Abridgment

Estimating Vehicle Weight Distribution Shifts Resulting From Changes in Size and Weight Laws

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Vehicle-weight-shifting methodology is an important element in the economic analysis model for changes in vehicle size and weight limits. The existing models were analyzed based on data for truck weights gathered in Texas since 1954. Results of the analysis show that the pattern of vehicle weight redistribution varies with vehicle class, which suggests that each vehicle class be considered separately. The historical and current use patterns of each vehicle type, practical maximum gross vehicle weight, and equipment-replacement policies should all be considered in a forecast. The phenomena described by the demand and volume-constraint concepts were observed in three vehicle types. Steering-axle weight distribution was not affected by the 1975 change in the Texas weight law, which allowed gross vehicle weight to increase from 72 000 to 80 000 lb, tandem-axle weight from 32 000 to 34 000 lb, and single-axle weight from 18 000 to 20 000 lb. The assumption that the distribution in axle weights for each type of axle has the same ratio to gross weight was found to be basically sound. The analyses of distribution of multiplying factors reveal large discrepancies and the need for further investigation. The findings suggest that further study is warranted to produce a more-accurate methodology for forecasting vehicle weight distribution under any proposed size and weight limits.

In evaluating the effects of the changes of motor vehicle size and weight limits on vehicle operating cost, fuel consumption, and highway maintenance and rehabilitation cost, one key element is the shift in vehicle weight distribution. In several previous studies on the economic effects of changes in size and weight limits, four methods were proposed to forecast the shifted vehicle weight distribution. These methods can be summarized as follows:

1. First Federal Highway Administration (FHWA) methodology: The methodology, presented in the Manual of Procedures for Conducting Studies of the Desirable Limits of Dimensions and Weights of Motor Vehicles (1), estimates axle weight distribution from data collected in states that have limits similar to those under investigation.
2. Second FHWA methodology: This methodology, also presented in the same report (1), is a step-by-step procedure used to predict vehicle weight distribution under the proposed size and weight limits from existing weight distribution.
3. The National Cooperative Highway Research Program (NCHRP) methodology: This is an improved and expanded version of the second FHWA methodology and is published in NCHRP Report 141 (2).
4. The Texas State Department of Highways and Public Transportation (SDHPT) methodology: This was developed during the Texas study on the effects of heavier trucks on highways (3). It is conceptually an improved version of the NCHRP methodology.

During the initial phase of the Texas truck weight study, both the first and the second FHWA methodologies were examined. The first methodology was found to be inadequate since it relied on data from states that had size and weight limits similar to proposed changes in the state in question. The compatibility of data and circumstances can vary significantly from state to state, which makes such great assumptions difficult. The second FHWA methodology is the predecessor of the NCHRP methodology; therefore, the second FHWA methodology was rejected in favor of the NCHRP methodology.

NCHRP SHIFTING METHODOLOGY

The NCHRP shifting procedure contains two parts: the first calculates the gross vehicle weight (GVW) distribution of each vehicle class under the current and the proposed limits, and the second calculates the axle weight distribution of each vehicle class under the current and the proposed limits. Both parts are essential to the overall computation of benefits and costs. Distribution of GVW is directly related to the calculation of vehicle operating cost, fuel consumption, and payload carried. Distribution of axle weight is needed for the estimation of the total number of 18-kip single axles to be expected. The NCHRP shifting procedure contains the following explicit assumptions (2):

1. Given an increase in legal weights, the empty weight of the trucks will increase to provide for the strength and durability of the vehicle in use under heavier payloads.
2. Trucks will carry increased payloads per trip and therefore operate with increased axle and gross weights.
3. Vehicle weight distribution will change from the current legal limits to future limits as a function of the change in practical maximum gross vehicle weight (PMGVW) of each vehicle class. PMGVW has been defined as the sum of the individual axle legal weights; the front or steering-axle weights are set at a reasonable amount consistent with that class of vehicle as indicated through roadside weighting.
4. Under the new legal limits, the change in axle weight distribution will generally be consistent with the increase to gross weight. The new distribution in axle weight for each type of axle is assumed to retain the same gross-weight ratio under the new limits as was found with roadside weightings under the current limits.

The pattern of shift of the NCHRP shifting-procedure model is based on past research, which indicates that with an increase in GVW limit or axle weight limit, the gross weight distribution will experience a shift to the right, as shown in Figure 1 (4). However, this model was based on 1962 truck weight study data and does not apply to more-recent size and weight situations.

The type of shift that was described in NCHRP Report 141 can be represented by Figure 2. Each weight interval of the current limit is adjusted by a multiplier to represent the weight interval under the proposed limit. The multiplying factor is assumed to be unity at the lowest gross weight interval and increases linearly until it reaches the practical maximum gross at the current limit, beyond which the factor remains constant and equals the ratio of PMGVW at the proposed limit over PMGVW at the current limit.

SDHPT SHIFTING METHODOLOGY

After the NCHRP shifting procedure had been reviewed, the following recommendations were made: (a)

Figure 1. Typical historical shifts in gross weight distribution.

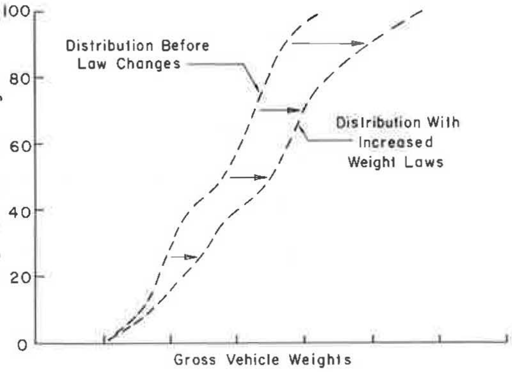
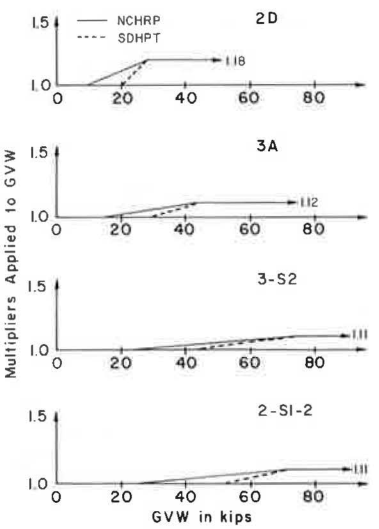


Figure 2. Multiplying factors used by NCHRP and SDHPT methodologies in forecasting vehicle weight distribution shift due to 1975 weight-law change.



that a computerized curve-fitting and curve-smoothing procedure be used, (b) that no substantial increase in empty vehicle weights be expected, and (c) that the procedure account for the fact that volume- and demand-constrained vehicles (vehicles that carry low-density cargo or less-than-trailer-load capacity) will not be much affected by the increase in weight limits. This was determined by allowing the upper range of the weight intervals to experience a more-substantial shift than the lower range (4).

These recommendations were incorporated into the SDHPT model, which varies from the NCHRP model in the following major areas:

1. The empty weight of the vehicle is assumed to be the same regardless of a change in size and weight limits.
2. A computerized curve-smoothing and curve-fitting procedure is used.
3. More of the heavily loaded vehicle trips are assumed to shift to a larger GVW in proportion to the ratio of future PMGVW limit to current PMGVW limit.
4. Lightly loaded vehicles are assumed to be unaffected by the change in the law (3).
5. Rather than keeping the number of vehicles constant and varying the payload, the SDHPT procedure holds the payload constant regardless of the weight limit.
6. The NCHRP procedure uses both GVW and axle weight distribution to compute the final costs and benefits, whereas the SDHPT procedure eliminates the calculation of axle weight distribution in an effort to further streamline the procedure.

The differences cited in items 3 and 4 above are reflected in the multiplying factors used.

Research done during the initial phase of the Texas truck-weight study recommended that the multiplying factors for 2D and 3A start increasing from 50 percent of the cumulative percentage of GVW, whereas 3-S2 and 2-S1-2 start increasing from 33 percent. It was also found that distributing the non-front-axle weight portion of GVW evenly among those axle groups does not affect the outcome significantly.

ADEQUACY OF EXISTING METHODOLOGIES

The SDHPT procedure was developed by using pre-1975 data. Since 1975, significant events that affect truck size and weight limits and operational aspects of the motor carrier industry have occurred; therefore, more-recent (or post-1975) data could provide valuable insight into the vehicle weight redistribution process. At the time the procedure was developed, there was little supporting evidence for the volume- and demand-constraint concepts or for the assumption that only those vehicles that operate near their current weight capacity would shift to higher GVW once the weight limit was increased (4).

In spring 1980, the Texas truck-weight survey data for the years 1976 and 1978 were made available. In an effort to update the data base and to validate the benefit-cost analysis methodology, a number of sample runs were made to compare the model's outputs based on pre-1975 data and post-1975 data. In the process, the need for additional refining of the current shifting methodology became apparent; hence, a number of analytical programs were developed to compare data with the projections based on the current weight-shifting methodology. Truck-weight data for Texas from 1954 were also plotted in an effort to gain insight into the weight redistribution process. The data were arranged in variety of ways and compared. These results indicated the following:

1. The historical-shift pattern shown in Figure 1 was not observed in the cumulative frequency plots for most vehicle types (see Figure 3--NCHRP and SDHPT plots represent their predictions of GVW distribution after 1975 weight-law change).
2. The change in the Texas weight limit in 1975 (single axle from 18 000 to 20 000 lb, tandem axle from 32 000 to 34 000 lb, and GVW from 72 000 to 80 000 lb) did not affect the steering-axle weight distribution.
3. What SDHPT methodology described as the volume- and demand-constraint concepts were more evident in three vehicle types (2D, 3A, and 2-S1-2) than in the fourth (3-S2).
4. The NCHRP model's assumption that "the new distribution in the axle weight for each type of axle may be assumed to retain the same ratio to gross weight under the new limit as was found in the roadside weighing" has merit and is reasonable.
5. The assumption in current methodolgies that truck weights will shift in proportion to the ratio of the proposed PMGVW limits to the current PMGVW limit is challenged. Figure 4 shows the multipliers computed from actual data. In comparing Figure 2 with Figure 4, a large discrepancy is noted. The

Figure 3. GVW distribution based on truck weight survey and on predictions made according to NCHRP AND SDHPT methodologies.

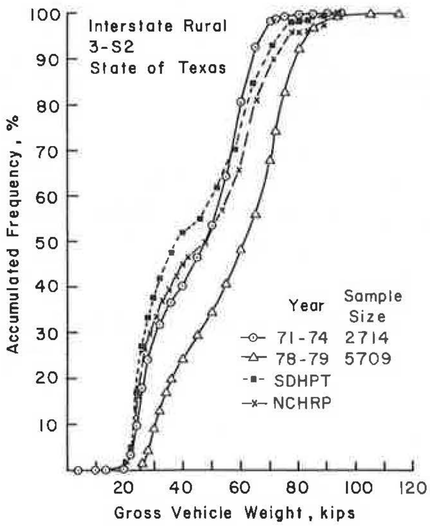
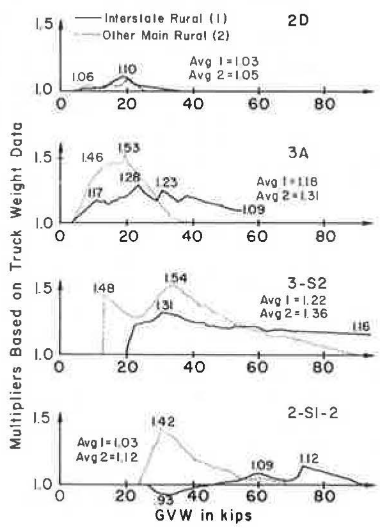


Figure 4. Multiplying factors based on truck-weight survey.



cause for such a discrepancy is not fully understood.

6. The historical and current use patterns of PMGVW under the proposed limit compared with those of PMGVW under the existing limit indicate that the redistribution of vehicle weight due to changes in size and weight laws varies from one vehicle class to another. Tire construction, trailer type, and terminal requirements must also be considered.

A vehicle-type-based methodology that allows consideration of the above-mentioned factors is preferred to a general one.

CONTINUING MODELING EFFORT

Based on the above observations, it was concluded that a more-accurate method of forecasting vehicle weight distribution for any given or proposed size and weight limit should be explored. There were three possibilities: (a) modify the SDHPT procedure, (b) approach the redistribution problem by developing axle-weight relationships rather than GVW, or (c) combine the GVW procedure for single-axle vehicles (2D and 2-S1-2) and the axle-weight procedure for vehicles that have tandem axles (i.e., 3A and 3-S2).

It may be possible to better understand the weight-redistribution process from an analysis of axle weights for certain vehicle types, particularly those that have tandem axles. Weight data from axle groups can be combined to obtain gross vehicle distribution for the estimation of vehicle operating cost and fuel consumption as in the current procedure.

CONCLUSION

The vehicle weight redistribution process under the new size and weight limits remains an important issue in the estimation of any resultant effects. Past methodologies--from the FHWA methodology and the NCHRP methodology to the latest SDHPT methodology--have all contributed to a better understanding of the redistribution process. However, the availability of more-recent data, particularly since the last change in vehicle weight limits in Texas as in many other states, has made the validation of these procedures necessary. The findings have confirmed some of the assumptions in the existing methodologies and have challenged a number of other assumptions. It is hoped that continuing research in this area will produce a methodology that can more accurately forecast vehicle weight distribution behavior under any proposed change in motor vehicle size and weight limits.

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This report reflects our views and we are responsible for the contents, facts, and accuracy of the data presented. The contents do not necessarily reflect the official views or policies of the Texas SDHPT. This report does not constitute a standard, specification, or regulation.

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