whereas TWS is conducted on the road. Although TWS is also aimed at obtaining a knowledge of the nation's trucks, it is obtained from a different perspective and places more emphasis on the dimension and loading aspects of the vehicle. For data on vehicle loading and axle spacing, TWS is definitely a much better resource than TIUS. However, for other aspects of the truck resources, such as the commodity carried, operator classification, engine makeup of the vehicle, TIUS is the preferred source.

At present, researchers or students of the field can only take these facts into consideration and make the best use of these two data sources when studying doubles or triples. Although the statutory environment for doubles and triples may be quite different after the passage of the Surface Transportation Assistance Act of 1982, the data collected in the past can still be useful both in ascertaining the trend of development of doubles and triples in the past and in serving as a guide to the future. The shortcomings of the past data sets, discovered in the course of this study, will surely help to determine future data requirements.

Although the TWS and TIUS data may have met current needs, both data sets are inadequate in some aspects to understand the operations and performance of doubles and triples in the future. As noted previously, TIUS has been structured to examine the truck resources in the United States across the whole spectrum. It does not target any specific needs of doubles and triples, or other vehicle types. In the future it may be necessary to include a special section of the survey to deal with specific questions. If doubles and triples have sufficient economic potential to have widespread use in the future, and if the need to understand such vehicle types also increases, a special section in the survey to deal with specific issues is warranted.

As for TWS, if a better sampling structure can be incorporated into the program, the reliability and usefulness of the data will definitely be much enhanced. At present the nonuniform techniques used from state to state make it difficult to characterize trucks on a nationwide basis. However, if the sampling plan is better defined and implemented on a national basis, statistical techniques could be used to process data and to assist federal, state, and local governments in their policy decisions.

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