# Gross Vehicle Weight Distributions as a Function of Weight Limits

ALAN M. CLAYTON AND ROBERT G. THOM

Weight limits are a principal determinant of the weight characteristics of large trucks. They provide a logical and practical base from which these weight characteristics can be predicted. Such predictions are necessary for evaluating the relative benefits and costs of alternative weight and dimension policies. During the past 20 years, Canada has had a weight limit policy that has stipulated a variety of different weight limit regimes to the same truck type. This has provided an on-road experiment of how weight limits translate into actual truck weights. This experiment has created a large and unique data set that permits relating actual truck weights to governing weight limits spanning a broad range. On the basis of this data set, empirical models linking the distribution of gross vehicle weights (GVWs) of three of Canada's most common large truck combinations to the GVW limit governing these trucks are developed. They assume an idealized complete compliance condition, with no violation of the limit. The three truck types for which models are developed are the 5-axle (3-S2) tractor-semitrailer, the 7-axle (3-S2-S2) B-train combination, and the 7-axle (3-S2-2) A-train combination. The complete compliance condition is of course violated if weight limits are not enforced or overweight operations are allowed by special permit. The predictive capability of the 3-S2 model is examined in relation to the GVW distribution of a sample of 3-S2s operating under a GVW limit different from those used in constructing the model. The predicted and actual distributions compare favorably.

Models for predicting distributions of the gross vehicle weight (GVW) of three truck combinations—5-axle (3-S2) tractor-semitrailers, 7-axle (3-S2-S2) B-trains, and 7-axle (3-S2-2) A-trains—are presented. The models predict these distributions as a function of the governing GVW limit for an idealized complete compliance condition, assuming no violation of the limit. They are constructed from a large data base of the weights of trucks operating on Canadian highways through 1974 to 1990. This period saw important changes in Canada's weight and dimension regulations, which in turn provided an extensive "real-life" experiment concerning the effects of weight limits on the operating weights of trucks.

Truck weight distribution models have three principal applications in highway engineering. One, they are useful for evaluating the benefits (i.e., truck productivity gains) and costs (i.e., infrastructure design and deterioration implications) of alternative weight and dimension limit policies. Developing such estimates has proven difficult in the past (*1,2*). Two, in combination with forecasts of truck movements, they can assist in forecasting total axle loadings for purposes of pavement design and the evaluation of pavement life. In the same vein, they could be helpful in any back-casting effort directed at constructing the likely historical loadings to which a pavement has been subjected. Three, growing use of the load factor design concept in bridge engineering requires more and better information about actual truck loads and load distributions (*3*).

A. M. Clayton, Department of Civil Engineering, University of Manitoba, Winnipeg, Manitoba, R3T 2N2, Canada. R.G. Thom, University of Manitoba Transport Institute, University of Manitoba, Winnipeg, Manitoba, R3T 2N2, Canada.

## MODELING THEORY

The idea behind these models stems from the observation that weight and dimension regulations are the principal determinant of the types, dimensional features, and—particularly for this work—weight characteristics of large trucks operating on a highway system (*4*).

Specifically, the modeling is based on the hypothesis that the distribution of GVWs of laden trucks can be related to and expressed as a function of governing GVW legal limits. This hypothesis emerged from observing two recurring attributes in Canadian truck weight data (*5*). The first, which is intuitively appealing, is that when the GVW limit for a particular truck type is relaxed, then a proportion of that type of truck's operations will increase payloads. This in turn leads to a new, shifted GVW distribution curve for this truck type. Second, truck weight distributions are reasonably stable for a given weight limit.

Why are these attributes present in truck weight data? The following explanation has been offered (*6*). Truckers try to maximize payloads, subject to the limitations imposed on doing so by the characteristics of the demand for freight movement by truck and the regulations limiting truck weights and sizes. In striving for this goal, some loads "weight-out," some "cube-out," and others—because of various demand considerations—do neither. Given reasonably stable demand with fixed weight limits, a steady-state hauling situation emerges, exhibiting regularity in truck weight distributions. If a higher GVW limit is imposed, increases in the shipment sizes of some weight-out movements take place, up to a level constrained by the new limit. Cube-out movements, on the other hand, must continue to be handled in their original cube-out quantities, at their original GVW levels. The weight limit increase, per se, does nothing to alter the incidence of partial loads. After some period of adjustment, a new steady state, including new weight distribution functions, can be expected to emerge.

## RELATED RESEARCH

Yu and Walton (*7*) evaluated a number of methods used to predict truck weight distributions under conditions of chang-

ing regulatory limits in the United States. The methods were found wanting on a variety of counts, including the data bases from which they were developed, their conceptual formulations, and their inability to produce adequate predictions. Yu et al. (*1*) accordingly developed the "Texas Shift" method. Similar to the models developed here, the Texas Shift method estimates GVW distributions as a function of governing weight limits.

In using the Texas Shift methodology in the Canadian context, Clayton and Plett (*6*) encountered two difficulties. The first stems from the essence of the Yu et al. methodology, namely extrapolation (by an eye-balling technique) of existing cumulative weight distribution curves to different weight limit circumstances. Different analysts (i.e., different "eyes") can have different results. Secondly, the method relies on an assumption that the ratio of the means of weights of a particular truck type to that truck type's practical maximum GVW is constant and independent of the regulation limit. This assumption was found wanting in the analysis of a large data set involving 3-S2 combinations.

## GENERAL CONSIDERATIONS RELATING TO MODEL CONSTRUCTION

### Modeling Process

The modeling requires relating measured truck weights to governing weight limits for each truck type, and developing empirical models of these relationships. For the models presented here, this involves four stages, illustrated in Figure 1.

Stage 1 is the acquisition of the truck weight information of interest for each truck type (e.g., the GVWs of 3-S2 tractor-semitrailers) under a series of weight limits (e.g., LIMIT 1, LIMIT 2, etc.). Stage 2 "corrects" these raw data sets by ridding them of overweight observations, thereby creating an idealized complete compliance condition. As discussed subsequently, this stage is necessary in order to retain the inherent rationale of the model. Stage 3 develops empirical models of a common form designed to reproduce the resulting corrected weight distributions for each of the governing limit cases. Stage 4 "marries" these models so as to permit their generalization as a function of the governing limit. The resulting generalized model permits estimating weight distribution curves given the governing weight limit.

### Data Base

Models are developed for three common truck configurations operating in Canada, namely the 5-axle (3-S2) tractor-semitrailer, the 7-axle (3-S2-S2) B-train combination, and the 7-axle (3-S2-2) A-train combination. The 3-S2 tractor-semitrailer is the most common configuration in the Canadian trucking fleet. It is used to transport the full range of commodities, in both truckload and less-than-truckload quantities. The 7-axle B-train is a large truck combination comprised of a 3-axle tractor plus tandem-axle semitrailer plus a second tandem-axle semitrailer. B-train combinations are generally used for hauling dense products (i.e., petroleum, lumber, bulk fertilizer, grain), in truckload quantities. The 7-axle A-train is another large Canadian truck combination composed of a 3-axle tractor plus tandem-axle semitrailer plus a second 2-axle trailer. Typical dimensional characteristics for these units are shown in Figure 2.

The models have been constructed from truck weight data obtained from four sources (Manitoba Department of High-

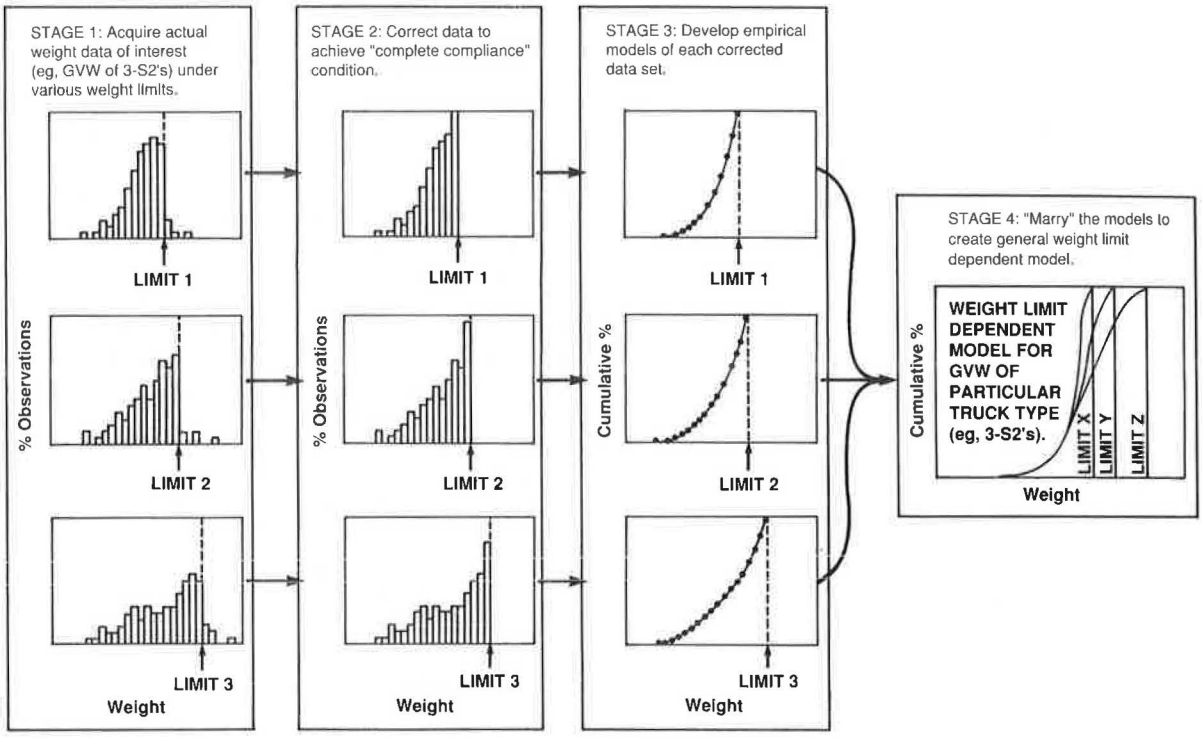


**FIGURE 1 Modeling process.**

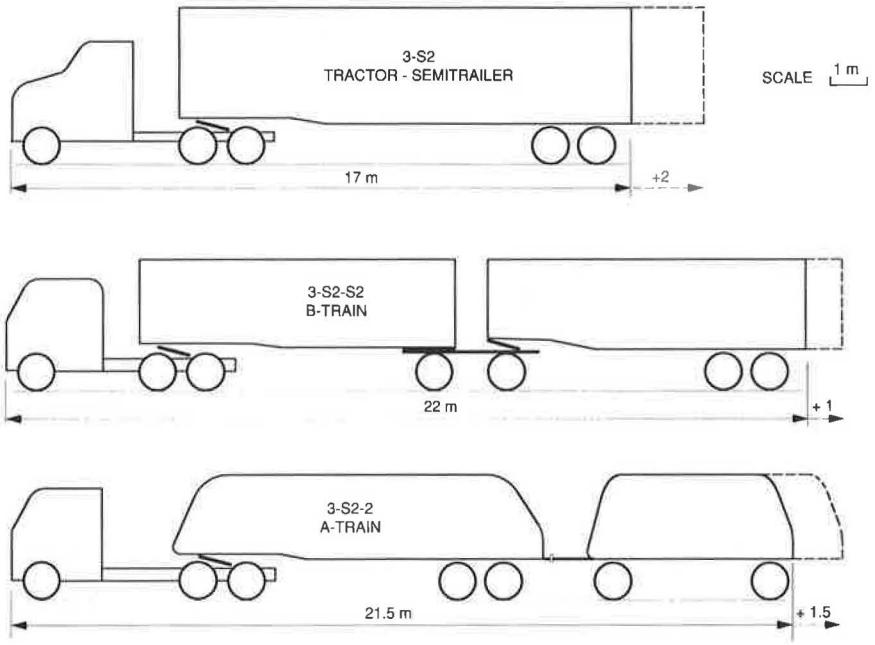


**FIGURE 2 Typical truck dimensional characteristics.**

ways truck weight surveys between 1972 and 1986; Atlantic Canada Truck Weight Survey of 1985; Saskatchewan Department of Highways truck weight survey of 1986; special winter 1990 surveys conducted in Saskatchewan and Manitoba concerning the weights of Canada's new "RTAC" trucks). Details regarding these data bases are presented elsewhere (*5,6,8,9*). Summary information concerning the content of these data sources is given in Table 1.

To do the modeling, this truck weight data have been related to governing weight limits. Nix et al. (*10*) and Nix (*11*) provide details concerning the weight and dimension regulations applicable during the survey periods considered.

### Rationale for Modifying the Raw Data

Many trucks operate overweight (*12*). The extent of overweight trucking is dependent on enforcement policies and practices (*13*), and the extent to which overweight trucking is specially permitted. Policies concerning these matters vary among and even within jurisdictions. In developing the model concept and the resulting formal GVW models, the issue of how to handle overweight observations in the various data sets required special attention.

Two approaches were considered. The first involves retaining the overweight observations in the data sets, and developing general weight limit-dependent distribution models incorporating an overweight element. This was done in the models reported elsewhere (*6*). The problem with this approach is that there is no way of objectively accounting for the effect of variations in enforcement and special permitting on the resulting models. For example, for data obtained under a condition of low enforcement, the relationship between truck weights and weight limits could be expected to be quite different than the same relationship under a high enforcement condition, other things being equal. At the extreme, these relationships might become virtually meaningless under a zero enforcement case (i.e., would a totally unenforced weight limit have any effect on truck loads?).

TABLE 1 SUMMARY OF ORIGINAL DATA SETS

| Truck Type | Effective GVW Limit (EGVW) (t) | Axle Limits (t) | Source | No. of Trucks Weighed |
|---|---|---|---|---|
| 3-S2 | 33.6 | 5.1/14.6/14.6 | Manitoba secondary highways | 8,806 |
| | 37.3 | 5.3/16.0/16.0 | Manitoba primary highways | 12,556 |
| | 40.5 | 5.5/17.0/18.0 | Atlantic provinces | 4,517 |
| 3-S2-S2 | 50.0 | 5.3/16.0/16.0/16.0 | Manitoba primary highways | 46 |
| B-train | 53.3 | 5.3/16.0/16.0/16.0 | Saskatchewan 1986 survey | 372 |
| | 56.5 | 5.3/17.0/17.0/17.0 | Saskatchewan special survey | 38 |
| 3-S2-2 | 50.0 | 5.5/16.0/16.0/9.1/9.1 | Manitoba primary highways | 78 |
| A-train | 53.5 | 5.5/16.0/16.0/9.1/9.1 | Saskatchewan 1986 survey | 513 |
| | 55.7 | 5.5/16.0/16.0/9.1/9.1 | Manitoba special survey | 18 |

The second approach, and the one selected, is to modify the original data sets—in a consistent, reproducible manner—to make them comply with the governing weight limits. This is done by assuming an idealized condition of complete compliance with the applicable weight rule. The idea behind this is that the developed models should express the ideal weight distributions that could be expected under particular weight limits, assuming compliance. To the extent that a jurisdiction does not enforce its weight limits and specially permits overweight operations, adjustments to the resulting weight distribution models could subsequently be reintroduced in an explicit manner.

The method used to modify data to the complete compliance condition is as follows. Trucks which exceed their legal GVW limit are assumed to have their payloads reduced to a level where their resulting GVWs are just at the limit. This is done by taking all weight observations which are greater than the limit and allocating them to the weight category whose upper boundary is the limit. This allocation method implies that the excess payload associated with overweight observations is removed from and does not influence the resulting complete compliance models.

## TERMS

The models make use of two terms requiring definition, namely, the effective GVW limit and the effective steering axle limit. The effective GVW limit (EGVW) is the lesser of: (i) the legislated GVW limit; or (ii) the sum of the axle weight limits, with the steering axle limit being set at the effective steering axle limit. The effective steering axle limit for each truck type is set at the mean weight of that truck type's steering axles observed in the field, plus twice the standard deviation of the sample of steering axle weights from which the mean is derived. Effective steering axle limits for the three truck types modeled here are shown in Table 2.

The effective GVW limit concept is required for this modeling exercise because trucks are often unable to achieve their fully permitted GVW limit either for lack of axles or an inability to shift adequate load to the front steering axle.

(The effective GVW limit used here is equivalent to the Yu et al. (*1*) practical maximum GVW concept. The calculation details are somewhat different, however.)

## MODEL DETAILS

### 5-axle (3-S2) Tractor-Semitrailer GVW Model

This model has been developed from GVW observations for 3-S2s operating under three different (effective) GVW limits (33.6 t, 37.3 t, and 40.5 t). This set of limits covers a GVW range which encompasses the actual limit for these trucks in most countries. Table 1 shows the sources and numbers of truck weight observations used for this model. Details involved in preparing this data set for modeling are given elsewhere (*6,14*).

Figure 3a shows the actual cumulative curves developed from these data sets. Figure 3b shows these same distributions corrected to achieve complete compliance. To illustrate the correction process, consider the 12,556 3-S2 trucks weighed on Manitoba primary highways on which the GVW limit for these units was 37.3 t. Of these 12,556 units, 159 had a GVW level of more than 38 t. These 159 observations were reallocated to the 37-38 t weight category, which in the final model is the weight category 37-37.3 t.

TABLE 2 EFFECTIVE STEERING AXLE LIMITS

| Truck Type | Effective Steering Axle Limit (kg) |
|---|---|
| 3-S2 | 0.08(Tandem Axle Limit in kg) + 4,000 |
| 3-S2-S2 | 5,300 |
| 3-S2-2 | 5,500 |

Source: after Plett, R. (*15*).

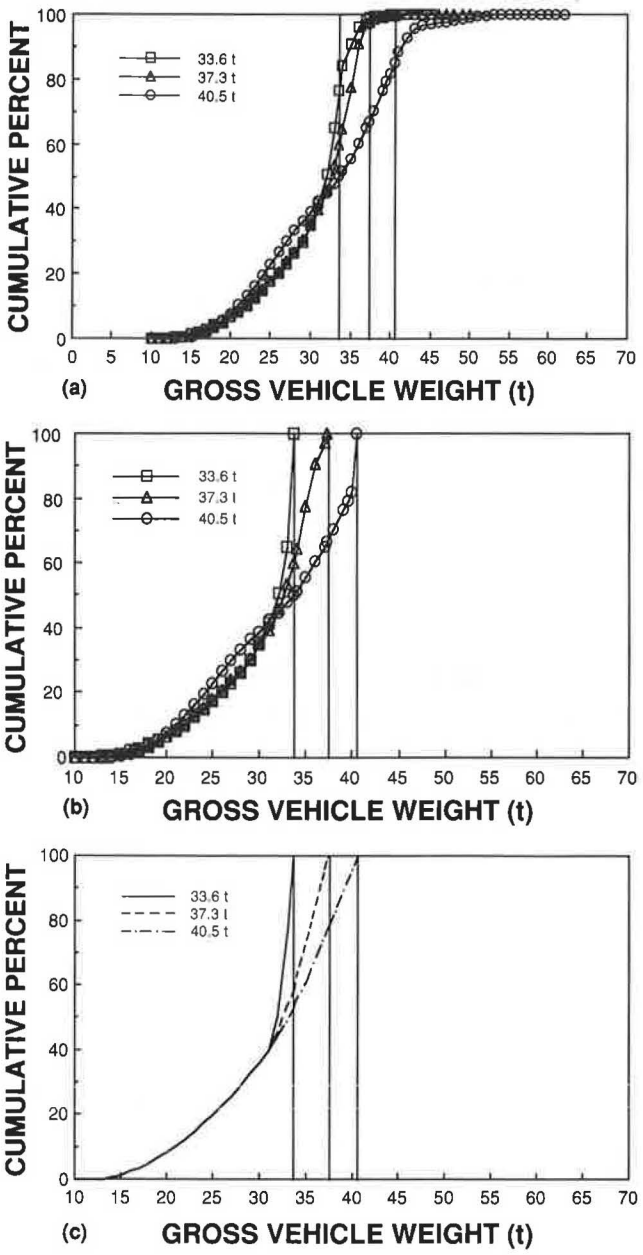


**FIGURE 3 GVW Distributions—3-S2s: (a) observed; (b) corrected; and (c) model.**

TABLE 3 CUMULATIVE GVW DISTRIBUTION MODELS

Models

| Truck Type | $x$ percent less than or equal to on a cumulative curve | $P(x)$ the GVW at which $x$ percent or less trucks operate (in t) |
|---|---|---|
| 3-S2 | for $x > 40$ | $P(x) = [\gamma(x - 40)^{\beta} + 31]$ |
| | for $x \leq 40$ | $P(x) = 13 + 0.75x - 0.0075x^2$ |
| 3-S2-S2 | for $x > 25$ | $P(x) = [\gamma(x - 25)^{\beta} + 47]$ |
| | for $x \leq 25$ | $P(x) = 17 + 2.25x - 0.042x^2$ |
| 3-S2-2 | for $x > 14$ | $P(x) = [\gamma(x - 14)^{\beta} + 45]$ |
| | for $x \leq 14$ | $P(x) = 15 + 4.07x - 0.1375x^2$ |

Parameters

| Truck Type | Curve Parameters |
|---|---|
| 3-S2 | $\gamma = 3.663908 - 0.18422$ (EGVW) $+ 0.002495$ (EGVW)$^2$ |
| | $\beta = -9.30265 + 0.498098$ (EGVW) $- 0.00611$ (EGVW)$^2$ |
| 3-S2-S2 | $\gamma = 8.994935 - 0.40784$ (EGVW) $+ 0.004574$ (EGVW)$^2$ |
| | $\beta = 24.71141 - 0.84735$ (EGVW) $+ 0.007462$ (EGVW)$^2$ |
| 3-S2-2 | $\gamma = -382.692 + 14.13420$ (EGVW) $- 0.12944$ (EGVW)$^2$ |
| | $\beta = 62.67494 - 2.31392$ (EGVW) $+ 0.021433$ (EGVW)$^2$ |

On considering the resulting corrected distributions of Figure 3b, it can be seen that irrespective of the GVW limit, the shape and position of the cumulative GVW distribution curves below the (approximately) 40 percent/31 t position is for all intents and purposes constant. Above this point, on the other hand, the curves diverge. Their divergence is consistent with the model hypothesis that the GVW limit is at work being an important determinant of their shapes and positions (i.e., the higher the limit, the more the cumulative distribution curve shifts to the right).

The fact that the different curves do become more or less the same below some point such as 40 percent/31 t is intuitively reasonable. A certain proportion of trucking activity occurs at GVW levels well below the governing GVW limits. For this activity, whether or not the governing weight limit is higher or lower (within reason of course) has little effect on the loads carried.

It was decided to model this distribution using two components. Below the 40 percent/31 t point, the distribution was assumed to be independent of the weight limit. Above this point, the distribution was assumed to be dependent on the governing weight limit. Note that there is nothing sacred about the 40 percent/31 t point; it is simply the point below which the observed cumulative distribution curves for 3-S2 units are (more or less) common. (While the same general feature—for the same reason—exists for other truck types, the point of commonality does vary.)

Below the 40 percent/31 t point, the distribution has been modeled using a general quadratic expression $P(x) = a + bx + cx^2$, where $P(x)$ and $x$ are defined below. The result is shown in Table 3.

Above the 40 percent/31 t point, the distribution has been modeled as follows. This portion of each distribution curve is defined by two variables, namely:

$$Q(z) = [P(x) - 31] \text{ (in t)}$$

where

$P(x)$ = GVW at which $x$ percent or less trucks operate and
31 = weight below which the curves are constant.

$$z = [x - 40] \text{ (in percent)}$$

where

$x$ = percent less than or equal to on a cumulative curve and
40 = percentage below which the curves are constant.

Note that $P(100)$ on the corrected distribution curves being modeled equals EGVW.

Figure 4 shows the plots of $Q(z)$ versus $z$ used in the modeling for each of the three data sets, at three different GVW

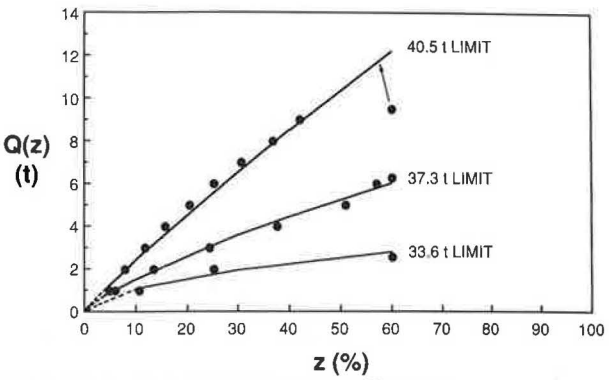


**FIGURE 4 $Q(z)$ versus $z$ for the 3-S2 model.**

limits. These plots are of the form $Q(z) = \gamma z^{\beta}$, where $\gamma$ and $\beta$ are parameters which are dependent on the governing GVW limit.

Alternatively, the relationship could equally be defined by

$$P(x) = [\gamma(x - 40)^{\beta} + 31], \text{ where } x \geq 40 \quad (1)$$

The fitted values of $\gamma$ and $\beta$ were determined by regression. These fitted values are shown in Table 4. While applying these fitted values to the $P(x)$ function by definition satisfies the 40 percent/31 t constraint, they do not necessarily satisfy the $P(100)$ complete compliance requirement. To satisfy this constraint, the fitted values of $\beta$ were adjusted so that the combinations of the resulting values of $\gamma$ (fitted) and $\beta$ (adjusted), for each GVW limit, would not contravene the complete compliance provision that $P(100)$ must equal the GVW limit. The resulting $\beta$ (adjusted) values are also shown in Table 4.

To complete the model, the values of $\gamma$ (fitted) and $\beta$ (adjusted) had to be related to the governing GVW limit—the determinant variable. It is this linkage which permits generalization of the model, wherein the (complete compliance) cumulative distribution curve (above the 40 percent/31 t point) can be estimated as a function of the governing limit. These relationships were established by regression, and are given in Table 3. These equations can be used to establish the values of $\gamma$ and $\beta$ in Equation 1 for a particular EGVW limit. In combination with Equation 1, they constitute the model for estimating that portion of the cumulative GVW distribution curve for 3-S2 units above the 40 percent/31 t point on the curve.

Table 3 then shows all aspects of the resulting, two-component model of the GVW cumulative distribution curve for 3-S2 tractor-semitrailers. Figure 3c shows the distributions predicted by this model for each of the GVW limits used in its formulation (i.e., illustrating the model's ability to predict its origins).

### 7-axle (3-S2-S2) B-train GVW Model

This model has been developed from three different GVW observations for 3-S2-S2s operating under three different (effective) GVW limits (50.0 t, 53.3 t, and 56.5 t). Table 1 summarizes the sources and numbers of truck weight observations used for this model. These data sets are small compared to those used for the 3-S2 GVW distribution.

TABLE 4 $\gamma$ AND $\beta$ VALUES AS A FUNCTION OF EGVW

| Truck Type | EGVW (t) | $\gamma$ Fitted | $\beta$ Fitted | $\beta$ Adjusted |
|---|---|---|---|---|
| 3-S2 | 33.6 | 0.29109 | 0.55246 | 0.53479 |
| | 37.3 | 0.26407 | 0.76336 | 0.77475 |
| | 40.5 | 0.29580 | 0.90931 | 0.84736 |
| 3-S2-S2 | 50.0 | 0.04010 | 1.00529 | 0.99942 |
| | 53.5 | 0.26992 | 0.73461 | 0.73687 |
| | 56.5 | 0.55612 | 0.65930 | 0.65734 |
| 3-S2-2 | 50.0 | 0.40804 | 0.57331 | 0.56256 |
| | 53.5 | 2.98670 | 0.24009 | 0.22811 |
| | 55.7 | 2.98434 | 0.28981 | 0.28666 |

Figure 5a shows the actual cumulative curves developed from these data sets. Figure 5b shows these same distributions corrected to achieve complete compliance. Visual inspection of these modified distributions led to the decision to model them in the same two-component manner, with the same function forms, discussed for the 3-S2 units in the preceding section. This time, however, the curve break-point was chosen as 25 percent/47 t. The model below this point is deemed to be independent of the GVW limit; above this 25 percent/47 t point, the model incorporates the GVW limit as the determinant variable.

Figure 6 shows the plots of $Q(z)$ versus $z$ used in the modeling for each of the three data sets, at three different GVW limits. Again, these plots are of the form $Q(z) = \gamma z^{\beta}$, where $\gamma$ and $\beta$ are parameters which are dependent on the governing

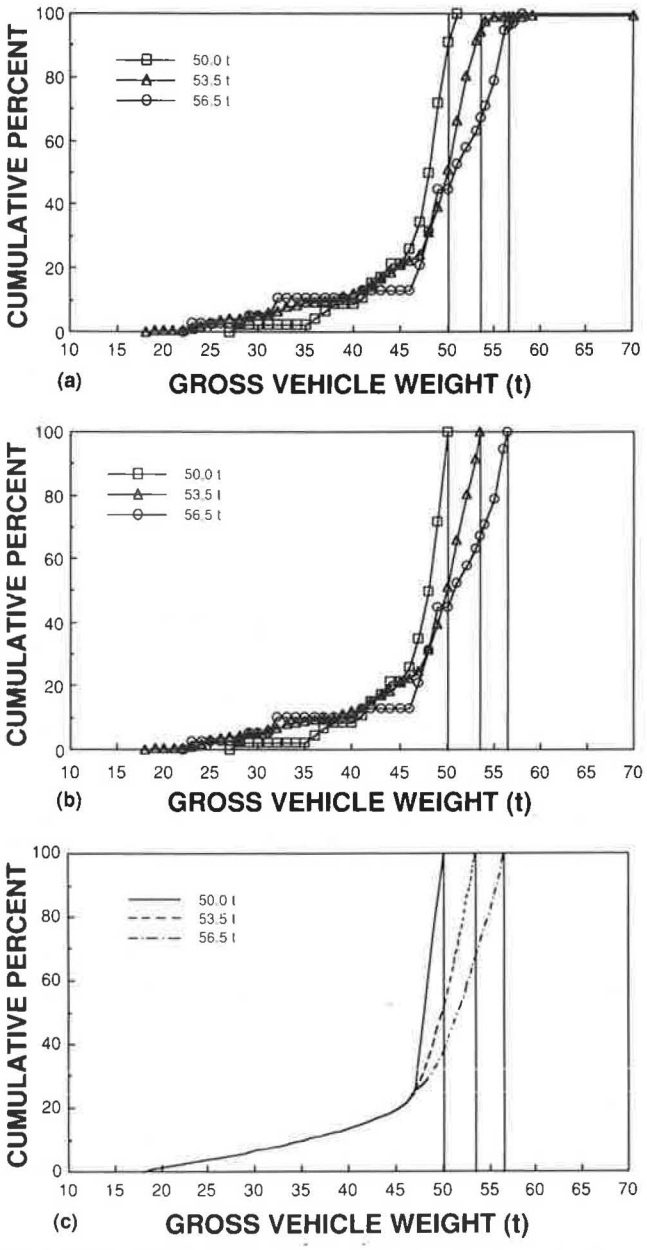


**FIGURE 5 GVW Distributions—3-S2-S2s: (a) observed; (b) corrected; and (c) model.**

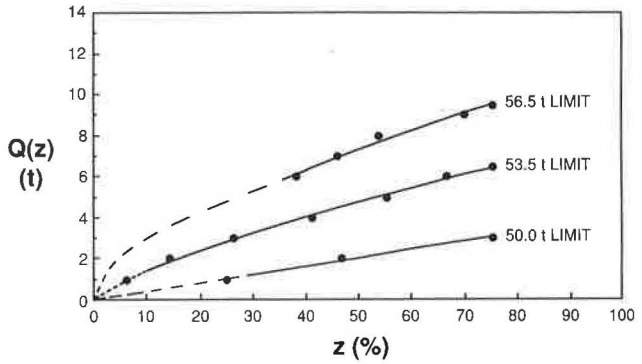


**FIGURE 6** *Q(z)* **versus** *z* **for the 3-S2-S2 model.**

GVW limit. The fitted values of $\gamma$ and $\beta$, determined by regression, are shown in Table 4. To satisfy the complete compliance constraint, the fitted values of $\beta$ were adjusted. The resulting $\beta$ (adjusted) values are also shown in Table 4.

Table 3 presents the resulting GVW distribution model for these 7-axle B-trains. Figure 5c shows the distributions predicted by this model for each of the GVW limits used in its formulation.

### 7-axle (3-S2-2) A-train GVW Model

This model has been developed from three different GVW observations for 3-S2-2s operating under three different (effective) GVW limits (50.0 t, 53.5 t, and 55.7 t). Table 1 summarizes the sources and numbers of truck weight observations used for this model. These data sets are roughly of the same size as those used for the 3-S2-S2 model, and much smaller than those used for the 3-S2 model.

This data has been modeled in the same manner described for the other units, using the same methodology. Figures 7a and 7b show respectively the actual and corrected cumulative GVW distribution curves for these units. This time, the curve break-point was chosen as 14 percent/45 t. The model below this point is deemed to be independent of the GVW limit; above this point, the model incorporates the GVW limit as the determinant variable.

Figure 8 shows the plots of *Q(z)* versus *z* used in the modeling for each of the three data sets, at three different GVW limits. They are again of the form $Q(z) = \gamma z^{\beta}$, where $\gamma$ and $\beta$ are parameters which are dependent on the governing GVW limit. The fitted values of $\gamma$ and $\beta$, determined by regression, are shown in Table 4. The values of $\beta$ (adjusted) required to satisfy the complete compliance constraint are also shown in Table 4.

Table 3 presents the resulting GVW distribution model for these 7-axle A-trains. Figure 7c shows the distributions predicted by this model for each of the GVW limits used in its formulation.

## TESTING THE 3-S2 MODEL

The special surveys referred to in the preceding provided a new data set which permits assessment of the predictive capabilities of the 3-S2 model that was developed, namely GVW

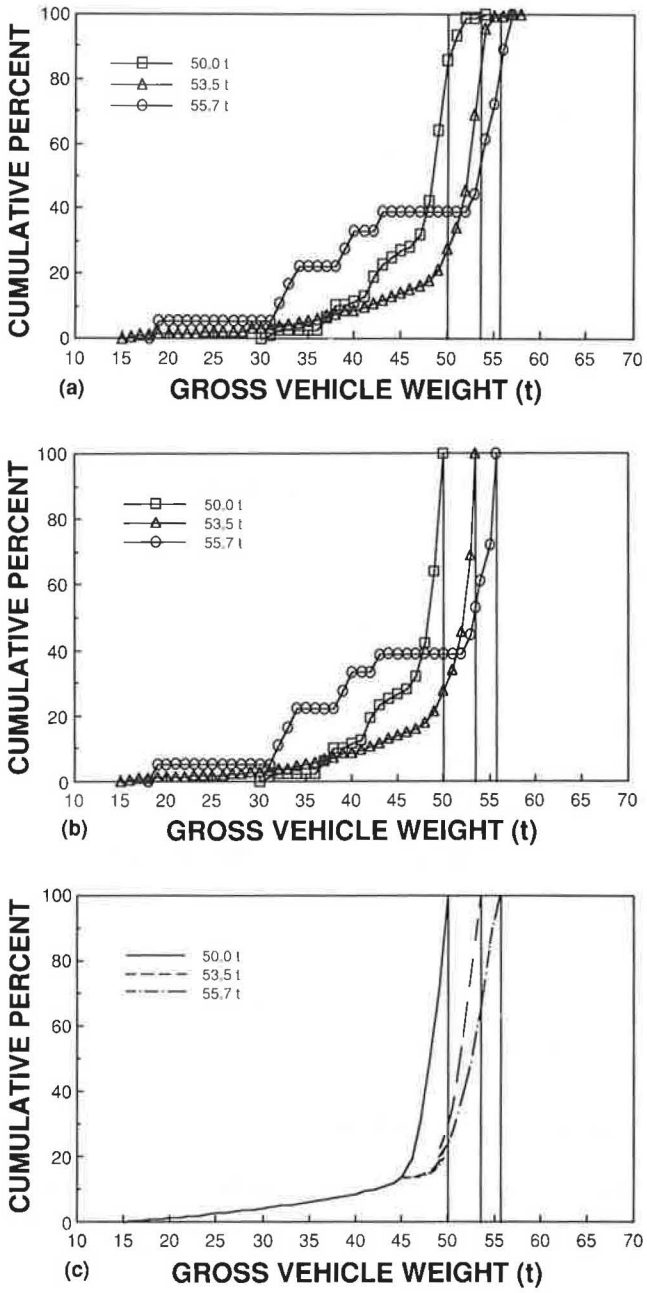


**FIGURE 7 GVW Distributions—3-S2-2s: (a) observed; (b) corrected; and (c) model.**

data for 3-S2s operating under new (1989) weight regulations applicable on primary highways in western Canada. These new regulations permit a GVW of 39.5 t for 3-S2 combinations, based on axle loads of 5.5/17.0/17.0 t. Figure 9 compares the actual cumulative GVW curve for 3-S2s operating under this 39.5 t GVW limit with the predicted curve based on the model. Visual inspection of the results indicates that the model appears to be able to predict this distribution reasonably well.

This comparison suggests that the model is reasonably able to predict weight characteristics of the *same* 3-S2 unit operating in the *same* region on the *same* highways (i.e., primary highways in western Canada), at a *different* weight limit (i.e., 39.5 t) than the weight limits applicable to the data base used

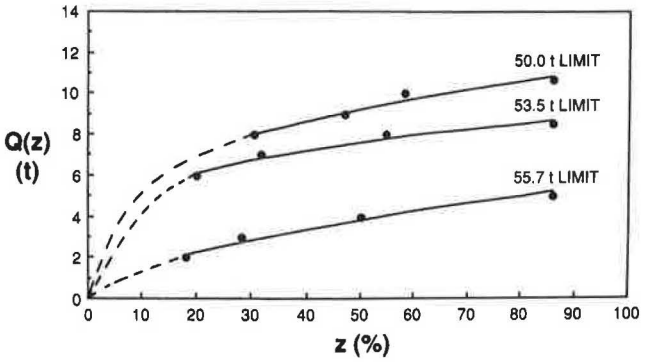


**FIGURE 8** *Q(z)* **versus** *z* **for the 3-S2-2 model.**

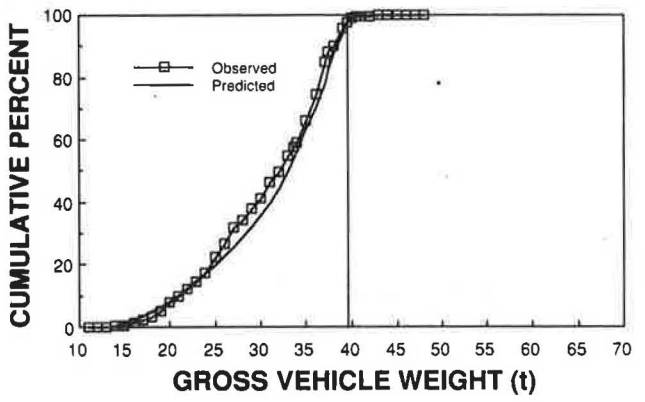


**FIGURE 9 Comparison of actual versus predicted GVW: 3-S2s.**

in formulating the model in the first place. Its ability to be transferred to other locales has yet to be assessed.

## DISCUSSION OF RESULTS

Two important considerations are implicit to the models developed here: (*a*) particular mixes of freight hauled by each of the truck types; and (*b*) particular weight and dimension regulatory situations, with their attendant implications on vehicle design and use. If either of these factors was significantly different from those present in the situation that created the data base modeled, different model characteristics could result.

Concerning the freight demand considerations implicit to these models, the following comments are relevant. The 3-S2 model has been constructed from a very large number of observations of the GVWs of these units hauling a wide mix of commodities. As discussed elsewhere (*6*), the model can be considered of an all-commodity nature, meaning that it represents the weight distribution that might be expected in a highway operation where no one commodity or small number of commodities dominates the freight handlings. At this stage, no objective measure of this all commodity concept is proposed. Suffice it to say that given a highway where one unusual commodity dominated the haul (e.g., feathers or gravel), substantially different weight distributions could be expected to result.

The A- and B-train GVW models have been constructed from much smaller data bases than those used for the 3-S2 model. As such, the commodity-mix-momentum behind the 3-S2 model is not incorporated in these models. For this reason, users of these models should show a greater concern for possible commodity-mix errors than need be shown when using the 3-S2 model. Counteracting the effect of this problem, however, is the fact that, relative to 3-S2 units, 7-axle A- and B-train combinations are normally employed in weight-out type operations. This means that most of the measurements of the GVW of these units tend to be skewed towards the weight limit. As such, to get a good indication on the GVW distribution of these units compared to 3-S2s does not require near as many observations. Put another way, if there is a 7-axle B-train on the road, it is likely that it is either full (on a weight-out basis) or empty. Seldom is it full on a cube-out basis or partly loaded.

Implicit to these models are the detailed weight and dimension regulation systems prevalent in western Canada between 1972 and 1990. The transferability of the resulting models into entirely different regulatory situations (i.e., Ontario's unique bridge-formula-based system) may not be possible.

The models assume the complete compliance condition, or in other words assume that GVW limits are strictly adhered to. To the extent that they are not adhered to (either illegally or legally), variations from the predicted distributions should be expected. At the extreme, if there is no enforcement, these models at the higher weight levels can be expected to exhibit errors.

## CONCLUDING REMARKS

1. Empirical models linking the distribution of GVWs of laden 3-S2s, 3-S2-S2s (B-trains) and 3-S2-2s (A-trains) to the GVW limit governing these trucks are presented, for a condition of complete compliance. The 3-S2 model was applied to a situation independent of the data set used in its construction, and was able to produce a quite acceptable prediction.
2. Being complete compliance models, they are intended to be used where truck weights are extensively adhered to. If they are not, the modeled distributions would have to be appropriately modified.
3. The models rely on the existence of stable relationships between truck weight distributions and fixed weight limits, as initially observed in the truck weight data used in their preparation.
4. Implicit to the models are the truck freight characteristics and weight and dimension regulatory systems particular to the data base used in the modeling. It seems reasonable to speculate that locale-specific considerations concerning these implicit factors would necessitate recalibration of the models if they were to be used in significantly different circumstances.
5. The appropriateness of extrapolating the models significantly beyond the weight limit boundaries present in their original data sets has not been assessed and requires investigation.

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