THE UNIVERSITY OF MANITOBA

WEIGHT AND DIMENSION CHARACTERISTICS OF LARGE TRUCK COMBINATIONS AS A FUNCTION OF REGULATORY LIMITS: MANITOBA HIGHWAYS

by

Randy Plett

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ABSTRACT

Examination of gross vehicle weight and axle weight distribution patterns of various vehicle types on different Manitoba highways in different years indicated a substantial degree of repetition which suggested a good possibility of developing models of these loading characteristics based on the regulatory environment within which the trucks have operated.

Data from the Manitoba Department of Highways and Transportation Truck Weight and Dimension surveys (1972-1986) was used in determining these weight distributions under differing sets of weight regulations. Models were then formulated by fitting mathematical formulae to these weight distribution curves.

The models showed, with one notable exception, a general pattern of increased vehicle weight characteristics corresponding to increase in regulatory limits. This confirms the hypothesis that governing weight limits do have a demonstrable effect on how trucks are loaded and thus on the actual weights observed in the field. Furthermore, it was shown that derived characteristics such as equivalent single axle loads and payload distributions were also dependant, in a large part, on these same regulatory limits and hence could be estimated through the use of the previously mentioned models.

A secondary objective of this research was to develop a standardized summary of the Manitoba truck survey results in a form which facilitates its use by the transportation

planning, engineering and research communities. This was done by collecting all data from 1972 to 1986 and placing them on one computer accessible magnetic tape in a format which eliminates inconsistencies in the survey format across the time base.

Another objective was to make use of the survey data in order to provide insight into changes in the large truck fleet mix operating in Manitoba since the 1970's and to investigate changes in the physical characteristics of this fleet. In this vein, it was discovered that:

(i) the size of the truck fleet in Manitoba has been increasing,

(ii) the average size of the vehicles which make up this fleet has been increasing,

(iii) both the power/weight ratio and the turning performance of many vehicles are less than those of design vehicles,

(iv) typical tandem axle spreads are consistently larger than those used in the AASHO road test on which most axle load equivalency factors are based,

(v) operators of gravel hauling trucks consistently ignore axle spacing requirements, and

(vi) in many cases, tire size rather than axle weight limit is the governing factor in determining the maximum legal axle weights.

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TABLE OF CONTENTS

PAGE

APPENDICES

LIST OF TABLES

LIST OF FIGURES

PAGE

PAGE

PAGE

CHAPTER 1

INTRODUCTION

1.1 THE GENERAL RESEARCH NEED

A sound knowledge about the physical and operating characteristics of the large trucks operating on today's highway systems is vital to planning, design, and management considerations concerning that infrastructure. First, such knowledge provides an important input in properly assessing changes to weight and dimension regulations governing large truck transportation. Second, it provides direct input into day-to-day pavement and bridge design, rehabilitation, maintenance, and management programs, being a direct reflection of live load conditions to be experienced by highway infrastructure. Third, effective geometric design and highway capacity analysis requires a proper understanding of both the physical and performance characteristics of the large truck population.

Various truck data collection and analysis efforts directed at developing this knowledge base have been undertaken by government and industry throughout Canada. A principal effort in this area is the on-road survey of trucks conducted by most provincial government highways agencies on an ongoing basis. These surveys produce masses of data on a variety of factors, including (usually) axle weights, gross vehicle weights (g.v.w.'s), license status, commodities, configurations, and dimensional characteristics of the surveyed vehicles. Nix and Clayton (1985), as well as Clayton and Lai (1985) provide an assessment of these surveys across Canada, and specific to Manitoba.

Much of this survey effort has produced data of questionable representativeness and usefulness (Clayton and Nix, 1986). This is particularly evident in the lack of many significant attempts to "generalize" or "model" the various phenomena measured in these surveys. In practice, each survey is typically thought of and treated as if it provides little more than a unique characterization of a particular phenomenon. The knowledge accumulated in one survey is seldom formulated in a manner which facilitates its predictive use in other situations (e.g., different highways, different provinces, different times, different regulatory environments).

This lack of generalization of the results of many of these truck surveys is not unique to Canada. Yu, Walton, and Ng (1983) observed that in the United States, "it has been difficult to predict future truck weight distribution patterns [that could be expected from] alternative legislation governing truck weights" -- even though, through the years, numerous surveys of that phenomenon (i.e., weight distributions) have been conducted in various regulatory environments. In a similar vein, from the bridge engineering perspective, the O.E.C.D. (1979) identified the need for "closer cooperation [respecting] the exchange of data and experience...concerning the magnitude, intensity, distribution and frequency of actual commercial traffic loads on highways" -- even though such loads have in fact been regularly surveyed in one way or another by nearly every highway agency in the developed world, often for decades.

Upon examination of the output from on-road surveys conducted in western Canada over the past fifteen years, and in particular, vehicle weight data developed in surveys of the Manitoba Department of Highways and Transportation as reported by Clayton and Lai (1986), it was concluded that the development of some useful generalizations from (at least some of) these survey results might be feasible. Specifically, examination of g.v.w. distribution patterns for various vehicle types on different highways in different years appeared to indicate a substantial degree of "repetitiveness". That repetitiveness was of a nature which suggested a good possibility for developing certain models of important highway loading phenomena based on practical explanatory determinate variables, and in particular, aspects of the regulatory environments within which the trucks have operated.

These considerations -- the need for knowledge about the physical and operating characteristics of large trucks to facilitate effective highway engineering; the fact that substantial resources are expended by governments and others to develop these required knowledge bases (often with limited success); and the observation that there appears to be a possibility to develop useful, general, transferable models of certain important truck characteristics from available data sources -- gave rise to this research.

1.2 RESEARCH OBJECTIVES

The major objectives of this research were:

(i) to develop models of the actual g.v.w. and axle weight distributions for standard laden large trucks operating on Manitoba highways, as functions of related regulatory weight limits, giving appropriate consideration to commodity handling variations, and

(ii) to develop models of derived equivalent single axle load (E.S.A.L.) and payload distributions for the same truck combinations based on the models developed in (1), standard E.S.A.L. factors, and appropriate tare weight relationships.

Three secondary objectives were also formulated:

(i) to develop a standardized time series summary of the Manitoba Department of Highways and Transportation truck surveys conducted through the period of 1972 to 1986, for the general use of the transportation planning, engineering, and research communities;

(ii) to investigate changes in key physical characteristics of the large truck fleet operating on Manitoba's highways since the early 1970's, based on the on-road survey data; and

(iii) to investigate changes in the large truck fleet mix operating on Manitoba's highways since the early 1970's, based on the on-road survey data.

1.3 GENERAL METHODOLOGICAL CONSIDERATIONS

The principal data source for the research was the truck survey data accumulated by the Manitoba Department of Highways and Transportation over the years. The limitations of that data source had to be accepted, and could not be mitigated by the research itself. The research has attempted to ensure that qualifications and limitations of this work which would arise from problems with the data source itself are explicitly enunciated.

The truck survey data tapes, in their original forms, were difficult to use for this research without extensive modifications to the data sets contained thereon. Accordingly, the data base was modified in the following manner: (i) it was converted into the SAS (Statistical

Analysis System) data set format (SAS Manual, 1985); (ii) all measurements taken prior to 1980 (in imperial units) were converted to metric; (iii) the two different sets of commodity codes used during the survey were normalized; and (iv) the data was grouped by highway class (where each highway class represents a particular regulatory regime). Chapter 5 (The Data Base) provides a full discussion of these modifications.

During the time period under consideration in this research (1972-1986), the regulatory situations governing the operation of large trucks in Western Canada underwent a number of changes. A substantial effort was therefore required to establish the precise regulatory provisions applicable to each observation in the database. The exact date and location of each observation, as well as the commodity carried and the direction of travel of each truck, was required in order to establish these provisions.

The database includes observations of vehicles which were operating under special permits (legally), contrary to the provisions of the governing basic regulatory limits. There was no basis for identifying (and hence removing) these observations from the database. This could produce some distortion in certain of the resulting relationships.

CHAPTER 2

EXISTING GENERAL KNOWLEDGE ABOUT THE EFFECTS OF REGULATIONS ON TRUCK FLEETS AND TRUCK CHARACTERISTICS

2.1 PURPOSE OF THIS CHAPTER

This chapter discusses the general issue of how weight and dimension regulations affect truck characteristics, examines some of the evidence of those effects, and identifies limitations in the knowledge base respecting those effects.

2.2 THE ROLE OF REGULATIONS IN AFFECTING TRUCK CHARACTERISTICS

Many factors influence and define the size, shape, weight, and configuration characteristics of large trucks operating on a highway. They include:

(i) freight characteristics such as density, fragility, shape, and form of the freight being handled. These attributes affect the freight containment box or platform type used. For example, liquids will be carried in tankers, lumber on flat decks, frozen foods in refrigerated vans, etc.;

(ii) route characteristics such as geometry and vertical grades. Roadway geometry can influence factors such as the length and/or number of trailers which can be used on a particular route. Steep vertical grades can affect power requirements and the need for tandem vs. single drive axle tractors;

(iii) terminal characteristics, and in particular, their capability and/or efficiency in handling different vehicle sizes and/or configurations and different types of freight/handling systems (i.e., end vs. bottom dump, end vs. side loading/unloading, etc.);

(iv) shipper and industry characteristics which may affect the degree to which a truck operator can exploit the productivity advantages inherent in the operation of very large trucks (i.e., larger trucks are generally more cost-efficient than smaller ones in terms of lower labour, fuel and equipment costs per unit of payload handling capacity). To this effect, a large truck is only advantageous if the demand for shipping is large enough to utilize its capacity. In many cases, such as city deliveries or the collection of bulk grain from small farms, these shipper/industry characteristics are the limiting factor in the truck size and weight; in others, such as the movement of bulk petroleum to a large retailer, these constraints do not apply;

(v) the weight and dimension regulations being the upper limits within which trucks (with the exception of specially permitted vehicles) are designed to maximize payload-handlings and flexibility while minimizing capital and operating costs. "...Trucks are designed to obtain the most effective use of what the size and weights laws permit." (Lill, 1986). These regulations do more than merely limit the maximum g.v.w. and axle weights of trucks; they also determine configuration characteristics, axle arrangements, etc.

The effects of the weight and dimension regulations on trucks -- the principal concern of this research -- is complicated by a number of factors over and above the "pure" regulations themselves. Nix, Clayton, Bisson and Sparks (1986) discuss a number of these, and demonstrate that consideration must be given to the following:

(i) the fact that many trucks are operated in more than one jurisdiction, and hence must be designed to conform to several sets of regulations (i.e., a least-common-denominator approach), often leading to less than optimum payloads in one or more of the jurisdictions.

(ii) the degree to which actual truck sizes and weights will conform to the regulatory limits as influenced by the level of enforcement of these regulations. Truckers are well aware of the economic advantages of running overloaded, and some can reasonably be expected to do so if the probability of being caught and/or the penalty for exceeding weight limits is low enough.

(iii) the fact that the impact of changing regulatory conditions does not occur instantaneously, but depends on the nature and extent of the changes as well as the ability of the industry to invest in the new equipment required to take full advantage of the changes. Industry expectations of future changes are also important.

2.3 IMPACTS OF REGULATIONS ON TRUCK CONFIGURATIONS: SELECTED EXAMPLES

Changes in weight and dimension regulations will result in changes over time in the large truck fleet. This has been observed in Atlantic Canada between the years of 1976 and 1984 (Good and Bisson, 1986). In 1976, the maximum allowable g.v.w. in this region varied from 36,500 kg in Nova Scotia to 56,700 kg in New Brunswick. 1978 saw the standardization of weight limits across the region at 50,000 kg. The result was that, between 1976 and 1984, the percent of total truck trips made by straight trucks as well as by 3-, 4-, and 5-axle tractor-semitrailers dropped. Only 6-axle tractor semitrailers showed any increase (from 2.9% to 13.2%). "Where once the 5-axle tractor-(semi)trailer was used extensively throughout the Atlantic region to conform to the lowest g.v.w. in place (36,500 kg), it is now being replaced to some extent by the 6-axle tractor-(semi)trailer, a vehicle well-suited for operating at the 50,000 kg g.v.w. limits that are presently in place." (Good and Bisson, 1986).

Similar changes in the fleet mix occurred in the prairie region following the increase in allowable g.v.w. limits from 36,500 kg to 50,000 kg in 1974. Clayton, Sparks and Mak (1983) noted the following observations respecting truck configuration changes in response to this increase:

(i) "There was an apparent substantial growth in the size of the 'large combination' truck fleet registered for extra-provincial operations." (Clayton et al., 1983).

(ii) There is a "continuing but declining dominance of 5-axle combinations and the attendant progressive adoption of doubles (and in particular 7-axle units) by the trucking industry" (Clayton et al., 1983).

Apparently, the liberalization of truck weight and dimension regulations in both the prairie and maritime regions of Canada has led to changes in the mix of different vehicle configurations by allowing new, more productive vehicle configurations onto the highway system.

Nix et al. (1986) describe the regulations affecting (and the resulting equipment used for) the hauling of two very different types of commodities in different regions of the country. The following descriptions of high-density petroleum and low-density LTL general freight hauls demonstrate the development of distinct vehicle types under the different regulations in effect across Canada. In most cases, the regulatory forces affecting petroleum and LTL freight haulers can be assumed to also apply to haulers of all types of high and low density freight, respectively.

2.3.1 Petroleum Haulers

In Manitoba, Saskatchewan, and Alberta, most petroleum is transported in 7-axle trains. These doubles are used because tractor semi-trailers cannot legally be loaded to the maximum g.v.w. limits in these provinces (53,500 kg - 56,500 kg). The restriction of tandem (and triple) axle loads to 16,000 kg limits the productivity of tractor semitrailers in the hauling of any dense bulk commodity. Unlike the prairie provinces, the Maritime region of Canada has few doubles in operation on its roadways. The largest and heaviest vehicles are normally six-axle 3-S3's (3-axle tractors with 3-axle semitrailers). The difference is due to the fact that the Atlantic Provinces Highway Strengthening Program of 1978 resulted in a g.v.w. limit of 50,000 kg or more throughout the Maritime region. Since triple axle groups are allowed higher weight limits than tandems, 3-S3's can legally operate at nearly 50,000 kg and make full use of the g.v.w. limits. Unlike their prairie province counterparts, Maritime truckers can do this without using doubles. In Ontario, the maximum legal g.v.w. is 63,500 kg, making double trailer combinations competitive because 3-S3's (and even most 3-S4's) cannot take full advantage of this limit.

2.3.2 LTL Freight Haulers

LTL freight haulers, because of the nature of their freight, are interested in operating equipment with the maximum available cubic capacity (a function of total trailer length). In the prairie provinces, the maximum legal combination length is 23.0 metres. This length allows the use of two 27' or one 27' and one 28' trailer (longer trailers are allowed on some roadways under special permits. The 21.0 m combination length limit in the Atlantic provinces means that double trailer combinations are very difficult to configure. The typical truck used in LTL operations in Atlantic Canada is a tractor with a 48' semitrailer.

2.4 EFFECTS OF REGULATIONS ON TRUCK PAYLOADS AND PRODUCTIVITY

Sparks and Neudorf (1987) have developed a model for predicting truck productivity (defined as the cost of operation per unit of useful output and measured in cents per tonne-km) in the transportation of petroleum products. Through the use of this model, an estimate of productivity can be calculated as a function of variables, which include the legislated maximum axle weight and g.v.w. limits. These calculations were performed by the authors (Sparks and Neudorf, 1987) for eight typical configurations used in various Canadian jurisdictions. All variables were kept constant with the exception of the configuration types and the weight limits under which they operated. The vehicles ranged from 3-S3 tractor semitrailers operating in New Brunswick at 50,000 kg to 3-S3-2 A-trains limited to 63,500 kg in both Ontario and British Columbia. The resulting productivity figures led to these conclusions:

(a) "Vehicle productivity was found to be highly sensitive to allowable gross vehicle weights and vehicle configuration (i.e., 5-axle semis versus 7-axle A-trains, etc.). Combination units (i.e., 7- and 8-axle A- and B-trains) were found to be typically 15-25% more productive than 5-axle semis operating at the same axle weights but higher gross weights." A-, B-, and C-train definitions are in Appendix D.

(b) "Vehicle productivity is very sensitive to permitted axle weights. Increasing axle weights translate directly to increased payloads and therefore increased productivity. Increasing gross vehicle weights, on the other hand, usually translate into different vehicle configurations (i.e., more trailers and more vehicles)."

Clayton, Nix and Sparks (1982) noted similar results among the different combination types used in the transportation of grain in the prairie provinces. Typical payload capacities of four categories of trucks on primary highways were found to be: 28-29 tonnes for truck and trailer combinations, 24-25 tonnes for tractor semitrailers, 37-40 tonnes for A-trains, and 36-39 tonnes for B-trains. The higher payloads of the larger vehicles offer significant advantages to the operators of these vehicles, and are the primary reasons for their increasing usage in the transportation of grain and other bulk commodities.

As in the Canadian provinces, doubles with more than 6 axles are employed in the United States for transporting dense bulk commodities in those states where high g.v.w. limits are allowed. For example, the TWS (FHWA Truck Weight Survey) results showed that 11-axle Michigan doubles operated at g.v.w. levels that were, on average, 34-38 kips greater than those of 5- and 6-axle doubles (Yu and Walton, 1984). It is clear then that the productivity advantages of larger trucks are being taken advantage of, both in terms of increased cubic capacity and in terms of higher weight payloads where the regulations allow.

It has been found, however, that in some cases, tare weight increases can completely negate any g.v.w. increases brought about by changing regulations. In Manitoba, Clayton and Lai (1986) observed that "Between early 1974 and 1984, the tare weights of average 3-S2 units have increased by 0.8 tonnes, the average g.v.w. has increased by 0.6 tonnes, and the average payload has fallen slightly (from 16.1 tonnes in early 1974 to 15.9 tonnes in 1984)."

In the case of cube-out commodities, a vehicle's cubic capacity is the major factor in determining its productivity. In Manitoba, the 6-axle A-train is the most productive vehicle for this type of freight, because it equals the 7-axle units in cubic capacity but has lower initial as well as operating costs. Clayton and Lai (1986) observed that average payloads of 6-axle A-trains in Manitoba in 1981/82 were 14.8 tonnes, whereas those of 7-axle trains in 1984 averaged 28.0 tonnes. The large difference in these two figures emphasizes the differences in the commodities transported by these two vehicle types

Yu and Walton (1984) observed that, in the United States, approximately 90% of 5- and 6-axle doubles weighed less than 80,000 lbs (36,300 kg). At this weight level, the payload capacity of this type of vehicle in terms of weight is no greater than that of a 3-S2. Clearly, the majority of these doubles must be utilized for their extra cubic capacity.

Based on the prediction that 75% of all LTL mileage within the United States would be covered by doubles in 1990, it was calculated that line-haul cost savings would total US$394,000,000 in that year. Taking into account the savings from reductions in breakbulk terminal operations as well as increases in capital costs for equipment and new terminals, it was estimated that the net benefit to the industry would be in the order of US$500,000,000 (National Research Council, 1986).

2.5 ENFORCEMENT

A recent study (Walton and Yu, 1983) has pointed out the degree to which the operation of overweight vehicles can be advantageous to truckers. They (Walton and Yu) calculated that oversize and overweight movements in the State of Texas will provide benefits to the trucking industry of US$1,400,000,000, while collection of fines from illegal and permit fees from legal overweight movements would yield only US$84,000,000. Clearly, the incentive is for trucks to be operated above the legal limits. The extent to which this will occur depends entirely on the level of enforcement. In this way, changes in enforcement levels will have an impact on the truck loading patterns (i.e., g.v.w. and axle weight distributions) independent of any changes in the weight regulations.

The precise relationship between level of enforcement and compliance with weight and dimension regulations is unknown, but Wyatt and Hassan (1985) discovered that, in Saskatchewan, "an inspection rate of about 5% appears to be sufficient to deter almost all witting infractors". At inspection rates below 5%, infractions rose quickly, while rates above 5% had very little effect on levels of compliance.

2.6 MODELS FOR ESTIMATING WEIGHT DISTRIBUTIONS

A procedure has been developed for estimating the weight distributions of a particular vehicle class given the distribution under existing conditions and a knowledge of the future axle weight and g.v.w. limits to be imposed (NCHRP, 1973). The basic assumptions used in the development of this model are that under any new increased legal weight limits,

(a) the empty weight of the trucks will increase, assuming legal weights are increased, to provide for the strength and durability of the vehicle in use under heavier payloads;

(b) trucks will carry greater payloads per trip, and therefore, operate with higher axle weights and higher gross weights; and

(c) operation under the new limits will change somewhat in proportion to the change in the practical maximum gross weight of each vehicle class, which is defined as the sum of the individual axle legal weights, with the front or steering axle weights set at a reasonable amount, consistent with that class of vehicle and what past roadside weighing has shown as normal practice. (NCHRP, 1973)

The construction of a new cumulative g.v.w. curve is done by increasing the gross weight value (abscissa) of each original g.v.w. interval by an amount proportional to the ratio of new versus old practical maximum gross weights. The points are then graphed with the new g.v.w. values replacing the old. New axle weights are calculated by assuming that their weight as a proportion of the g.v.w. will remain unchanged for each accumulated percent interval (ordinate).

The NCHRP method has been tested against the data collected during the transition from 74,000 lbs to 80,000 lbs g.v.w. limits in several states and was found reliable. Under other situations, there is doubt as to its effectiveness because it does not account for factors other than allowed weight increases. For example, there is no allowance for the possibility of new configurations appearing to absorb certain segments of the total traffic, leaving a reduced percentage of the total for 3-S2s. The method assumes that all loads previously hauled by 3-S2s will continue to be hauled by these trucks--an inadequate assumption given the current Canadian regulatory environment.

Another method of projecting future truck weight distribution patterns was developed through observations of the weight distribution changes in the state of Texas following the increase in maximum allowable g.v.w. to 80,000 lbs (36,300 kg) in 1975 (Yu, Walton and Ng, 1983). This method involves predicting the mean and standard deviation of future truck weight distributions based on the assumption that they are directly related to the maximum allowable g.v.w. The old cumulative distribution curve is shifted by eye and tested for acceptability with both the student t and chi-squares tests. As with the Whiteside method, it is assumed that no new configurations will be utilized under the new regulations.

2.7 LIMITATIONS IN THE KNOWLEDGE BASE

Attempts have been made to quantify the benefits to the trucking industry of relaxed weight limits, but a variety of factors have made this objective all but unreachable. Some early attempts such as the 1973 Alberta Highway Benefit Study used a methodology consisting of a calculation of the payload increases made possible by higher g.v.w. limits, a further calculation of the reduction in the number of truck trips required to haul similar total tonnages, and an estimation of total savings from the multiplication of reductions in truck mileage by an operating cost/mile figure (Nix and Clayton, 1986). One problem with this approach is the possibility that shippers' demand for greater loads does not (or will not) match the capacity of the new configurations. It would seem realistic that many shipments currently being made by truck are already at or near their maximum size, and could not expand further unless extra storage facilities were constructed (not always of economic benefit). For this reason, it is an over-simplification to assume that loads would all increase in direct proportion to the payload capacity increases of the trucks.

It was discovered (Clayton, Sparks and Mak, 1983) that some traffic, historically routed through the U.S., was diverted to Canadian routes after g.v.w. limits were raised in Canada. Presumably, the diverted traffic consisted of heavily loaded trucks (i.e., those which can take advantage of higher weights allowed on the Canadian roads). The increase in truck traffic on Canadian roads due to this phenomenon would not be spread across the g.v.w. spectrum, but rather concentrated in the area above the limits set in the U.S., a phenomenon which is not accounted for by many cost/benefit studies.

There is a lack of understanding of the temporal aspect of truck weight and configuration changes. As reported by Nix and Clayton (1986), some early research seems to accept a period of approximately five years for trucking firms to take full advantage of liberalized regulations. Of course, this is an over-simplification, since equipment can be used for ten years or more (although some can be modified in a short time), and it would seem reasonable that many companies would put off upgrading to more efficient equipment until their old vehicles could no longer be used. On the other hand, if the regulation changes involve only axle weight increase, most companies could take advantage of them almost immediately, since no new investment in equipment would be required. Clearly, the actual adjustment period for trucking firms depends on the type and extent of regulation changes as well as the flexibility of equipment presently in use.

CHAPTER 3.

THE HIGHWAY ENGINEERING AND PLANNING NEED FOR KNOWLEDGE OF TRUCK CHARACTERISTICS

3.1 PURPOSE OF THIS CHAPTER

This chapter outlines some of the basic procedures involved in pavement, bridge, and highway geometry design, etc. for the purpose of showing where, and in what form, knowledge of large truck characteristics is required. That knowledge in turn is useful for guiding the formulation of models being explored by this research. The descriptions of design procedures are not meant to be comprehensive. They are meant to outline the need for truck knowledge and hence may overemphasize the truck-related aspects of the procedures.

The chapter first examines the truck characteristics data needs of "classical" pavement, bridge and geometric engineering planning, design and evaluation procedures and problems. Secondly, the more particular related data requirements for the planning and engineering of highways in Manitoba and other Canadian jurisdictions are then considered. Apparent opportunities for possible improvements in Manitoba design and evaluation practices through better use of the Manitoba truck survey data base are also identified.

3.2 CLASSICAL DESIGN REQUIREMENTS

3.2.1 Engineering of Flexible Pavements

According to Yoder and Witczak (1975), "the classical definition of flexible pavements includes primarily those pavements that have an asphalt concrete surface. The load-carrying capacity of a truly flexible pavement is brought about by the load-distributing characteristics of the layered system".

Essential to all pavement design is the calculation of internal pavement stresses resulting from repetitions of heavy truck axle passes. The vehicle considerations applicable to these calculations are:

(i) **Axle spacing.** The spacing of axles is important since closely spaced axles tend to have overlapping stress envelopes, leading to higher point stresses within the pavement than would occur with two widely spaced axles with similar weights.

(ii) **Loads per tire.** In theoretical design procedures for flexible pavements, the internal pavement stresses required to compute adequate pavement thicknesses are estimated from a point load on the surface, representing a single tire. In empirical design methods, similar relationships between tire loadings and appropriate pavement thicknesses are derived from empirical tests such as the AASHTO road test.

(iii) **Tire pressure.** It is usually assumed that the contact pressure between the pavement surface and the bottom of the tire is equal to the tire pressure. No commonly used pavement design method takes tire pressure into account in the calculation of pavement thickness because increased tire pressures have little influence on stresses far below the surface. It is, however, desirable to be informed about increasingly high pressures as they necessitate the use of higher quality surface materials.

Design methods can be subdivided into two categories. Empirical methods rely on road test results for design relationships as well as for axle equivalency figures. Theoretical methods use Boussinesq theory (flexible pavements) or stress calculations for concrete beams and slabs (rigid pavements). Most theoretical methods are not "purely" theoretical in that they employ some aspects of road test data in varying degrees. The following subsections describe an example of each type.

3.2.1.1 The AASHTO Method (AASHTO 86) is based on empirical relationships derived from the AASHTO road test and makes use of several assumptions in applying its equations to situations where soil conditions, climate, and traffic characteristics differ from the conditions present at the road test site. It is the most widely used method in the United States.

The design charts (published in AASHTO 86) allow a designer to calculate a required structure number (SN) as a function of the soil support, a regional factor, and E.S.A.L.'s over the design life of the pavement. The structural number then defines the required thicknesses of the various pavement layers while giving the designer the flexibility to choose from a variety of materials.

The axle weight equivalency factors have been derived from the AASHTO road test results and are tabulated for weight intervals of 2 kips. These factors vary with changes in the pavement cross-section (represented by its SN) and with the terminal serviceability index (the minimum acceptable level of pavement surface quality).

<u>3.2.1.2 Theoretical Design Methods</u> employ adaptations of Boussinesq theory for the calculations of internal stresses, deflections, and strains. The critical design variable in a typical asphalt pavement may be the vertical stresses at the subgrade, vertical surface deflection, shear stress, or tensile stresses at the bottom of the asphalt layer. The Asphalt Institute Method is based on limiting the subgrade vertical strain. The thickness of the asphalt layer is calculated as a function of the strength of the subgrade and the load pressures on the pavement surface. For highway pavement designs, the method uses the standard AASHTO equivalency factors (Yoder and Witczak, 1975).

In summary, the traffic related data requirement for flexible pavement design, regardless of the design method, is for axle repetitions and weight distributions from which estimates of E.S.A.L.'s can be calculated. In particular, these vehicle-related figures are required: (i) traffic level forecasts (AADT); (ii) traffic classification data; and (iii) axle weights distributions for each class of heavy truck (from which E.S.A.L. figures are calculated).

In addition, variables such as tire pressures and axle spacings must be known if they differ significantly from assumed values. For example, the AASHTO equivalency factors for tandem axles are based on standard spacings used during the AASHO road test. Any deviation from this standard will change the axles' damaging effect on pavements independent of the axle load.

3.2.2 Engineering of Rigid Pavements

Rigid pavements are "made up of Portland cement concrete... The rigid pavement, because of its rigidity and high modulus of elasticity, tends to distribute the load over a relatively wide area of soil; thus, a major portion of the structural capacity is provided by the slab itself" (Yoder and Witczak, 1975).

Internal stresses within rigid pavements are due to a number of factors, some of which are quite independent of wheel loads. These include changes in temperature and/or moisture levels, as well as the deformation of the subgrade from frost action or other factors. A discussion of these effects is beyond the scope of this research. The vehicle-related considerations applicable to the calculations of internal stresses are:

(i) Loads per tire: Rigid pavements act very much like a beam supported continuously by a dense viscous fluid. A point load will cause a bending moment to occur within the beam. Invariably, the critical stress is the tensile stress of the concrete at the bottom of the pavement layer. Increasing the point load will lead to a corresponding increase in this tensile stress.

(ii) Tire and Axle Spacing: As in the case of a beam, point loads will cause a moment throughout the pavement slab, the maximum occurring at the point of load application. Any subsequent load placed elsewhere on the slab will add to the moment at the point of the original load. The positions of the loads will determine the magnitude of the bending moments anywhere on the pavement. In this way, the tire and axle spacing become important, since very close spacing yields much higher moments and tensile stresses.

(iii) Tire Pressures: Very high tire pressures result in significant stress concentrations due to smaller loaded areas. These are most significant on roads with smaller traffic volumes, since these are usually constructed of non-reinforced concrete, with less resistance to shearing forces.

(iv) Position of the Load on the Pavement: A similar load will cause dissimilar stresses within the pavement, depending on where it is placed on the pavement slab. Three different cases are corner loading, edge loading, and interior loading. Most design methods provide influence charts for rapid calculation of stresses for almost all cases.

As in the case of flexible pavements, both empirical and theoretical methods are available for the calculation of minimum pavement thickness.

The AASHTO empirical method (AASHTO 86) is similar to the AASHTO method for flexible pavements, in that it makes use of empirical relationships derived from AASHTO road test results to calculate the required pavement thickness and also uses the concept of present serviceability index as a measure of the pavement surface quality. In addition, the axle weight equivalency factors have been derived from road test results. Unlike the case for flexible pavements, the pavement cross-section is represented by slab thickness rather than by a structural number.

The PCA (Portland Cement Association) Method (Packard, 1984) is based upon the calculation of internal stresses for a worst case situation where the truck axles are placed "at or near the pavement edge and midway between the joints" (Packard, 1984). Similarly, the worst case pavement deflection was calculated for a situation where the axle is placed "at the joint with the wheels at or near the corner" (Packard, 1984).

The method does not require the use of axle load equivalencies. Instead, it requires a forecast of both single and tandem axle weight distributions. The method then proceeds by proposing a trial thickness. This thickness of concrete is checked against the forecasted axle weight distribution. It if is inadequate, a different pavement cross-section must be proposed and checked.

In summary, the traffic data required by both of these methods is the same as that required for the design of flexible pavements, namely: (i) forecasts of total vehicle traffic (typically for a 20-year design life); (ii) forecasts of axle weight distributions for both single and tandem axle groups; (iii) forecasts of the number of trucks of each configuration as a percentage of total traffic; and (iv) from these previous factors, an estimate of ESAL's over the design life of the pavement. As in the case of flexible pavements, tire pressures and axle spacings become important only if they deviate significantly from normal values. In most cases, they are not required for design purposes.

3.2.3 Bridge Engineering

Bridge design begins with a determination of the loads and forces which the proposed structure will be expected to withstand during its life. The loads are divided into the following categories: dead loads, live loads, impact loads, wind loads, thermal forces, current flows, ice loads, etc. Those loads which are brought about wholly or partially by truck traffic are live loads and impact loads. Since impact loads are usually estimated as a function of the live load, they can be ignored here.

The AASHTO design code is widely used across North America (the CSA guidelines are the Canadian equivalent, differing mainly in the use of the metric system). The code proposes a group of five design vehicles which can be classified into two groups. The first group is the H loadings, illustrated in Figure 3.1. These are seldom used. The HS loadings (Figure 3.2) are more representative of modern truck traffic. For very long spans where more than one truck can be present on the same span, equivalent lane loadings have been calculated. These consist of a combination of a uniform load over the length of the span and a point load (Figure 3.3). In the United States, all interstate bridges are designed to HS20 standards. The bending stresses caused by one of these design vehicles are greater than those caused by an 80,000 lb (36,300 kg) 3-S2 vehicle for all span lengths (U.S. DOT, 1981), meaning that bridges designed to this standard are adequate for use by typical U.S. traffic, particularly considering the large safety factors typically used in bridge design. Loadings exceeding the HS20 designation can be obtained by proportionatly increasing weights of the standard HS trucks.

The OHBD (Ontario Highway Bridge Design) code was adopted by the Province of Ontario in 1970. The basis for the code's development was an extensive survey of the loads and axle spacings of Ontario's heavy trucks. The first step was the development of a continuous arithmetic function to describe the infinite variety of possible combinations of axle weights and spacings. The equivalent base length "is defined as an imaginary finite length on which the total weight of a given sequential set of concentrated loads is uniformly distributed such that this uniformly distributed load would cause force effects in a supporting structure not deviating unreasonably from those caused by the sequence itself." (Csagoly and Dorton, 1978). The Ontario Bridge Formula, which was then developed to govern allowable vehicle weights, is a continuous function of the equivalent base length of the truck. The function was derived so that it conformed to the AASHTO design truck stresses up to a base length

FIGURE 3.1: STANDARD H TRUCK LOADINGS FOR BRIDGE DESIGN

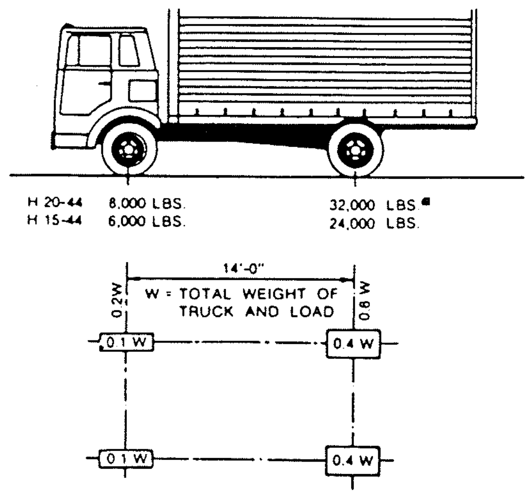
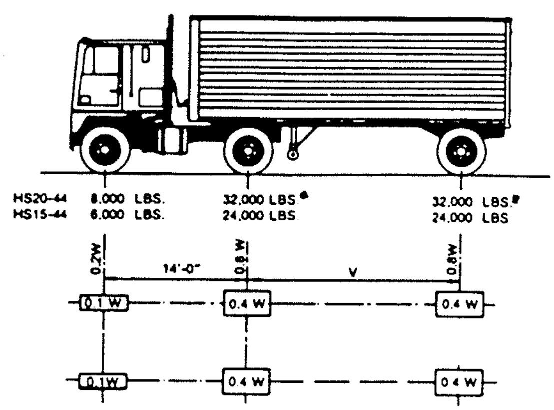
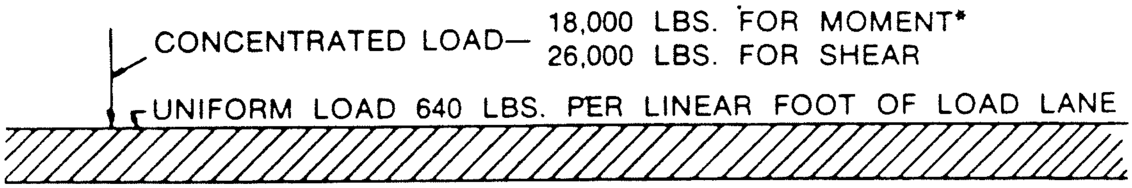


FIGURE 3.2: STANDARD HS TRUCK LOADINGS FOR BRIDGE DESIGN

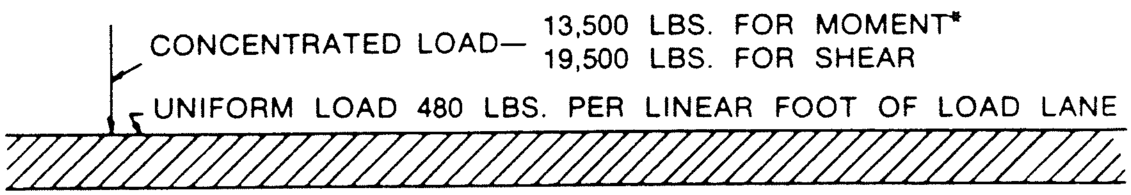


* Figures 3.1 and 3.2 are from AASHTO, "Standard Specifications for Highway Bridges", 1983.

FIGURE 3.3: ALTERNATE UNIFORM LANE LOADINGS



H20-44 LOADING
HS20-44 LOADING



H15-44 LOADING
HS15-44 LOADING

* Figure 3.3 is from AASHTO, "Standard Specifications for Highway Bridges", 1983.

of 30 feet. Beyond this point, it was set to keep stresses from exceeding the AASHTO levels by more than 30%.

Subsequent vehicle surveys indicated that a certain number of vehicles exceeded the maximum loads set out by the bridge formula. A new curve, placed above the bridge formula curve, was introduced. This new curve, the MOL (maximum observed load) curve was the basis for the OHBD design truck, developed so that it, along with its various sub-configurations, fell on or near the MOL curve. Thus, the design truck used in Ontario is more representative of the actual vehicle traffic using the highways in that province than the AASHTO and CSA design trucks used almost everywhere else.

In summary, bridge engineers require a knowledge of the various stresses resulting from the most heavily loaded vehicles expected (typically the heaviest legal loads) to make use of the particular bridge in question.

Generally, more detailed knowledge about actual truck weights and dimensions can lead to more efficient bridge design. In Ontario, data from extensive surveys of truck characteristics led to the formation of new design standards which are more closely based on actual truck loads, allowing savings in structural materials despite a higher design load (Csagoly and Dorton, 1978). As reported by the O.E.C.D. (1979), there is a need for data on "...practically all engineering aspects dealing with the evaluation of the load-carrying capacity of existing bridges, especially on such items as...data concerning the magnitude, intensity, distribution and frequency of actual commercial traffic loads."

3.2.4 Geometric Design

In the design of vertical highway grades, the object is to reduce by as much as possible the decreases in overall quality of the traffic stream flow which result from speed reductions of heavy trucks on grades. The main variables involved are the steepness of the grade, its length, the truck's g.v.w., and its horsepower. If speed reductions become significant, climbing lanes may be required. Figures 3.4 and 3.5 (TRB 1985) indicate the magnitude of expected speed reductions for trucks with weight/horsepower ratios of 200 and 300 lbs/hp. In Manitoba, a vehicle with a g.v.w. of 56,500 kg (125,000 lb), even with a 450 hp tractor (a very high horsepower rating), would have a weight/horsepower ratio of 311 lb/hp and would exhibit speed reductions on grades in excess of those plotted in Figure 3.5. Clearly, it would be advantageous to collect data on both g.v.w. and horsepower rating of these vehicles to help in the design of vertical grades, since the effects on highway capacity of large, slow-moving vehicles on grades are quite large.

Geometric design of turning roadways is based on the use of specific design vehicles, the turning performance of which are known. The most demanding of these is the WB-50 design vehicle. A number of other vehicles presently in use in Western Canada are graphically represented (Figure 3.6) along with a value representing the maximum expected off-tracking given the dimensions of each vehicle, and assuming a 180-degree curve with a 13.7 m (45') radius travelled by the outer front wheel of the vehicle. It can be seen that of these vehicles, only the B-train falls short of the cornering performance of the design

FIGURE 3.4: PERFORMANCE CURVE FOR TRUCKS ON GRADES
(300 lb./hp.)

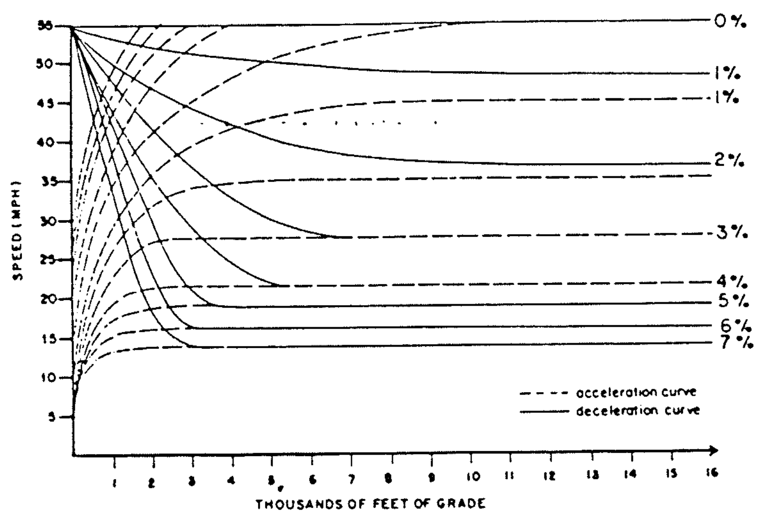
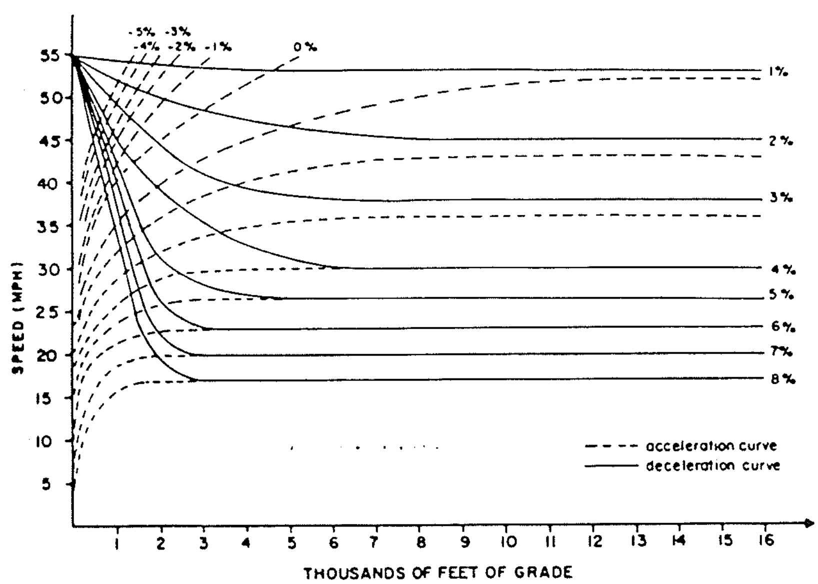
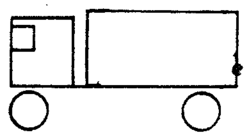
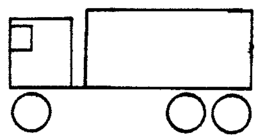
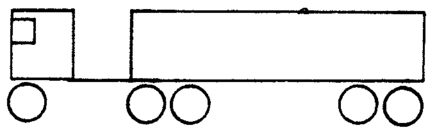
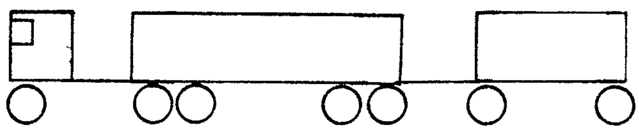
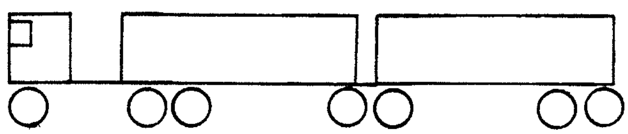
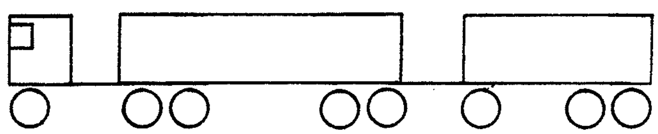
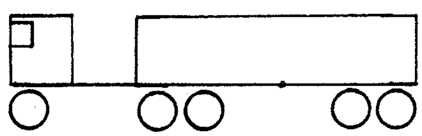


FIGURE 3.5: PERFORMANCE CURVE FOR TRUCKS ON GRADES
(200 lb./hp.)



* Figures 3.4 and 3.5 are from AASHTO, "A Policy on Geometric Design of Highways and Streets", 1984.

FIGURE 3.6: OFFTRACKING PERFORMANCE OF VARIOUS VEHICLE COMBINATIONS

Configuration	Mean Off-Tracking	
2	0.82 m.	
3	1.13 m.	
3-S2	5.92 m.	
3-S2-2	4.31 m.	
3-S2-S2	6.38 m.	
3-S2-3	3.87 m.	
WB-50	5.85 m.	

Off-tracking calculations are for a 180 degree curve with a 13.7m. (45') outer radius.

vehicle by a significant amount. For this reason, it is important for geometric designers to have knowledge of the dimensions of those vehicles which may make use of any particular intersection so that it can be designed accordingly. It is also desirable to have some forecast of the number of these vehicles expected to use the intersection, since very small numbers of encroachments off the roadway may be tolerated for the sake of economy.

3.2.5 Other

In assessing the relative degrees of safety of differing sizes and configurations of trucks, the major requirements for data are:

(i) annual vehicle miles travelled classified by weight, configuration, body type, dimensions, etc.; and

(ii) accident frequency for each kind of truck (TRB, 1986).

This type of data would allow comparisons of accident frequency among different truck types with corrections for their unequal levels of exposure.

When assessing changes in weight and dimension regulations, knowledge about both benefits (mainly in reduced transportation costs) and costs (deterioration of highway facilities, decreased capacity, etc.) is needed. The data requirements are:

(i) annual vehicle miles travelled classified by road type, truck configuration, origin, destination, traffic volume, etc.; and

(ii) axle weight distribution (from which E.S.A.L.'s can be calculated), operating costs per mile, payloads, etc., for each classification of truck (TRB, 1986).

This data allows a researcher to estimate differences in some of the net benefits and costs among different truck types and configurations, and is useful in the evaluation of alternative weight and dimension scenarios.

3.3 SPECIFIC MANITOBA PAVEMENT DESIGN REQUIREMENTS

The pavement design procedure currently used in the Province of Manitoba is relatively insensitive to the size and weight of expected truck traffic on a roadway. The procedure (Young, 1982) subordinates traffic characteristics to environmental considerations such as the frost susceptibility of soils. The reasons for this apparent imbalance include the fact that traffic on Manitoba roadways is relatively light, rarely exceeding 10,000 AADT (Young, 1982), meaning that environmental factors dominate in determining the life of almost all pavement segments.

The depth of granular base required under a particular pavement surface is calculated as a function of the soil group index. This group index is defined as follows (Young, 1982):

$$\text{Group Index} = 0.2\,a + 0.005\,ac + 0.01\,bd$$

where

a = percentage passing 75 μm sieve greater than 35 but less than 75 (0-40)
b = percentage passing 75 μm sieve greater than 15 but less than 55 (0-40)
c = portion of the liquid limit greater than 40 but less than 60 (0-20)
d = portion of the liquid limit greater than 10 but less than 30 (0-20)

The depth of base material is then modified according to estimates of future traffic volumes (usually calculated as twice the existing traffic). The modifications are presented in Table 3.1.

Table 3.1. Modifications to base material depth (adapted from Young, 1982)

Design Traffic Volume	Percent of Standard Design
< 200 AADT	50%
200 - 800	66.6%
800 - 2000	75%
2000+	100%

As far as heavy truck characteristics are concerned, the only data required for pavement design in Manitoba is an estimate of truck numbers as a percentage of total traffic. If this figure exceeds 10%, the modification to the base material depth as specified in Table 3.1 is increased by one category.

On roads where design traffic volumes and truck traffic exceed 2000 AADT and 10% respectively, special attention is required. In these cases, studies are done to determine accurate forecasts of traffic volumes as well as axle weight distributions. It would seem that, as traffic volumes and truck weights increase over the years, more highway segments will experience a need for this type of data, particularly in light of the fact that trucks in operation today have a much more pronounced effect on pavement life than those used at the time of this design method's conception.

3.4 SPECIFIC ALBERTA AND SASKATCHEWAN REQUIREMENTS

In Alberta, the Asphalt Institute Design Method is used while in Saskatchewan, both this and the "Saskatchewan Method" are used. Both require similar data inputs which include:

(i) AADT (Average Annual Daily Traffic). This includes all vehicles, both automobiles and heavy trucks.

(ii) Estimated growth rates for AADT. The period over which growth estimates are required depends on the roadway type and the design method used. Fifteen years is typical.

(iii) Percent trucks or a breakdown of various truck types if possible.

(iv) Estimates of equivalent axle loads per truck or estimates of E.S.A.L.'s for each particular truck type if possible.

These design methods differ from the one used in Manitoba in that they go much farther in determining the impact of heavy vehicle traffic on the design. These methods take into account the variability in both the numbers of trucks expected on the roadway and in the destructive effects of each truck, whereas in Manitoba, only numbers of trucks have a bearing on design (i.e., do they make up more or less than 10% of total traffic).

CHAPTER 4

MANITOBA'S REGULATORY SYSTEM

4.1 PURPOSE OF THIS CHAPTER

This chapter outlines the basic regulations in effect on Manitoba's highway network from 1972 (prior to the Western Canadian Highway Strengthening Program of 1974) to the present (1988). The chapter also distinguishes between the "basic" and the many non-standard regulations which may apply to only certain vehicles, on certain routes, or at certain times of the year. The purpose of these two tasks is to summarize the many regulations which encompass the operation of heavy vehicles and thus to illustrate the rationale behind the scheme used in grouping trucks and in eliminating specific observations from these groups which form the basis of the weight characteristics analysis performed in Chapter 6. To complete the picture, an outline of regulations in effect on roads not included within the provincial highway network has also been provided.

First, however, the system of truck classification in Manitoba is explained and relevant terms are defined.

4.2 TRUCK CLASSIFICATION SYSTEM AND DEFINITIONS

The Manitoba Department of Highways and Transportation subdivides heavy trucks (those with more than four tires) into 36 categories numbered from 8 to 43. Pictorial representations of each of these categories are shown on the truck survey form (Appendix A).

For the purpose of this paper, the data collected in only 6 different categories was used, as follows:

Two axle straight trucks	- Truck Code 8
Three axle straight trucks	- Truck Code 9
Five axle tractor semitrailers	- Truck Code 14
Seven axle A-Trains	- Truck Codes 33 & 34
Seven axle B-Trains	- Truck Code 41, and
Eight axle A-Trains	- Truck Code 35

A number of relevant definitions is listed in Appendix D.

4.3 SUMMARY OF REGULATORY DEVELOPMENTS: 1970-1987

Between 1970 and 1987, there were two major revisions to Manitoba's weight and dimension regulations. Prior to September 11, 1974, the maximum allowable gross vehicle weight (g.v.w.) on primary highways was 33,600 kg (74,000 lb). Axle loads were limited to 14,500 kg (32,000 lb) and 8,200 kg (18,000 lb) for tandem and single axles, respectively. These limitations prevented the effective use of anything larger than a standard 3-S2 tractor semitrailer combination. A 20,000 kg (44,000 lb) g.v.w. limit in effect on the secondary highway system limited the effectiveness of anything larger than a 3-axle truck on these roadways.

The changes made in 1974 included an increase in the maximum allowable g.v.w. to 50,000 kg (110,000 lb) on specified primary highways, making double trailer combinations practical for the transport of commodities with high densities. Axle loads were also increased (from 8,200 kg to 9,100 kg for single and from 14,500 kg to 16,000 kg for tandem groups), but tire loads remained at 9.0 kg/mm (500 lb/in). It should be noted that the entire primary highway network was not lifted to the 50,000 kg limit at that time. Much of the primary network remained restricted to 33,600 kg (74,000 lb). The limits on some of these roads were increased to 36,500 kg (80,000 lb) on November 18, 1974. At intervals over the next six years, more highways and segments of highways were added to the 50,000 kg category.

A second major change occurred on August 13, 1981, when g.v.w. limits were raised again, this time to 56,500 kg (125,000 lb) on primary and 47,630 kg (105,000 lb) on secondary roads. Axle weights and tire loads were kept at the previous levels. The effect of these changes was to allow trains to operate on secondary roads and to increase the advantage of operating 7 and 8-axle trains on the primary network. Prior to 1981, 7-axle trains were not used extensively, because their maximum g.v.w. was limited to 50,000 kg vs. 48,800 kg based on axle weight limits for a 6-axle A-train. After the excess tare weight caused by the addition of an extra axle is accounted for, there is little payload advantage to operating the larger combination under these conditions.

There has been little change in the dimension regulations since 1970, with the exception of an increase in combination length from 65 feet (20.0 m) to 70.0 feet (21.5 m) on January 1, 1979 in order to accommodate doubles which began to operate following the 1974 g.v.w. increases. The limit was raised again on July 29, 1980 to 75.5 feet (23.0 m) to accommodate the use of long wheelbase tractors in double trailer combinations. To prevent short wheelbase tractors from being used in combinations with very long trailers, a 16.75 m limit was imposed on the distance from the kingpin to the rear of the truck.

Semitrailer lengths have increased by 3 feet, from 45 to 48 feet, but this has not been as a result of Manitoba regulation changes (an increase in allowable tractor-semitrailer lengths of less than one foot on January 1, 1979 to 65 feet (20.0 m), caused by metrification of the regulations). Rather, the increase is mainly the result of regulatory changes in neighbouring jurisdictions.

Beyond these basic regulations, there have, from time to time, been a number of instances where added restrictions have been applied, or special easement of regulations has occurred. These additional regulations shall be referred to in this paper as "non-standard regulations". They include increased axle weight limits during winter months, increased allowable widths for trucks carrying loose fodder, etc. A list of the more influential non-standard regulations appears under the heading of "exceptions" in section 4.4. This list is not comprehensive, since the total number of such exceptions is extremely large, and the majority of them have only a very limited effect.

4.4 DETAILED REGULATION PROVISIONS

A summary of the detailed regulations is provided below in Tables 4.1 (primary highways) and 4.2 (secondary highways). The figures in these tables were used in the development of the relationships discussed in Chapter 6. Through the years, however, there have been a number of exceptions to these basic provisions. These have been noted below under the heading of "exceptions". The most noteworthy of these is the restriction of single axle weights on primary and secondary highways to 9,000 kg (19,900 lb) and 8,000 kg (17,700 lb), respectively, between January 1, 1979 and August 12, 1981. This decrease in allowable single axle weight limits resulted from the conversion of statutory weight limits from the imperial to the metric system of measurement and was negated on August 13, 1981. Since the resulting aberration was relatively small, and probably influenced actual axle weights very little, it was decided (for the purpose of analysis) to group those trucks operating under these limits with those operating under the 9100 kg and 8200 kg limits.

Exceptions

Fall, 1971 - Spring, 1981:

> All trucks hauling raw forest products during the winter months (December, January, February) were allowed a 15% premium on axle loads and gross vehicle weights. The 15% premium on gross vehicle weights did not apply, however, between the fall of 1974 and the spring of 1981 on highways governed by a 50,000 kg (110,000 lb) g.v.w. limit.

October 11, 1972 - September 10, 1974:

> The maximum gross vehicle weight on the #1 highway from Winnipeg to the Ontario boundary was increased to 40,800 kg (90,000 lb). Tire loads were decreased to 400 lb/in (7.0 kg/mm) until December 14, 1973.

TABLE 4.1:
MANITOBA PRIMARY HIGHWAY REGULATIONS
* adapted from tables 3.5 - 3.8 (Girling 1988)

Date in Effect	Prior to Sept. 11/74	Sept. 11/74 - Aug. 12/81		Aug. 13/81 - Feb. 18/82	Feb. 19/82 Present
Road Class	Class A	Specified Class A	Specified Class A	Class A	Class A1
Maximum G.V.W.	33600 kg.	50000 kg.	36500 kg.	56500 kg.	56500 kg.
Steering Axle Wt.	8200 kg.	9100 kg.	9100 kg.	5500 kg.	5500 kg.
Single Axle Wt.	8200 kg.	9100 kg.	9100 kg.	9100 kg.	9100 kg.
Tandem Axle Group Wt.	14500 kg.	16000 kg.	16000 kg.	16000 kg.	16000 kg.
Tridem Axle Group Wt.	14500 kg.	16000 kg.	16000 kg.	16000 kg.	16000 kg.
Tire Loads	9.0 kg./mm.	9.0 kg./mm.	9.0 kg./mm.	9.0 kg./mm.	9.0 kg./mm.
Height	4.15 m.	4.15 m.	4.15 m.	4.15 m.	4.15 m.
Width	2.60 m.	2.60 m.	2.60 m.	2.60 m.	2.60 m.
Lengths:					
Trucks	12.50 m.	12.50 m.	12.50 m.	12.50 m.	12.50 m.
Tractors	12.50 m.	12.50 m.	12.50 m.	12.50 m.	12.50 m.
Tractor semitrailers	20.00 m.	20.00 m.	20.00 m.	20.00 m.	20.00 m.
Combinations	20.00 m.	20.00 m. (21.50 m. after Jan. 1/79)	20.00 m. (21.50 m. after Jan. 1/79)	23.00 m.	23.00 m.

1. Proof of manufacturer's load rating for the front axle is required above 5500 kg. (12000 lbs.).

2. if the distance from the kingpin to the rear of the last trailer exceeds 16.74 metres (55.0 ft.), the maximum allowable length for trains is reduced to 21.5 metres.

3. The above axle loads are subject to the following conditions as of August 13,1981:

Steering axle to front drive axle	> 3.0 metres
Single axle to single axle	> 3.5 metres
Single axle to axle group	> 3.5 metres
Axle group to axle group	> 5.0 metres
Axle group to axle group (for end dump bulk trailers as of Nov. 8,1982)	> 4.0 metres

The combined load on adjacent axle groups is reduced by 330 kg. for each 0.1 metre reduction below these levels.

TABLE 4.2:

MANITOBA SECONDARY HIGHWAY REGULATIONS
* adapted from tables 3.5 - 3.8 (Girling 1988)

Date in Effect	Prior to Sept. 11/74	Sept. 11/74 - Aug. 12/81	Aug. 13/81 - Feb. 18/82	Feb. 19/82 - Present
Road Class	Class B	Class A	Class B	Class B1
Maximum G.V.W.	20000 kg.	33600 kg.	47600 kg.	47600 kg.
Steering Axle Wt.	8200 kg.	8200 kg.	5500 kg.	5500 kg.
Single Axle Wt.	8200 kg.	8200 kg.	8200 kg.	8200 kg.
Tandem Axle Group Wt.	14500 kg.	14500 kg.	14500 kg.	14500 kg.
Tridem Axle Group Wt.	14500 kg.	14500 kg.	14500 kg.	14500 kg.
Tire Loads	9.0 kg./mm.	9.0 kg./mm.	9.0 kg./mm.	9.0 kg./mm.
Height	4.15 m.	4.15 m.	4.15 m.	4.15 m.
Width	2.60 m.	2.60 m.	2.60 m.	2.60 m.
Lengths:				
Trucks	12.50 m.	12.50 m.	12.50 m.	12.50 m.
Tractors	12.50 m.	12.50 m.	12.50 m.	12.50 m.
Tractor semitrailers	20.00 m.	20.00 m.	20.00 m.	20.00 m.
Combinations	20.00 m.	20.00 m. (21.50 m. after Jan. 1/79)	23.00 m.	23.00 m.

1. Proof of manufacturer's load rating for the front axle is required above 5500 kg. (12000 lbs.).

2. if the distance from the kingpin to the rear of the last trailer exceeds 16.74 metres (55.0 ft.), the maximum allowable length for trains is reduced to 21.5 metres.

3. The above axle loads are subject to the following conditions as of August 13,1981:

Steering axle to front drive axle	> 3.0 metres
Single axle to single axle	> 3.5 metres
Single axle to axle group	> 3.5 metres
Axle group to axle group	> 5.0 metres
Axle group to axle group (for end dump bulk trailers as of Nov. 8,1982)	> 4.0 metres

The combined load on adjacent axle groups is reduced by 330 kg. for each 0.1 metre reduction below these levels.

December 14, 1973 - September 10, 1974:

> The maximum gross vehicle weight on the #1 highway from Winnipeg to the Saskatchewan boundary was increased to 36,500 kg (80,000 lb).

January 1, 1979 - August 12, 1981:

> Steering and single axle weights were reduced to 9,000 kg (19,900 lb) and 8,000 kg (17,700 lb) on primary and secondary highways, respectively.

Fall, 1981 - present:

> All trucks hauling raw forest products during the winter months are allowed the following weight limits:
>
> Single axles - 9,200 kg (20,000 lb)
> Tandem axles - 18,000 kg (40,000 lb)
> Gross vehicle weight - 59,000 kg (130,000 lb)

January 7, 1981 - present:

> Axle load limits have been increased by 10% during the period from December 1 to February 28.

Highways within the City of Winnipeg are designated as class A highways. These are subject to 36,500 kg g.v.w. limits as well as to limits of 9,100 kg and 16,000 kg on single and tandem axles, respectively. Dimension limits are the same as those applicable on both class A1 and B1 provincial highways.

The weight limits in the city of Winnipeg have been increased to class A1 levels (56,500 kg g.v.w. maximum) on many trucks routes (City of Winnipeg By-law No. 1573/77) except that some bridge weight limits are restricted to 36,500 kg or 50,000 kg. The increased weight limits are applicable only to truck traffic with an origin or destination (not both) within the City of Winnipeg, and making use of the most direct route to the Perimeter Highway or Lagimodiere Boulevard. In addition, trucks may operate under class A1 limits if they do not move off these two highways during the entire course of their trip.

4.5 DEVELOPMENT PROSPECTS

Until now, Manitoba weight and dimension regulations have developed in a similar manner to those in the other two prairie provinces, often incorporating legal limits identical to those in Saskatchewan and Alberta. However, in doing so, the province of Manitoba has come up with a set of regulations largely incompatible with those of eastern and central Canada (particularly Ontario). The differences in the regulations mean that extraprovincial trucks must tailor both their equipment and loads to comply with the lowest common denominator of the many sets of limits. This approach obviously causes a definite but hard-to-measure decrease in extraprovincial trucking productivity.

The joint RTAC/CCMTA Committee on Heavy Vehicle Weights and Dimensions has recently developed and introduced a "plan that will assist each jurisdiction in implementing vehicle weight, dimension and configuration regulatory principles that will lead to national uniformity". The western provinces, including Manitoba, presently allow the permitting of these RTAC vehicles which can take advantage of increases in both allowable weights and dimensions of heavy vehicles. Table 4.3 summarizes the changes recommended by the report.

The Manitoba Department of Highways and Transportation has recently completed a study aimed at introducing a new system of road classification beyond the statutory classification

TABLE 4.3

PROPOSED MANITOBA HIGHWAY REGULATION CHANGES
(RTAC/CCMTA)

	CLASS A1 HIGHWAYS	
	Current	Proposed
Maximum G.V.W.		
A-train	56500 kg.	53500 kg.
B-train	53500 kg.	62500 kg.
C-train	56500 kg.	53500 kg.
Steering Axle Wt.	5500 kg.	5500 kg.
Single Axle Wt.	9100 kg.	9100 kg.
Tandem Axle Group Wt.	16000 kg.	17000 kg.
Tridem Axle Group Wt.		
Tractor-Semitrailer	16000 kg.	24000 kg.
B-train	16000 kg.	23000 kg.
Tire Loads	9.0 kg./mm.	10.0 kg./mm.
Axle Spacings		
Single-Tandem	3.50 m.	3.00 m.
Tandem-Tandem	5.00 m.	5.00 m.
Tandem-Tridem	5.00 m.	5.50 m.
Height	4.15 m.	4.15 m.
Width	2.60 m.	2.60 m.
Lengths:		
Tractors	12.50 m. (length)	6.20 m. (wheelbase)
Tractor-Semitrailer	20.00 m.	25.00 m.
Trains	23.00 m.	25.00 m.

1. The 24000 kg. and 23000 kg. limits to tridem axle group weight would be allowed provided that no two adjacent axles within the tridem have a combined weight in excess of 17000 kg.

system (PTH, PR) presently in use. The list of recommendations includes the introduction of a "functional classification system" which will group all rural highways under one of these headings: expressway, arterial (primary or secondary) and collector. The new system will mean that expressways or arterials will be defined as provincial trunk highways or future provincial trunk highways. Future provincial trunk highways are those which are presently denoted as Provincial routes, but will be upgraded as soon as possible to PTH standards. Presumably, this means that some secondary roads will be upgraded to 9,100 kg/16,000 kg axle load limits and reclassified as PTH's. In addition, elimination of spring restrictions on primary highways (expressways and arterials) would be a priority if these changes came into effect.

The weight regulations of all roads will remain the same, except in those instances where former PR's are upgraded to the standards of their new classification (expressways or arterials) and become PTH's. In all probability, the number of roads affected will be small. The plan would also lead to the elimination of spring weight restrictions on all primary highways, not a great change, since the majority of such highways are already free of these restrictions.

CHAPTER 5

THE DATA BASE

5.1 PURPOSE OF THIS CHAPTER

This chapter describes the data base used in this research. In particular, it (i) provides a general description of the annual truck survey of the Manitoba Department of Highways and Transportation - the source of the data used in this research - and the resulting "raw" data base; (ii) outlines difficulties faced in using the raw data base; (iii) describes modifications of the raw data base made to facilitate this research; (iv) provides a documentation of the resulting modified data file; and (v) outlines limitations to this research associated with or derived from limitations in the data base itself.

It is hoped that the information provided here will aid in any efforts to recreate or extend the results of this research. In addition, a knowledge of the data base (including its shortcomings) will illustrate the need for a more rationalized and comprehensive approach to data collection.

5.2 SUMMARY OF THE MANITOBA TRUCK SURVEY

Since (at least) 1960, the Manitoba Department of Highways and Transportation has conducted annual surveys of trucks operating on Manitoba's provincial highway network. The surveys were conducted at a series of on-road survey stations at various points on

Manitoba's highway networks by crews operating either a permanent scale, such as the one currently located and operating at Headingley (on the Trans-Canada Highway west of Winnipeg), or a portable scale set up at temporary locations throughout the province. Among other things, but of particular relevance to this research, the surveys have included the collection of information about axle weights, truck origins and destinations, commodity handlings, axle spacings, overall dimensions and tire widths. This research has focused on analysis of the data collected through the period 1972-1986 inclusive.

Prior to 1984, the surveys were conducted at thirteen different sites located throughout the province, varying from year to year with the intent (presumably) of providing a reasonably representative, province-wide perspective on truck operations. Since 1984, budgetary restrictions have necessitated the scaling down of the scope of the survey such that only three locations have been surveyed each year.

The survey sites were normally operated for 8-hour periods for 4-5 consecutive days (weekdays only) in each of the four seasons. The aim was to capture as large a sample of trucks as possible, as well as to spread the survey times out over the length of the year so that seasonal variations in truck characteristics could be captured. While the general intent was that the entirety of the truck traffic passing through each site would be surveyed, heavy traffic conditions sometimes dictated that scale operators wave on some (normally unloaded) vehicles during peak traffic periods. Laden trucks were seldom permitted to pass through the site without being surveyed.

The survey results from 1960 to the present have been computerized by the Manitoba Department of Highways and Transportation and are stored on standard label computer tapes. The data is stored in raw form - unsorted except by collection year. Nonetheless, when understood, the data base can be readily sorted and tabulated using the S.A.S. (Statistical Analysis System). The huge size of the resulting raw database is unsuitable for analysis using microcomputers.

5.3 PROBLEMS IN USING THE DATA BASE

Although the magnitude of the data base is (probably) sufficient for the purpose of studying truck characteristics in Manitoba, there are problems in making full use of the information which result in some limitation of its value. While some of these problem are unavoidable, a number could have been (and can be in the future) eliminated by a more careful planning of the methods of collection and storage. Problems include:

(i) the absence of some types of potentially useful information which could have been collected with little or no increase in the cost of the survey. Two examples of this which would have been of value for this research are volume loading information, and truck body type - both of which are routinely collected in other surveys. A knowledge of truck body type would have facilitated the calculation of more accurate payload values since tare weights could be estimated by averaging the g.v.w.'s of unladen trucks for each body type rather than over the entire population. Volume-loading data, on the other hand, would have provided better insights into truck productivity considerations for cube-out traffic.

(ii) the discontinuity of the survey formats through the period of study. This resulted from an overhaul of the survey in 1979/1980, with the result that a direct comparison of the data before and after this time period is difficult without modifications to one or the other of the new data files. Changes which occurred after the 1979 survey include: (i) the metrification of measured weights and dimensions (thus, for example, after 1979, weight was measured in kilograms rather than in units of 100 lbs); (ii) commodity code changes (the total number of commodity classes was reduced from over 300 to only 35); and (iii) the deletion of some pre-1980 survey variables (e.g., sequence number) as well as the collection of others which had previously not been part of the survey (e.g., minute, licensing province).

(iii) uncertainty about the regulatory environment governing trucking movements through survey sites at intersections of highways with differing weight and dimension regulations, none of which are stated explicitly on the survey form or on the computer tapes of truck observations.

(iv) no provision for coding information respecting the application of winter premium weight allowances or spring loading restrictions governing operations at the survey site in question. The survey records supply none of this information, and the researcher is obliged to find the applicable governing situation from some other records (a typically burdensome, sometimes impossible, task).

(v) no provision for coding special permitting information.

There are two other considerations which must be kept in mind when using the data base and attempting to draw general conclusions from it. These include:

(i) uncertainty about the general representativeness of the survey results with respect to the choice of survey locations. The possibility exists that biases have been introduced resulting from the selection of survey locations, and that the weight and dimension data is not totally representative of province-wide truck characteristics, particularly in the years following 1983 when only 3 stations were surveyed.

(ii) uncertainty in the survey results caused by drivers who purposely avoid the scale sites when operating overweight vehicles. In other words, "sites ... become well known to truck operators who plan any overweight operations to bypass the scales or travel when the scales are closed." (French and Solomon, 1986). Quite understandably, a driver who suspects he is overloaded will not hesitate to avoid any scale even if it is operating for non-enforcement purposes because he will have no way of knowing this fact with any degree of certainty.

5.4 DATA BASE MODIFICATIONS

The major modification of the data base was the creation of SAS data sets from the previously unsorted raw data files. The advantage of this alteration in data format is that it greatly simplifies the programming requirements for sorting, tabulating and graphing the data.

Simultaneous with the change from raw data to SAS data sets was the conversion of all Imperial units to their corresponding metric equivalents. This change affected the 1972 to 1979 data sets only, and did not include tire widths which are still measured in inches. These conversions consisted of changing dimensions, previously recorded to the nearest 1/10 ft, to metres and of changing weights, previously measured to the nearest 100 lbs, to kilograms. In grouping the observations, it is possible for some to be included in an adjacent category due to the rounding of the original measurements. This effect is minor, and is not felt to cause a significant distortion.

The changeover to SAS data sets also included an adjustment of commodity codes for the purpose of achieving uniformity across the entire timeframe of the survey. This means that the 300+ separate categories used in the 1970's had to be grouped and fitted to conform to the 35 categories used in present day surveys. There were some cases in which categories did not correspond exactly, resulting in uncertainty over the load classification; however, these cases were rare, and are not perceived as any threat to the validity of the pre-1980 data. Both sets of commodity codes as well as the system of fitting the old to conform to the new set are listed in Appendix B.

Several new variables were created in an attempt to correct or minimize the shortcomings discussed earlier. These variables are:

ROAD: a variable which characterizes the legislative environment under which the particular truck is operating. Specifically, it denotes the maximum legal g.v.w. allowed on the road on which the truck was found to be travelling and indirectly denotes the applicable axle weight limits as well. Single and tandem axle weight limits of 8200 kg and 14500 kg, respectively, apply when ROAD = 44, 74, or 105, while 9100 kg and 16000 kg limits apply when ROAD = 80, 110, or 125. ROAD was found by noting the highways on which the scale was situated and subsequently using ENT (entry direction) and EXT (exit direction) to determine each truck's routine (i.e., which highway it was on, and which highway it exited to). The regulations in effect at the time of the survey on the particular road or roads in question then determined the value of ROAD (1000's of lbs).

In cases where the road used to enter the survey site did not have the same g.v.w. limit as the road used to exit the site, the lower value was assumed to be the governing limit. A problem with this assumption is that some vehicles operating on secondary highways do so only to gain access to the primary system. In a case such as this, the vehicle would operate under primary highway weight and dimension limits, but would be recorded as being subjected to the limits in effect on the secondary highway. This fact should be kept in mind in the examination of weight distributions, particularly those on secondary highways.

REGU: A variable which applies only to Manitoba weight data collected during the year of 1974. It was necessary because of the unique regulation change which occurred on August 18, 1974. On this date, a maximum g.v.w. of 74,000 lb (33,600 kg) was set for secondary highways. Previously, this had been the maximum for the primary highway system. The end result from the researcher's point of view is the elimination of ROAD as a meaningful variable since two different observations, one on a primary highway and the other on a secondary road, could have the same value for ROAD depending on the time of year during which the survey was held. REGU was formed to differentiate between the two periods of dissimilar regulatory environments. If REGU = "PRE", the survey was taken before August 28, 1974, while REGU = "POST" means a survey time after this date.

GVW: the sum of variables AXLD1 to AXLD10 which represent the loads on each axle from front to rear of the vehicle.

NAX: the number of axles of the observed truck. The existence of this variable simplifies the process of sorting when number of axles rather than truck type is the sorting criterion.

WP: if yes, denotes the presence of winter premiums during the survey period. For a period from January of 1983 to the present, axle load limits (but not g.v.w. limits) have been increased by 10% during the winter months (December 1 to February 28) in recognition of the fact that a frozen subgrade has much greater strength than under normal conditions.

One final modification to the data involved the creation of a separate file (i.e., #16, see next section) which deleted stations with a preponderance of one or another particular commodity. To this effect, it had been noted that certain survey locations had a preponderance of a particular commodity (e.g., gravel). Since commodity density has such an important bearing on the g.v.w. of the trucks used to transport it, a high percentage of a very dense (or a very light) commodity among the total number surveyed would have the result of shifting the g.v.w. distribution considerably.

It was decided that in any one year, no more than 20% of the total laden 3-S2 or straight trucks travelling on a particular class of road should be carrying any one commodity. If this was not the case in a particular year, the stations with the highest percentage of the excessive commodity group were deleted until a "20% rule" was satisfied. The only exception to this rule was for commodity No. 26, which is defined as "misc. goods, unknown commodities".

The data set which resulted from these exclusions is referred to as "all" commodities, to distinguish it from data sets made up of one or more individual commodity groups which are referred to by the name of the commodities represented. A more complete description of the rationale behind the creation of the "all" commodities group is provided under the heading of "6.2 Analytical Considerations".

5.5 DOCUMENTATION OF THE DATA FILE

This research is based upon a new data tape provided by the Manitoba Department of Highways and Transportation, subsequently modified as noted in Section 5.4. The resulting modified data files are presently contained on a computer tape located in Room 305 of the Engineering Building at the University of Manitoba. The tape contains sixteen files as listed in Table 5.1:

Table 5.1 Contents of tape volume - UM0104

FILE NO.	DSNAME	BLKSIZE	BLOCK COUNT	EST. FEET	CREATED
1	MANHWYS.TRKWTS72	32760	93	44.0	04MAR88
2	MANHWYS.TRKWTS73	32760	118	55.5	04MAR88
3	MANHWYS.TRKWTS74	32760	120	56.4	04MAR88
4	MANHWYS.TRKWTS75	32760	120	56.4	04MAR88
5	MANHWYS.TRKWTS76	32760	73	34.7	04MAR88
6	MANHWYS.TRKWTS77	32760	75	35.6	04MAR88
7	MANHWYS.TRKWTS78	32760	100	47.2	04MAR88
8	MANHWYS.TRKWTS79	32760	91	43.0	04MAR88
9	MANHWYS.TRKWTS80	32760	80	38.0	04MAR88
10	MANHWYS.TRKWTS81	32760	105	49.5	04MAR88
11	MANHWYS.TRKWTS82	32760	64	30.6	04MAR88
12	MANHWYS.TRKWTS83	32760	76	36.1	04MAR88
13	MANHWYS.TRKWTS84	32760	31	15.3	04MAR88
14	MANHWYS.TRKWTS85	32760	27	13.5	04MAR88
15	MANHWYS.TRKWTS86	32760	17	8.9	04MAR88
16	MANHWYS.ALL	32760	856	396.3	04MAR88

The first fifteen files contain data on all truck observations at all scales involved in the Manitoba Department of Highways and Transportation truck weight and dimension surveys from 1972 (files number 1) to 1986 (file number 15). The files include the following variables for each truck observation:

STN: The station number. A complete list of station numbers and their locations appears in Appendix C.

YR: The last two digits of the survey year.

MON: A two-digit number denoting the month of the year during which the truck was surveyed, i.e., MON = 1 means January, while MON = 12 means December.

DAY: The day of the month during which the truck was surveyed.

RESTR: Restrictions. 1 = YES, 0 = NO. (Dept. of Highways did not identify this variable)

FLAX: The position of a floating (lift) axle (if any), i.e., FLAX = 2 means the second axle from the front is floating.

PER: Per = 1 means the truck is operating under a special permit, while PER = 0 means no such permit is in effect. (Dept. of Highways has indicated that this data is not reliable)

TYP: The type of truck ranges from TYP = 8 (a two-axle straight truck) to TYP = 42 (an eight axle B-train). A complete list of truck types can be seen on the truck survey form in Appendix A.

COMM: Commodity code. A complete list of these codes can be seen on the truck survey form in Appendix A.

TRL: Truck length in metres including the load.

TRW: Truck width in metres including the load, but not including side-mounted rear view mirrors.

TRH: Truck height in metres including the load.

$TIRE_x$: The widths of the tires (in inches) on axle number x. The value of x ranges from 1 (the front steering axle) to 10. $TIRE_x = 0$ if the number of axles is less than x. (Note: The tire width data was not converted to metric units)

$AXLD_x$: The loads on axle number x (1 to 10) in kilograms. $AXLD_x = 0$ if the number of axles is less than x.

$AXSP_y$: The spacings between axles in metres. y = 1 to 9 and AXSP1 is the spacing between axles 1 and 2.

WP: Winter premium. If WP = YES then the truck was operating during a period of time when winter axle load premiums were in effect.

ROAD: The maximum g.v.w. allowed for the truck on the particular road it was travelling. (Details are in Section 5.4)

NAX: The number of axles on the truck.

REGU: (1974 observations only) REGU = PRE means the observation occurred before the regulation changes on August 28, 1974. REGU = POST means the observation occurred after that date. (Details are in Section 5.4)

File number 16, MANHWYS.ALL, includes observations from all years of the survey from 1972 to 1986. Certain stations were omitted from this data file in order to produce a more representative set of 3-S2 vehicles. The omitted stations were those which were dominated by a single commodity group. A full explanation of the method and rationale behind the creation of this data file is given in Section 6.2 "Analytical Considerations".

5.6 RESEARCH LIMITATIONS ASSOCIATED WITH DATA BASE LIMITATIONS

There were a number of areas in which the data base fell short and subsequently reduced the effectiveness of attempts to use it as a basis for truck weight and dimension modelling. Although most of these limitations were unavoidable, or would have been excessively expensive to correct, some may have been eliminated/minimized had more extensive use of the survey results in the past caused improvements and corrections to be incorporated into the data collection process.

Differentiation of body types (i.e., end dump, low boy, etc.) of the trucks would have allowed calculations of tare weights for each specific body type, leading to more accurate measures of payloads. As it stands, the same tare weight figures have been used to calculate payloads of everything from gravel to petroleum, despite the fact that the trailers used for these two tasks are quite dissimilar and probably have dissimilar tare weights. It would seem that including a description of truck body type on the survey form would be easy, inexpensive, and would not add any more than a few seconds of survey time required for each truck.

In many cases, the scales have been located at the intersections of two highways. This only causes problems when one of the roads is a primary, while the other is a secondary highway. In such cases, it is difficult to tell whether the truck should be subject to the primary or secondary weight limits. Current practice in Manitoba is to allow trucks using secondary highways to operate under primary highway weight limits if the major part of their trip mileage is on primary highways, either their origin or destination is located off the primary system, and they use the shortest route to move between their point of origin (or destination) and the primary highway system.

The problem arises because nowhere on the survey forms is it recorded whether these conditions are being met. In this study, it is assumed that all vehicles on secondary highways are subject to secondary highway limits, but clearly this is not always the case. Unfortunately, this limitation of the data base has not been addressed even after more than a decade.

A third problem concerns the fact that some drivers may be aware that their trucks violate weight and/or dimension regulations and hence avoid the scales, if possible. The effect is that the weights recorded at the scale will not include a portion of the very heavy trucks which are using these highways. The problem is most acute at the permanent scale locations which are well known by truckers. When temporary scales are set up, many truckers are caught by surprise and have no opportunity to avoid them. One method which has been used to alleviate the problem is to stop issuing tickets for overweight infractions at the scales during the weeks of the survey in the hopes that truckers will then enter the scale regardless of their weight. This solution probably reduces the problem somewhat, but it is hard to imagine that all truckers are aware of this policy and trust the Department of Highways and Transportation enough to be weighed while knowingly overweight. Since it is impossible to know the extent to which this avoidance has been occurring, all that can be done at this time is to present the data as collected, but keeping in mind that it may slightly under-represent overweight vehicles.

The final and possibly the most severely limiting problem encountered was associated with inconsistent planning behind the determination of the number of sites in each survey year. It was decided many years ago that the proper number of stations to be surveyed each year was thirteen. This number was kept more or less constant until 1984, when it was reduced to three due to budgetary constraints. Furthermore, the selection of survey sites has not been at random, because the permanent weight scales at Headingley, Emerson, and Westhawk have been chosen as survey sites on a very regular basis. The result is that year-to-year comparisons of such things as percent trucks or mean E.S.A.L.'s per truck are difficult, since the precision and confidence levels of these numbers change over the years as the number of stations change.

It would seem that the approach adopted by the U.S. Federal Highway Administration would provide more statistically valid information. The FHWA (Federal Highway Administration) has published a set of guidelines which outline in detail the performance monitoring system. This system is designed to ensure a minimum accuracy for annual average daily traffic, percent trucks and other figures generated from roadside traffic counts and surveys. The heart of the system is a statistical procedure for determining the minimum number of survey sites required for the calculation of statistically valid highway performance figures. This procedure yields the appropriate number of survey sites required to produce figures within the precision and confidence levels desired by the highway agency.

Possibly alternative data collection methods could be employed, such as the use of weigh-in-motion equipment. Although there are concerns as to the accuracy of weigh-in-motion data, it is clear that the greatly increased volume of data available from such scales "will result in a better understanding of how pavement performance is related to traffic loading.. and in improved pavement design procedures" (French and Solomon, 1986).

CHAPTER 6

WEIGHT CHARACTERISTICS OF LARGE TRUCKS OPERATING ON MANITOBA HIGHWAYS

6.1 PURPOSE OF THIS CHAPTER

This chapter analyzes characteristics of the truck fleet in manitoba, and also of the tare weights and payloads of various vehicle configurations within the fleet. In addition, it details the procedures used in developing the weight distribution models and shows the results of modelling each of the weight characteristics of all pertinent truck types. The effects of regulation changes on these truck weight characteristics are also explored.

6.2 TRUCK FLEET CHARACTERISTICS

The major objective of this research is to develop models of g.v.w. and axle weight distributions of specific large truck types operating on Manitoba highways, as a function of governing regulatory limits. There are, of course, a wide variety of large truck configurations observed on the highways. Many are used only infrequently - and the truck survey efforts (and therefore the database used in this research) typically records only a small number of observations for such units. Attempting to develop weight distribution models for these infrequently observed units was considered futile. Instead, the research focused on developing models for the most prevalent configurations. This section examines the changing characteristics of the fleet operating on Manitoba's highways between the early seventies and the present, with a view to providing a general indication of the relevance of various configuration types to the Manitoba highway system - which in turn provides the basic justification for selection of the various configuration types considered in detail in the remainder of the chapter.

The truck fleet in Manitoba has changed in two fundamental ways during the decade-long transition period following the Western Canada Highway Strengthening Plan of 1974. First, the size of the fleet in terms of actual numbers of vehicles has increased, and secondly, the composition of vehicles making up the fleet has shifted. The purpose of this chapter is to present a picture of the truck fleet in Manitoba as it exists in the present as well as to show the fluid nature of this picture by noting the changes which have taken place over a period of approximately ten years. It is important to remember that constant change means that any attempt to characterize the state of the fleet will be somewhat behind the times, and can only serve to give an idea of what the fleet "was" like at the time of data collection.

Vehicle registration statistics suggest a steady growth in the non-resident truck fleet in Manitoba since the 1975-1976 registration year. At that time, only 1,110 trucks with more than four axles were registered in Manitoba from the provinces of British Columbia, Alberta, Saskatchewan, and Ontario. The figure for 1983-1984 is 7308 vehicles (see Figure 6.1). It should be noted, however, that due to the changing of reciprocity agreements in 1982, it became much more advantageous for companies to register trucks in provinces other than their own, even in cases where the expected mileage within those provinces was low. This accounts for the sudden steep rise in the graph line between 1980-1981 and 1982-1983. This reciprocity change means that a direct comparison of truck registration numbers across the 1982 time period is meaningless. However, the trend of steady increase which is present both prior to and after this data indicates a pattern of growth in the numbers of these trucks. A rise in 4+ axle vehicles base-plated in Manitoba occurred simultaneously (Figure 6.2), resulting in an overall increase in the total number of large trucks sharing the highways with Manitoba motorists.

Substantial relaxations of weight and dimension regulations in western Canada have allowed the usage of increasingly larger and heavier tractor semitrailers and trains. No picture of the Manitoba truck fleet would be complete without a knowledge of the percentages of the total fleet which are made up of A- and B-train combinations, tractor semitrailers, straight trucks, etc. Figure 6.3, comprised of data collected at Manitoba Department of Highways truck weight and dimension survey sites, shows a clear trend toward the greater usage of multi-trailer truck trains as well as a decline in the number of smaller straight trucks. Since there is no reason to believe that this general increase in truck size has ceased and further liberalization of weight and dimension regulations are imminent in the wake of RTAC recommendations, the trend can be expected to continue into the near future.

FIGURE 6.1: NON-RESIDENT TRUCKS REGISTERED IN MANITOBA (FOUR OR MORE AXLES)

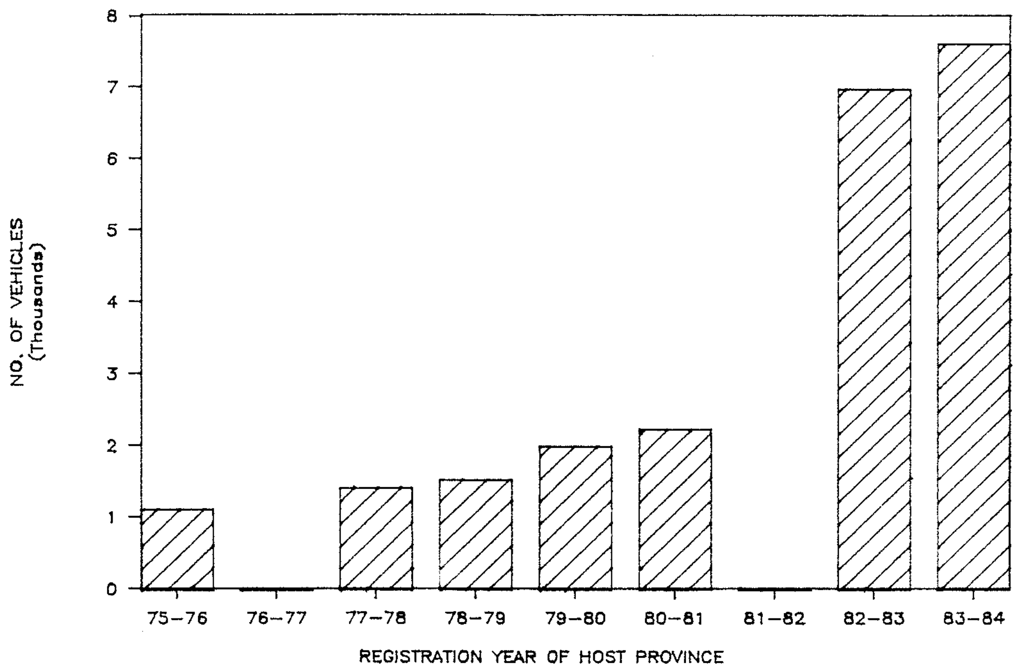


FIGURE 6.2: RESIDENT TRUCKS BASE-PLATED IN MANITOBA (FOUR OR MORE AXLES)

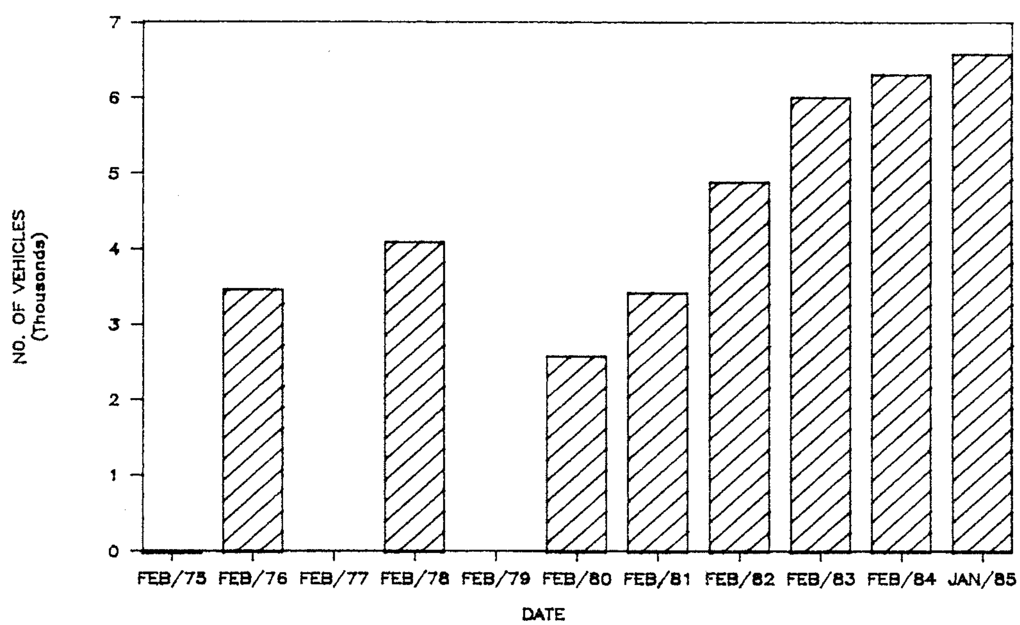
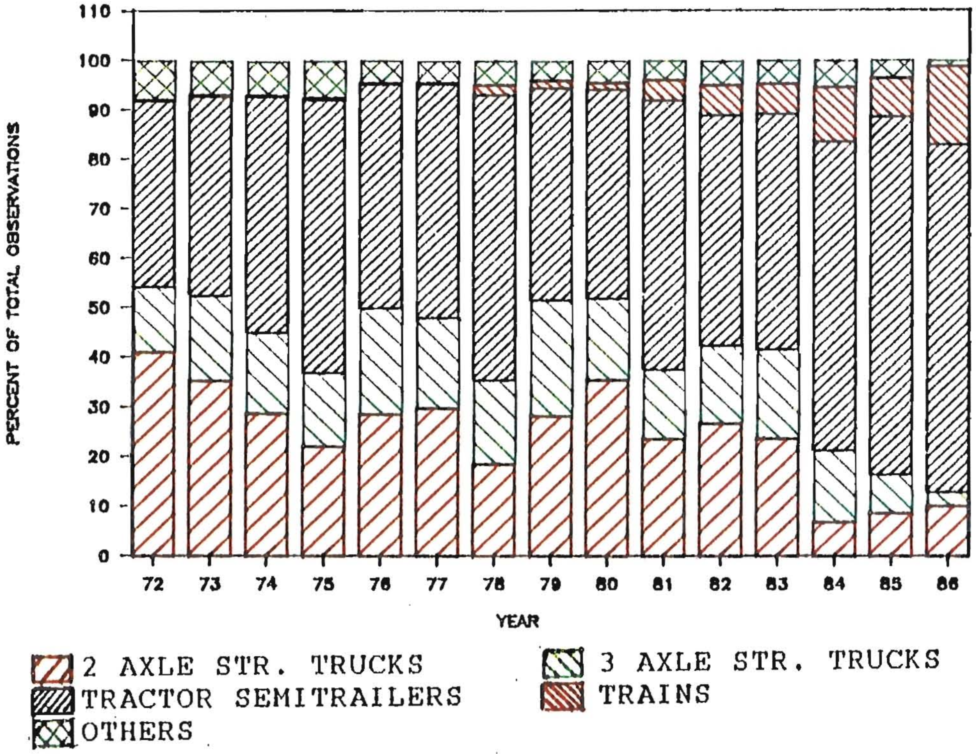


FIGURE 6.3: BREAKDOWN OF MANITOBA TRUCK FLEET MIX



6.3 ANALYTICAL CONSIDERATIONS

6.3.1 Conceptual

This research deals with truck regulations, in particular, the ways and extent to which these regulations affect vehicle weight and dimension characteristics - especially truck axle weight and gross vehicle weight distributions. The framework within which this has been done is presented here.

The effects of weight and dimension regulations on truck characteristics are part of a complex interaction among three systems.

The Transportation System (T)

This system is composed of (among others):

(i) the road network, including all classes of highways, streets, and bridges,
(ii) vehicles of various types, sizes, and capabilities,
(iii) operational policies and practices,
(iv) operating companies, and
(v) government imposed regulations governing operators.

The Activity System (A)

This system is composed of all social and economic factors affecting or affected by the transportation system. It may be regarded as the demand for trucking services as well as the source of the resources used by the transportation system in satisfying this demand.

Flow Patterns (F)

This system is composed of (among others):

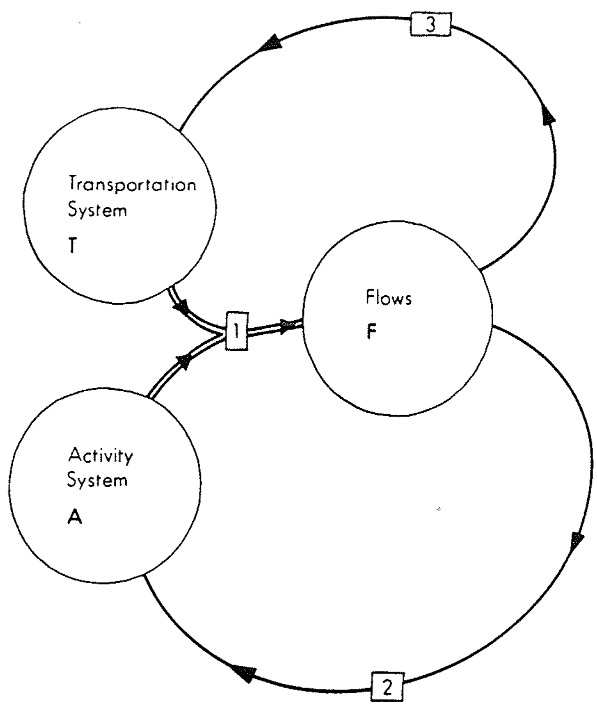
(i) origin and destination patterns,
(ii) commodity movement patterns,
(iii) truck mileage,
(iv) axle weights, and
(v) gross vehicle weights.

Descriptions of the basic relationships among these three systems are provided by Manheim (1979) and are illustrated in Figure 6.4.

The major thrust of this research is to study and model two specific aspects of relationship 1. The first of these sub-relationships is the influence of truck weight and dimension regulations (a component of the transportation system) on truck axle weights (a flow pattern characteristic) and the subsequent effect on E.S.A.L.'s per truck (one measure of resource consumption). The second sub-relationship is the effect of weight and dimension regulations on gross vehicle weights of specific truck types and subsequently on the service levels provided (measured in terms of payload per truck).

The intention was to model these two relationships under the assumption that all other factors remain constant. This, of course, could never truly be the case since the data was collected over a period of several years during which changes in the activity system occurred. It is assumed that these variations in the demand for trucking would be responsible for much of the variation in the size of the truck fleet and, to a lesser extent,

Figure 6.4. System interactions.



for changes to the fleet mix but only superficially for variations in the weight distributions of particular vehicle types, which is the variable being modelled here.

The following examples will graphically illustrate each of the modelled relationships. The first example compares the effects of two alternate sets of weight regulations (transportation systems T1 and T2) on the axle weight distributions of two axle straight trucks (flow patterns F1 and F2). The axle weight distributions in turn result in dissimilar E.S.A.L. per truck figures (resource consumption results R1 and R2). The second example compares the effects of the alternate sets of regulations on gross vehicle weights distributions (F1 and F2) and hence on payloads (service levels S1 and S2).

Example 1: Transportation System Effects on Resource Consumption

In this example, the transportation system change will consist of an increase in maximum legislated single and tandem axle group weights, similar to the changes which occurred in Manitoba (and other prairie provinces) in 1974. The two systems are summarized in Table 6.2.

Table 6.2 Transportation systems

	T1	T2
Steering axle weight limit	5500 kg	5500 kg
Single axle weight limit	8200 kg	9100 kg
Tandem axle weight limit	14500 kg	16000 kg

For the purpose of the example, the effects of the transportation system change will be examined with respect to axle weight distribution shifts of two axle straight trucks only.

From the truck weight survey results presently stored in file #16 of data tape UM0104, i.e., the "ALL" dataset (see Section 5), Figures 6.5 and 6.6 were developed to graphically display the shift in axle weights of the trucks under the two sets of regulations. These axle weight distributions (F1 and F2) directly affect resource consumption (i.e., pavement damage) measured in terms of E.S.A.L.'s. In this case R1, the E.S.A.L. per truck figure for the first scenario, was found to be .324 E.S.A.L.'s/truck, while R2 was .396 E.S.A.L.'s/truck, an increase of 22% resulting directly from regulation changes.

FIGURE 6.5: STEERING AXLE WEIGHTS OF TWO AXLE STRAIGHT TRUCKS UNDER DIFFERING SETS OF WEIGHT REGULATIONS

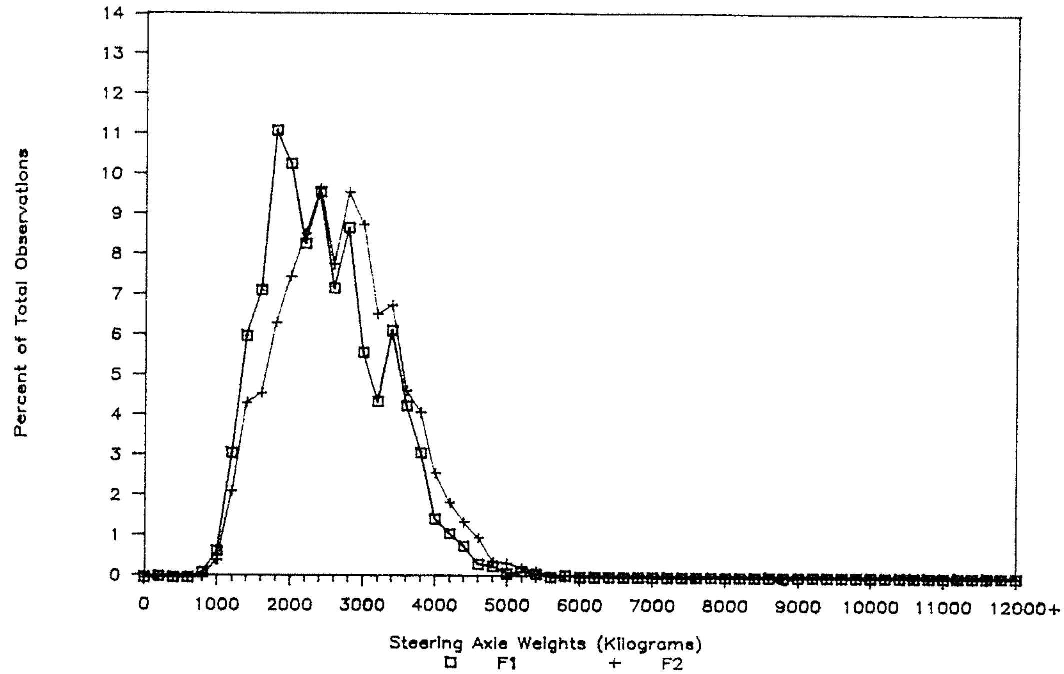
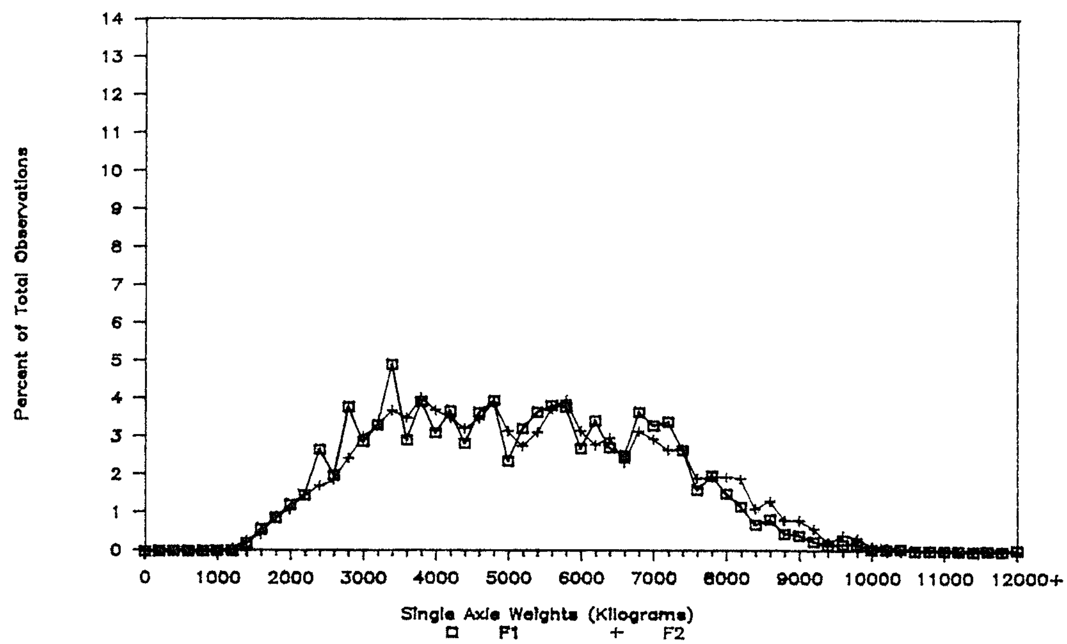


FIGURE 6.6: SINGLE AXLE WEIGHTS OF TWO AXLE STRAIGHT TRUCKS UNDER DIFFERING SETS OF WEIGHT REGULATIONS



Example 2: Transportation System Effects on Service Levels

Here, the transportation systems will be identical to the T1 and T2 systems in the previous example (Table 6.2). As with axle weights, the transportation system change resulted in a general increase in gross vehicle weights of the two axle straight trucks. The resulting gross vehicle weight distributions are illustrated in Figure 6.7.

To relate these g.v.w. curves to service levels (S1 and S2), the mean tare weights of two axle straight trucks are subtracted from the g.v.w. curves, resulting in estimates of payload distributions under both sets of regulations. The difference between T1 and T2 led to the direct increase of mean payloads from 3434 kg to 3468 kg, only a 1% change.

It would be potentially useful if, in the future, attempts were made to explore the possibility of predicting changes in truck weight characteristics under various regulatory limits by extrapolating beyond known weight distributions. For example, what would be the effect of introducing new weight limits and creating a transportation system (T3) which has not existed previously, and for which no truck weight data has been collected? Let T3 be a set of regulations as follows:

(i) Steering axle weight limit - 5500 kg
(ii) Single axle weight limit - 10000 kg
(iii) GVW limit - 15500 kg

Figure 6.8 shows the results of representing the gvw distribution curves under T1 and T2 by mathematical relationships (normal distributions) and then extrapolating the parameters of these relationships to produce a new estimated curve of gvw distribution under the conditions imposed by T3.

FIGURE 6.7: GROSS VEHICLE WEIGHTS OF TWO AXLE STRAIGHT TRUCKS UNDER DIFFERING SETS OF WEIGHT REGULATIONS

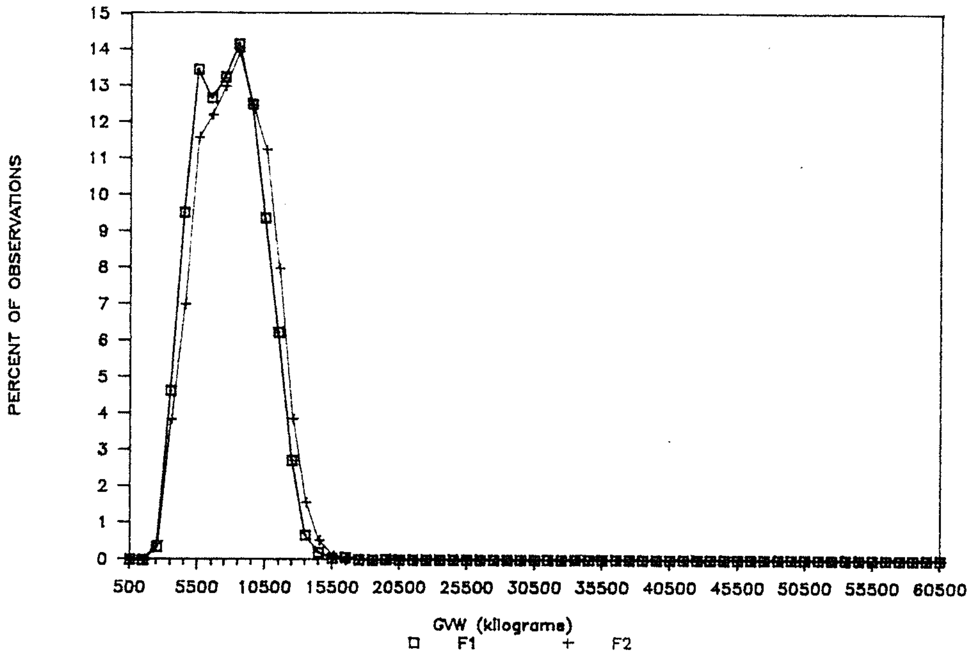
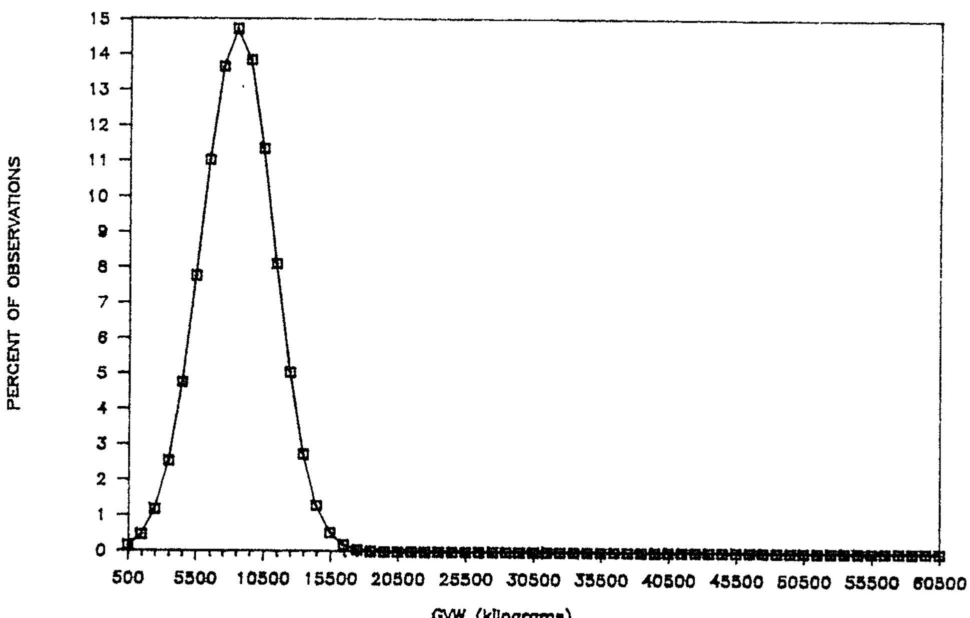


FIGURE 6.8: GROSS VEHICLE WEIGHTS OF TWO AXLE STRAIGHT TRUCKS UNDER REGULATION SET T3



The new curve shown in Figure 6.8 has a mean of 8550 kg and standard deviation of 2699 kg. If one also extrapolates the mean tare weight of these vehicles and subtracts it from the gvw distribution, the result is a payload figure of 3570 kg, an excess of 2.9% over the corresponding figure for transportation system T2.

6.3.2 Methodological

(i) In assigning values of ROAD (regulated weight limit) to survey observations, it was assumed that the response of the trucking industry to regulation changes in terms of adjusting loads to reflect the new weight limits was instantaneous. This approach was taken because no method of establishing the true transition period (and time deleting the transition observation) with any degree of accuracy has ever been developed. It is reasonable to assume that, given regulation changes which do not require changes in equipment, this transition period will be short and any effect on overall weight distributions will be small.

(ii) When a survey station was located at the intersection of a primary and a secondary roadway, it was assumed that a truck was subject to the primary weight regulations only if it both entered and exited the intersection on the primary roadway. If it entered from (or exited to) a secondary road, it was considered to be governed by the secondary weight regulations. This method necessarily brings some error into the procedure, since the provincial government will allow trucks with points of origin (or destination) off the primary highway network to use the secondary system in order to gain access to the nearest primary highway without being subject to secondary weight restrictions - but only in cases where the major portion of the trip is on the primary network. Since there was no way to determine the number of such vehicles, they were classified as secondary highway users. Similarly, there is a possibility that a number of specially permitted vehicles were counted since there is no way to identify them and separate them from the bulk of the observations.

(iii) Vehicles operating under winter premiums or spring restrictions were excluded. Since there is a record of the dates during which winter premiums have been in effect, observations falling within those periods were excluded from the database. Since there is no such record of spring restrictions, all observations recorded during the months of April and May were deleted. Although this means that some non-restricted observations were discarded, it ensures that all weight restricted vehicles are removed, leaving only those governed by the basic regulations.

6.3.3 Statistical

(a) Commodity Distributions

When modelling the behaviour of truck gross vehicle weights and axle weights, it is important to obtain representative data with as little bias as possible. Unfortunately, factors other than the regulatory regime play a significant part in determining truck weight characteristics and can distort the true picture of the trends followed by these characteristics if they are not held steady during the analysis.

One such factor is the commodity carried by a particular truck. Clearly, a survey year during which sites are located on routes which carry an abnormally high proportion of very dense commodities may show high average truck weights compared to other years during which more representative survey sites were chosen. The Manitoba Truck Weight Survey data includes instances where survey sites were located on routes which were dominated by a particular commodity (some survey sites recorded more gravel loads on 3-S2 trucks than all other commodities combined). Data from such sites is not representative of the situation existing in the province as a whole.

An accurate depiction of truck weight trends requires that any survey site which is not representative of the province-wide trucking situation should be excluded from the database. An inspection of commodity distribution charts of each survey site revealed that this was mainly a problem of getting rid of sites with high percentages of gravel. For the analysis of weight characteristics of 3-S2's and straight trucks, it was decided that no more than 20% of the total laden vehicles travelling on a particular class of road should be carrying the same commodity group. If this was not the case, the stations with the highest percentage of the excessive commodity groups were deleted until the "20% rule" was satisfied. The only exception to this rule was for commodity No. 26, which is defined as "misc. goods, unknown commodities". It was felt that an excessive number of these loads would not affect the overall weight distribution curve since this commodity classification includes a wide variety of materials with an equally wide variation in density. The figure of 20% was chosen after an examination of the database revealed that this number would result in the deletion of most of those survey stations with high percentages of a single commodity, and yet would retain the maximum portion of other stations.

The data file which resulted from the exclusion of these stations is referred to as "all" commodities to distinguish it from data made up of one or more individual commodity groups which are referred to by the name of the commodity represented.

Doubles, on the other hand, were not subjected to this rule, due to their very small numbers in comparison to 3-S2 vehicles and to the tendency for loads to be dominated by a few commodity groups on almost all highways in all years. It would be illogical to look for a widely distributed mix of commodities among these vehicles since that type of loading is not representative of the province-wide loading patterns of these vehicles. Rather, these vehicle types are used for very narrow ranges of commodities in comparison to 3-S2 vehicles. For this reason, and due to the lack of sufficient data, it was assumed that the stations surveyed yielded commodity distributions representative of the entire province, and no deletions were made from the observations of these vehicle types.

The different commodity codes of each province mean that the "20% rule" will not result in uniform treatment of survey sites from province to province. This limits the transferability of the "all" dataset from province to province.

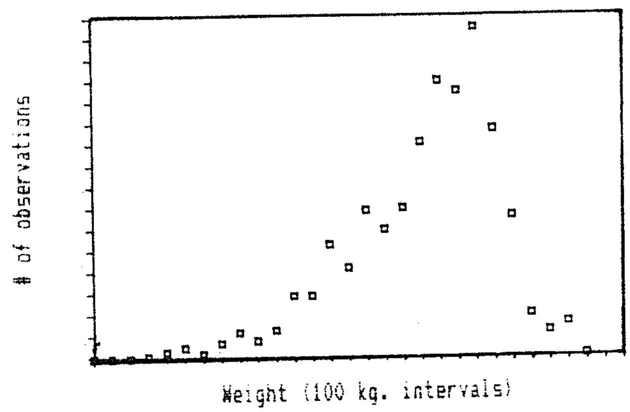
(b) <u>Curve Fitting and Statistical Measures</u>

Observations within each of the many gross vehicle weight and axle weight distributions extracted from the weight and dimension survey results were grouped into weight categories as follows:

(i) Gross vehicle weight: 1000 kg groupings
(ii) Single axle weight: 200 kg groupings
(iii) Tandem axle weight: 400 kg groupings

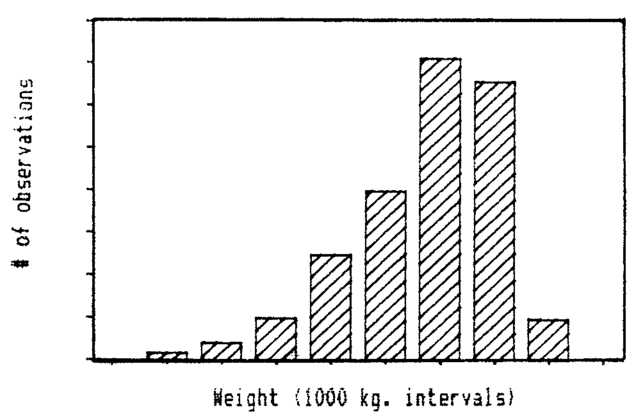
The weight of these observations were then represented by a value x at the midpoint of each of the weight categories. Each weight distribution was then modelled by a probability density function fitted to these x values.

Step 1



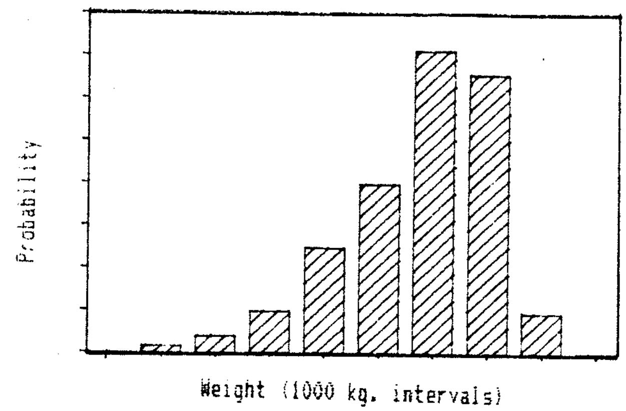
The gvw or axle group distribution data was graphed with weight intervals of 100 kg, exactly as it was stored on the data tapes.

Step 2



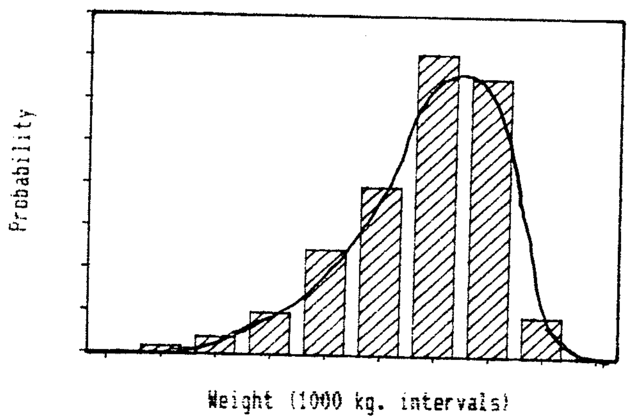
The trucks were then grouped by weight into 1000 kg intervals. Intervals for axle weights were 200 kg (single axles) or 400 kg (tandem axles). This grouping process resulted in a "smoother" curve without much of the wide variation or "noise" of the original graphs.

Step 3



The scale of the y-axis was changed to express the probability function of the vehicle weights, thus normalizing all graphs, regardless of the total number of observations. The sum of all weight interval probabilities is now equal to 1.00.

Step 4



A mathematical probability function was developed to fit as closely as possible the centrepoints of each weight interval. Thus, the weight distribution of this particular truck type can be represented by the probability density factor.

In using these functions to reproduce the numerical weight data, three steps are required. First, the appropriate variables are used in conjunction with the probability function to calculate the probability density at weight level x. Next, the result must be multiplied by the weight interval width. The final step is to multiply this result by the total number of observed vehicles to yield the number of vehicles expected to have weight characteristics within the weight interval in question.

The attempts to find equations which closely modelled these curves began with simple normal and log-normal distribution functions. The parameters of these functions were adjusted by trial and error until no more improvement could be made in the goodness of fit as measured by the chi-square test.

It was found that several of the distributions seemed to be made up of not one, but two distinct populations. A majority of the observations formed a classic log-normal distribution with the steep end approaching the maximum permissible weight level. The minority were grouped in a near normal distribution at lower weight levels. The solution was to develop a "hybrid" curve made up of the superposition of a normal onto a log-normal distribution. Hence, a total of three types of curves were used in modelling the various weight distributions.

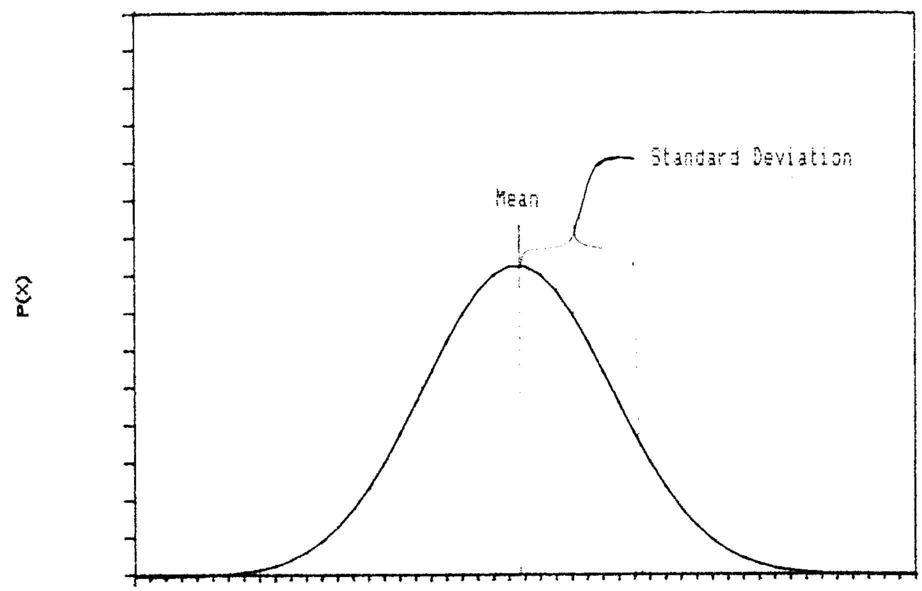
A full description of all three curve types follows:

(i) Normal Distribution:

The normal probability density function is most often written thus:

$$p(x) = \frac{1}{(2\ \pi)^{1/2} * S.D.} * e^{-(x-u)^2/(2*(S.D.)^2)}$$

where x = a truck weight characteristic (gvw or axle weight)
p(x) = probability density function for the variable x
e = 2.7183
π = 3.1416
u = population mean
S.D. = population standard deviation



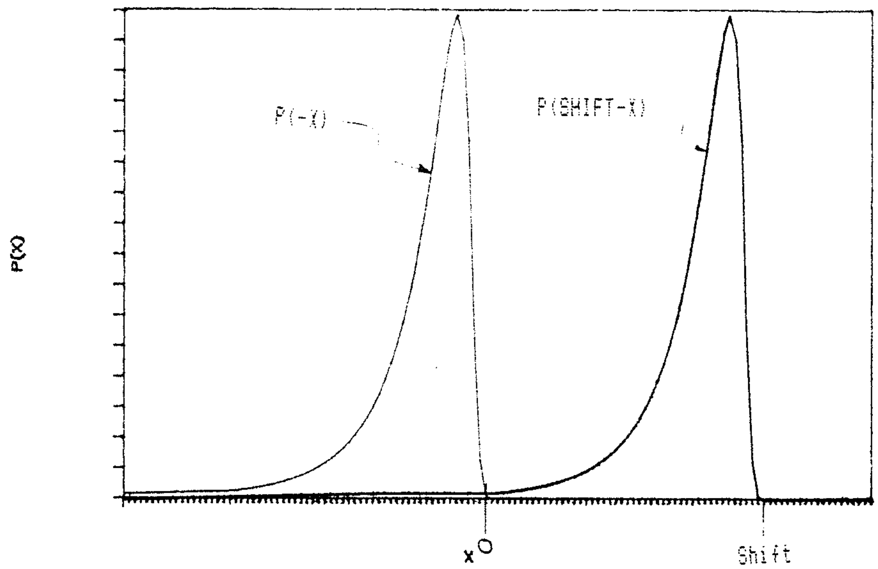
The resulting curve is bell-shaped, ranges from negative to positive infinity, peaks at a value equal to u, and has an area equal to 1.

(ii) Log-Normal Distribution:

The log normal probability density function is related to the normal distribution in that it is equivalent to the normal distribution of the logarithm of x. It is written as follows:

$$p(x) = \frac{1}{(2\pi)^{1/2} * S.D. * x} * e^{-[(\ln(x)-\ln(E))^2]/(2*(S.D.)^2)}$$

where x = a truck weight characteristic (gvw or axle weight)
p(x) = probability density function for the variable x
e = 2.7183
π = 3.1416
ln(E) = the mean of the natural logarithms of the population elements
S.D. = the standard deviation of the natural logarithms of the population elements



The resulting curve begins at zero and stretches to positive infinity. To reverse the direction of the curve and shift it to the right, the x variable has been replaced by (SHIFT - x) where SHIFT is a variable denoting the amount of rightward movement.

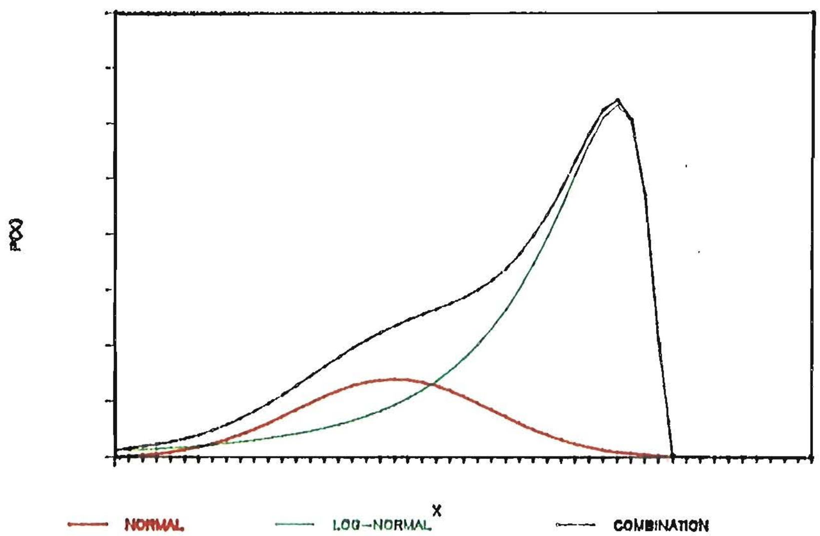
(iii) Combination Curve:

The combination curve is comprised of a log-normal curve covering an area of .75 and a normal curve covering an area of 0.25 for a total area of 1.00. The probability density function is written as follows:

$$p(x) = \frac{.75 * e^{-[(\ln(SHIFT-x)-\ln(E))^2]/(2*(SD2)^2}}{(2\pi)^{1/2} * SD2 * (SHIFT-x)}$$

$$+ \frac{.25}{(2\pi)^{1/2} * SD1} * e^{-(x-u)^2/(2*(SD1)^2}$$

where x = a truck weight characteristic (gvw or axle weight)
p(x) = probability density function for the variable x
e = 2.7183
π = 3.1416
ln(E) = the mean of the natural logarithms of those population elements represented by the log-normal portion of the curve
u = the mean of the population elements represented by the normal portion of the curve
SD1 = the standard deviation of the population represented by the normal portion of the curve
SD2 = the standard deviation of the natural logarithms of the population represented by the normal portion of the curve
SHIFT = the x-axis position at which the reverse log-normal curve first becomes equal to zero



The resulting curve looks much like a log-normal curve with the exception that a smaller curve is superimposed on the tail of the log-normal distribution. The position of the smaller curve is determined by the value of u.

In fitting the functions to the survey data, the measure by which goodness of fit was judged is called the chi-square test. This is a relatively simple test involving the chi-square test statistic defined as follows:

$$x^2 = \sum_{i=1}^{k} \frac{[ni - E(ni)]^2}{E(ni)}$$

where x^2 = the chi-square test statistic
k = the number of intervals into which the x axis is divided over the length of the distribution
ni = the number of observations found in interval i
E(ni) = the expected number of observations in interval i based on the probability density function

Of course, the lower the value of the test statistic, the better the overall fit of the curve to the truck weight data. A useful "rule-of-thumb" (Mendenhall and Reinmuth, 1982) is that no value of E(ni) should fall below 5 in order that an adequate approximation of the chi-square distribution is achieved. This means that at the upper and lower ends of each truck weight distribution, where the values of E(ni) are liable to fall below 5, the values of both ni and E(ni) are summed to infinity (or to -infinity in the case of the lower end of the distribution) so that the outermost intervals become infinite in length.

(c) **Survey Precision**

Prior to 1984, the number of sites incorporated into the Manitoba Department of Highways and Transportation Truck Weights and Dimension Survey was kept more or less constant at thirteen per year. The reasons for the original selection of thirteen sites are unclear, but budgetary constraints resulted in the reduction of survey sites to only three per year beginning in 1984.

The change in survey site numbers has affected the precision of statistics derived from the survey. For instance, the following equation can supply estimates of the precision of the mean tare weight statistic derived from the survey results in this case for 3-S2's surveyed in 1977 and 1985.

$$n = \frac{(Zd/2)^2 * S.D.^2}{D^2}$$

where n	=	number of observations
Zd/2	=	the number of standard deviations within which there is a probability equal to the desired confidence level that a normal random variable will fall.
S.D.	=	coefficient of variation of E.A.L./vehicle
D	=	precision (FHWA 1982)

The values of these variables for the years 1977 and 1984 are:

	1977	1985
n	837	80
Zd/2	1.96	1.96 (Zd/2 for a 95% confidence level)
S.D.	2565	2168
D	174	475

These results mean that there is a 95% chance that the estimate of the mean tare weight for 3-S2's in 1977 (13556 kg) is within plus or minus 174 kg of the true value. Similarly, the estimate of the mean tare weight for 3-S2's in 1985 (14777 kg) is within plus or minus 475 kg of the true value.

6.4 TARE WEIGHT DISTRIBUTIONS AND PAYLOADS

6.4.1 By Vehicle Type

This section presents an analysis of tare weights measured in the Manitoba Department of Highways and Transportation Weight and Dimension surveys. A number of tare weight charts and graphs have been developed which are based on measured weights of empty vehicles collected throughout the years and at all survey locations. Figure 6.9 (Tare weights of tractor semitrailers) shows tare weights of those vehicles on a year to year basis from 1974 to 1986. This figure was developed from all observations of empty 3-S2 vehicles without regard for the regulatory limits under which they operated. Figures 6.10 to 6.12 show these same observations sorted by gvw limit.

Figure 6.9 clearly shows a trend of rising tare weights beginning at about 1980. Prior to this time, their levels had remained fairly constant. Since figures 6.10 to 6.12 show that tare weights have not increased significantly within each of the gvw limit categories, it becomes apparent that the general tare weight increase may have been brought about by tare weight differences between weight limit categories. In other words, it is known that the relative numbers of observations within the 37500 kg gvw limit category have increased over the years relative to those within the other categories. If there is a significant difference in tare weights between categories, this could explain the expected pattern of tractor-semitrailer tare weight increases dependent on regulatory limits, which suggests that

FIGURE 6.9: TARE WEIGHTS OF TRACTOR SEMITRAILERS

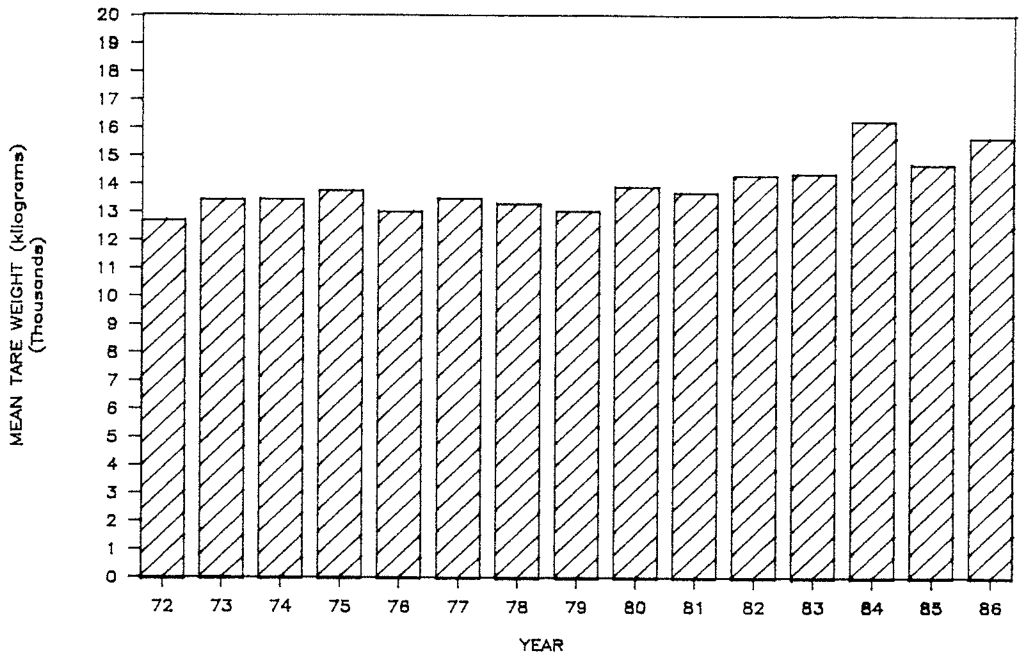


FIGURE 6.10: TARE WEIGHTS OF TRACTOR SEMITRAILERS
(33600 KG. WEIGHT LIMIT)

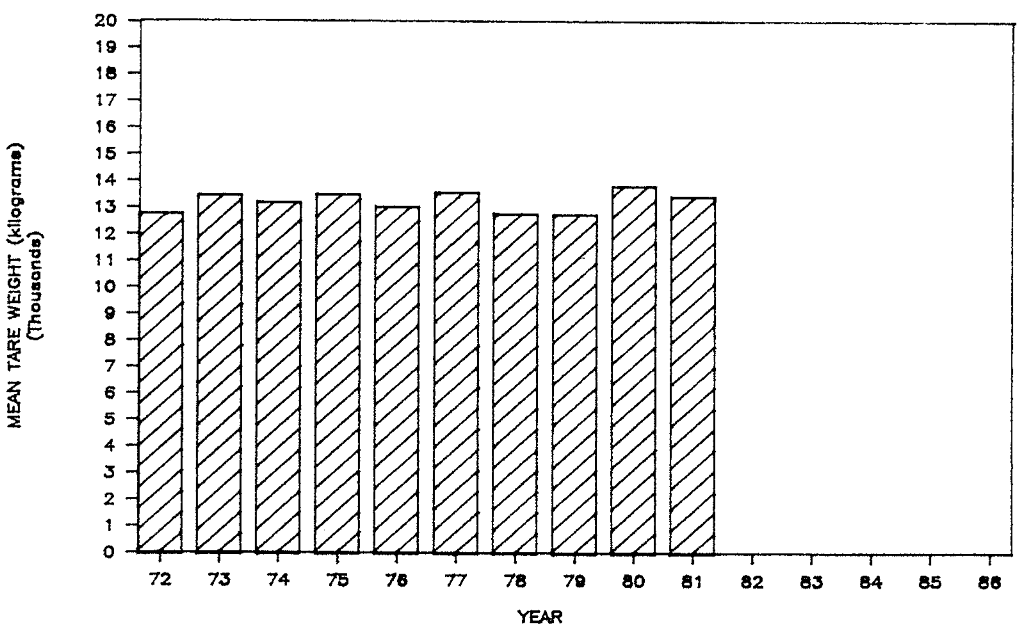


FIGURE 6.11: TARE WEIGHTS OF TRACTOR SEMITRIALERS
(36500 KG. WEIGHT LIMIT)

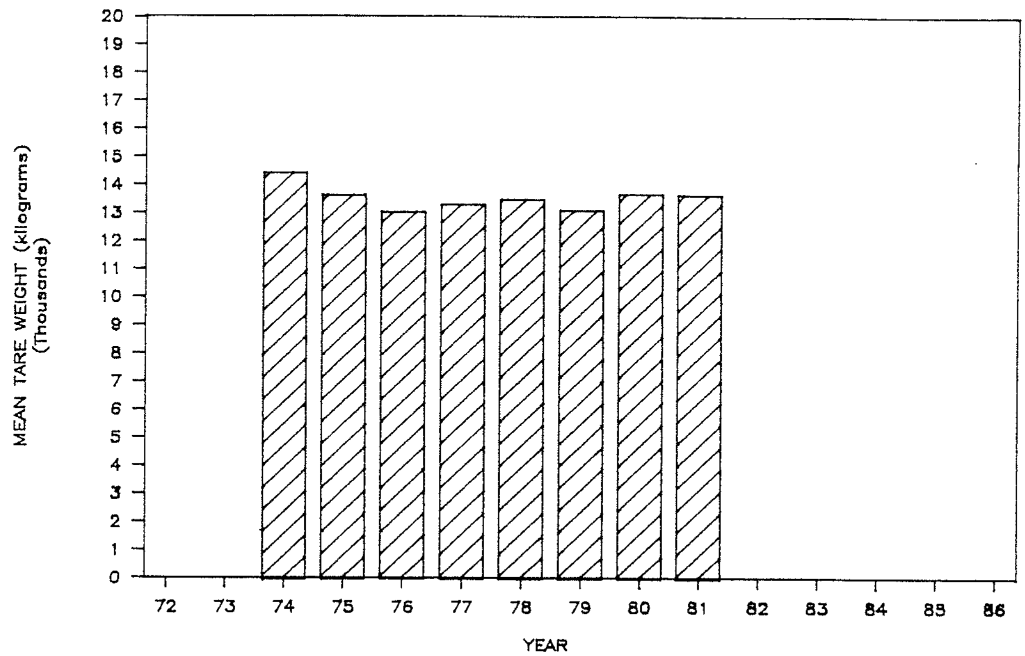
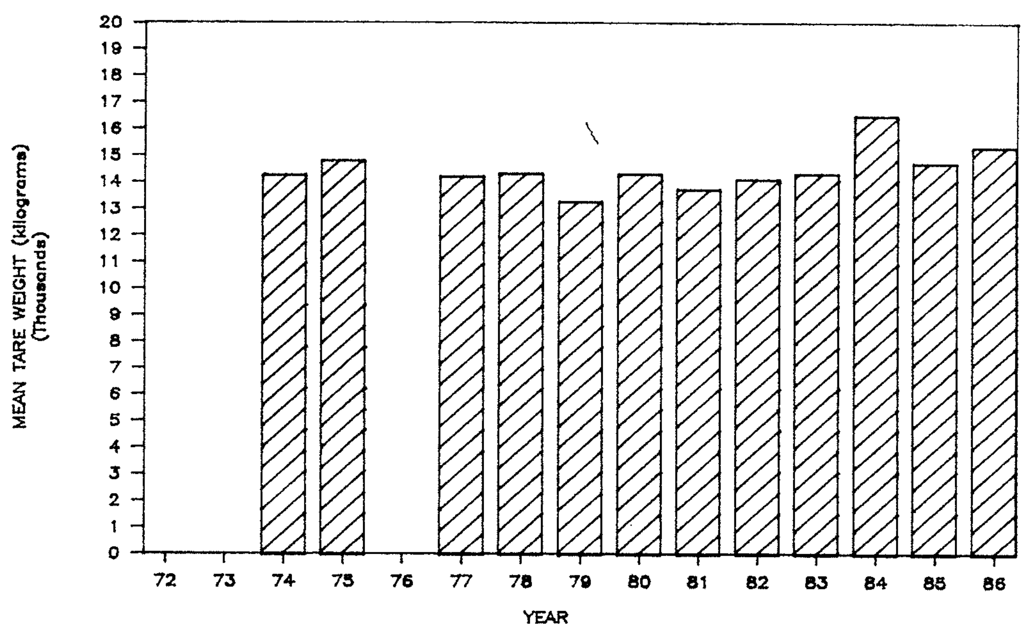


FIGURE 6.12: TARE WEIGHTS OF TRACTOR SEMITRIALERS
(37500 KG. WEIGHT LIMIT)



the general increase in tare weights of 3-S2's following 1980 is a reflection of increasing regulatory limits during this period.

Table 6.3. 3-S2 tractor semitrailer tare weights

Regulatory Limit (kg)	Mean Tare	Std. Dev.	No. of Obs.
20,000	13,119	2,165	248
33,600	13,282	2,180	3,829
34,500	14,868	2,455	226
36,500	13,461	2,476	2,525
37,500	14,232	2,518	2,568

Straight Trucks: Figures 6.13 to 6.16 show similar patterns in the tare weights of two- and three-axle straight trucks. There is some evidence of tare weight increases independent of weight regulations (particularly for three axle trucks). In conjunction with these increases, there are significant differences in tare weights due to differing regulations (see Tables 6.4 and 6.5).

Table 6.4. Two-axle straight truck tare weights

Regulatory Limit (kg)	Mean Tare	Std. Dev.	No. of Obs.
13,700	4,302	1,192	3,858
14,600	4,641	1,302	3,196

Table 6.5. Three-axle straight truck tare weights

Regulatory Limit (kg)	Mean Tare	Std. Dev.	No. of Obs.
20,000	7,672	1,723	2,685
21,500	8,219	1,993	1,852

FIGURE 6.13: TARE WEIGHTS OF TWO AXLE STRAIGHT TRUCKS
(13700 KG. WEIGHT LIMIT)

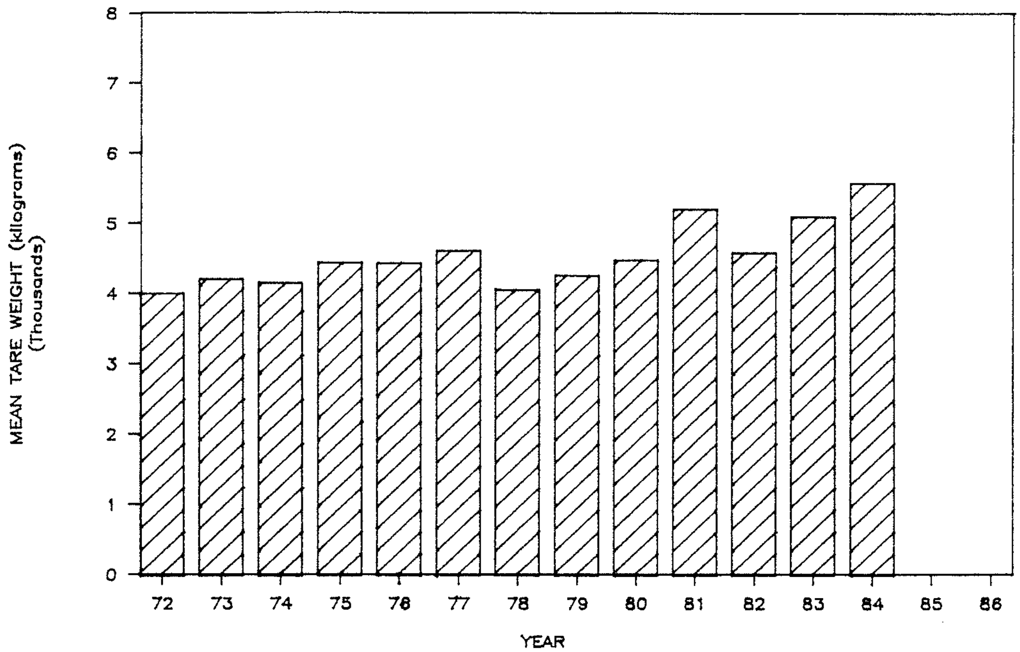


FIGURE 6.14: TARE WEIGHTS OF TWO AXLE STRAIGHT TRUCKS
(14600 KG. WEIGHT LIMIT)

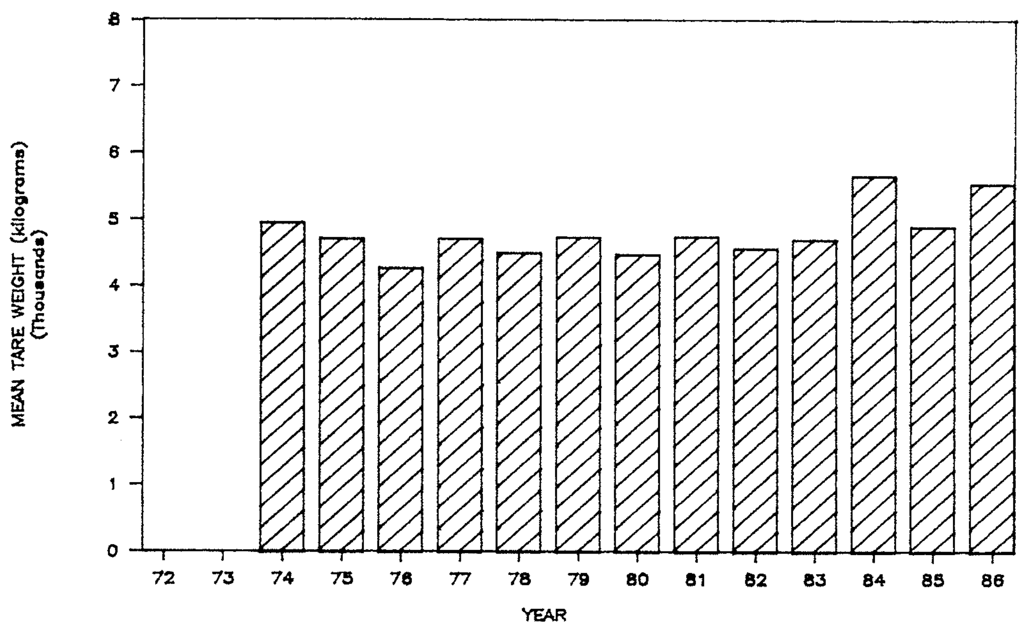


FIGURE 6.15: TARE WEIGHTS OF THREE AXLE STRAIGHT TRUCKS (20000 KG. WEIGHT LIMIT)

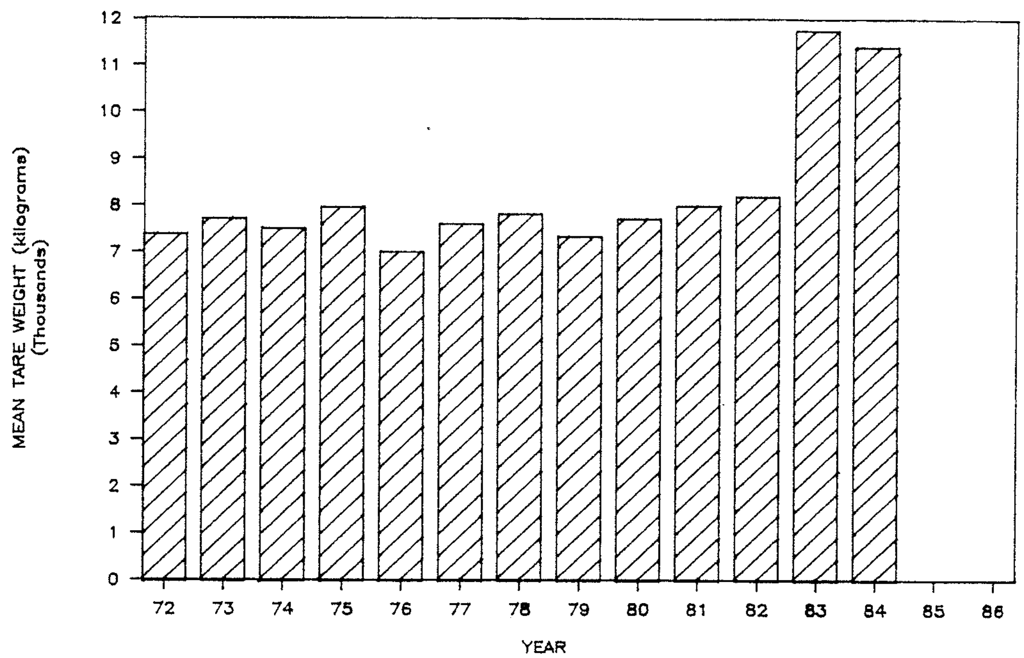
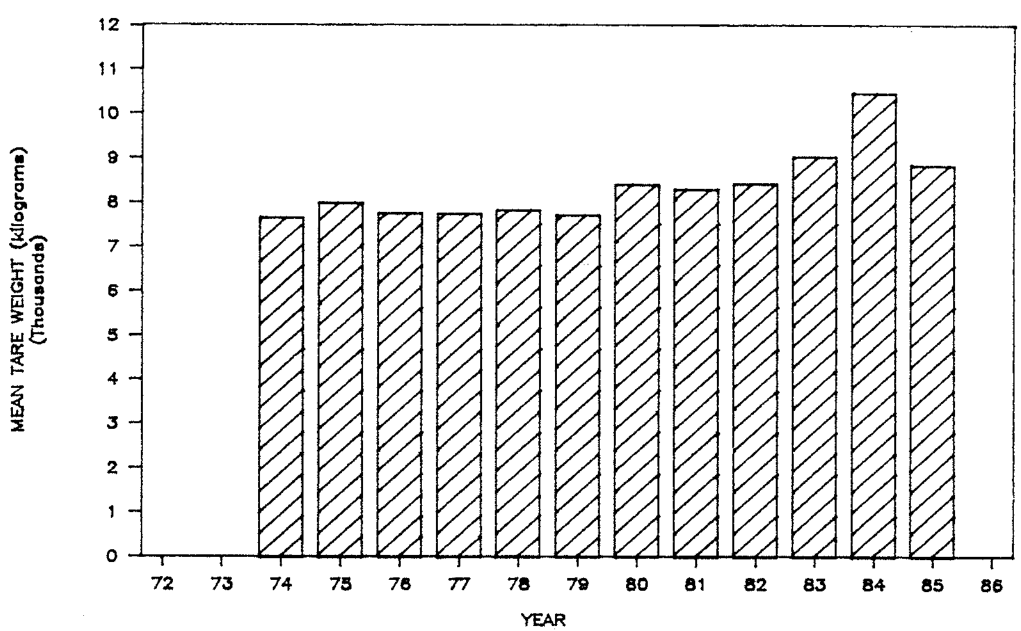


FIGURE 6.16: TARE WEIGHTS OF THREE AXLE STRAIGHT TRUCKS (21500 KG. WEIGHT LIMIT)



Doubles: There is insufficient data available to determine whether the same trend applies to A- and B-trains.

In summary, tare weights of straight trucks and 3-S2's appear to have been increasing since approximately 1980, and are influenced by at least two different variables. Tare weights of both straight trucks and 3-S2's tend to move upwards as weight limits are relaxed. In the case of straight trucks, other variables of an unknown nature seem to be causing increased tare weights, since approximately 1980, independent of regulation changes.

6.4.2 By Number of Axles

In this section, a simple "rule of thumb" for estimating the tare weights of a certain class of vehicle based on the number of its axles has been developed. Vehicle tare weights, independent of highway type, were sorted by number of axles. The mean tare weights of each category were then graphed and a regression line fitted to them (see Figure 6.17). The resulting relationship is as follows:

$$\text{Tare Weight (kilograms)} = -3{,}650 + 4{,}350X - 160X^2, \quad X \geq 2$$

where

X = number of axles

$R^2 = .994$

6.4.3 Payloads

This equation can be used in approximating the payload of various truck types by subtracting the regression line from the maximum g.v.w. values corresponding to the particular truck configuration. This has been done with the following configurations: 2-axle straight truck, 3-axle straight truck, 4-axle tractor semitrailer, 5-axle tractor semitrailer, 7 axle B-trains, and 6, 7, and 8-axle A-trains. The resulting chart of maximum payloads under weight regulations existing in Manitoba prior to the permitting of RTAC vehicles (Figure 6.18) clearly shows the advantages of the larger vehicle combinations to truck operators.

6.5 TWO-AXLE STRAIGHT TRUCKS

6.5.1 G.V.W. Distributions

The g.v.w. distribution graphs of straight trucks (Figures 6.19 and 6.20) show the weight distributions of these trucks in the "ALL" commodity category under gvw limits of 13700 kg and 14600 kg, respectively. Both curves have near bell-like shapes and little skew in either direction. There is little difference between the g.v.w. curves with the exception of a 450 kg upward shift in the curve of straight trucks operating under the higher weight limit. In both instances, the majority of vehicles were operated at weights well below the legislated maximums. Mean weights were found to be 7,736 kg and 8,109 kg for vehicles

FIGURE 6.17: VEHICLE TARE WEIGHTS AS A FUNCTION OF NUMBER OF AXLES

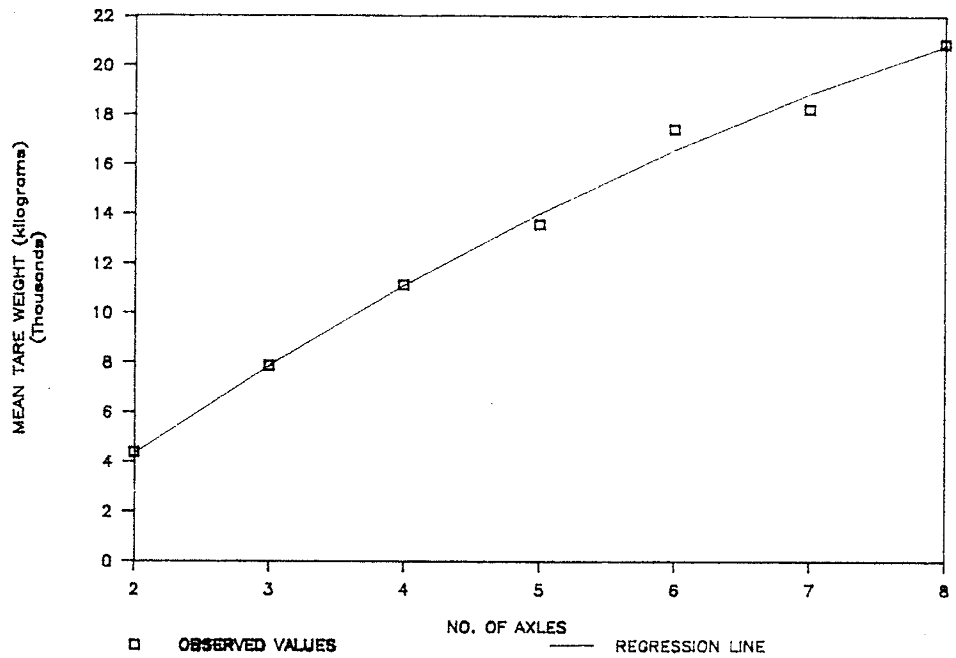
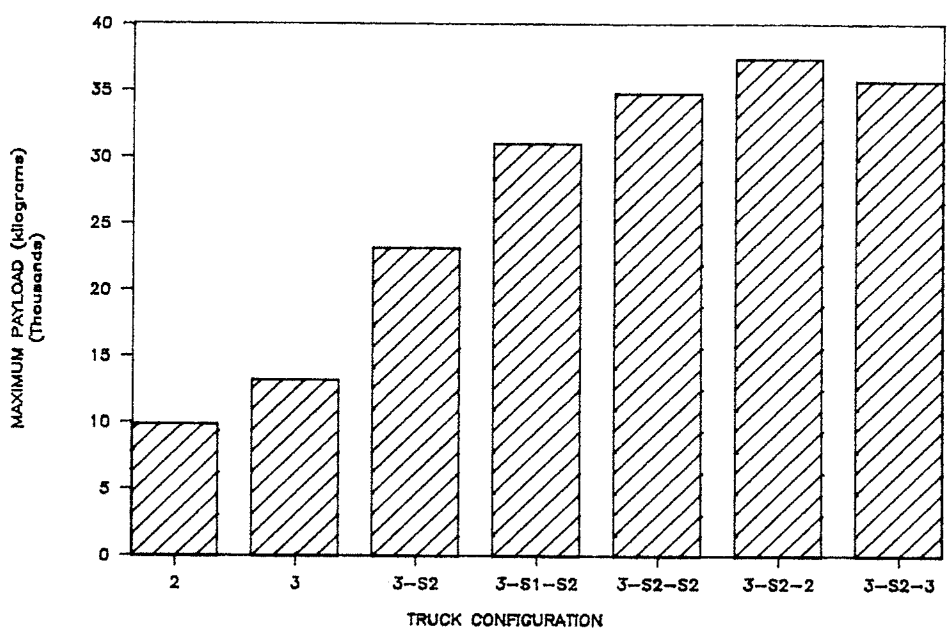


FIGURE 6.18: MAXIMUM PAYLOADS OF VARIOUS VEHICLE COMBINATIONS ON PRIMARY HIGHWAYS IN MANITOBA



legally limited to 13,700 kg and 14,600 kg, respectively. In both cases, overweight trucks accounted for under 5% of all observations.

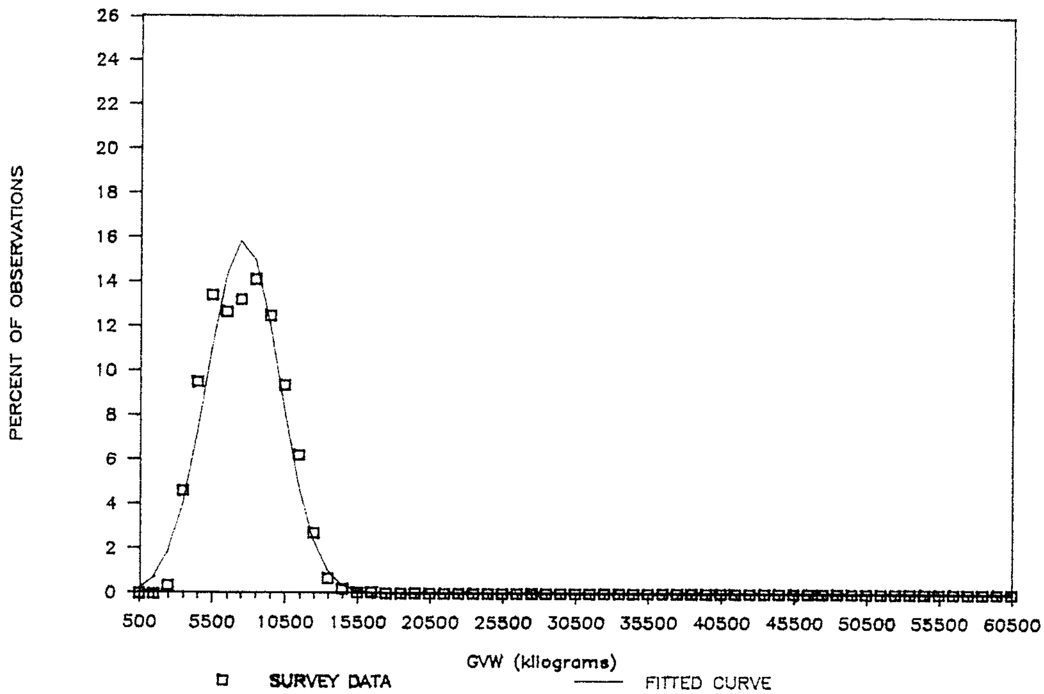
Although a combination curve composed of log-normal and normal distributions produced the best fit in terms of minimizing chi-square values, it was decided that normal curves would be used to represent these distributions, since there was no evidence of two distinct populations within the set of weighed vehicles. The homogeneous nature of the truck population dictated the use of a single (non-combined) distribution curve.

The parameters of the fitted normally distributed curve are as follows:

Parameter	13,700 kg Limit	14,600 kg Limit	Parameter Relationship
Mean (u)	7,650 kg	8,100 kg	u = .500 limit + 800 kg
Std. Deviation (S.D.)	2,500 kg	2,600 kg	S.D. = .111 limit + 978 kg

The mean and standard deviation shown here represent the parameters of the fitted curve and hence may not correspond precisely to the mean and standard deviation of the actual data values. Both parameters, the mean and standard deviation, increased as the legislated weight limit increased. The parameter relationship equations are of a linear form, connecting two points (parameter values at different weight levels0. They can be used in predicting parameter values at weight limit levels other than the two on which they are based. The increase of the mean occurred at only one-half the rate of the limit increase. This indicates that gross vehicle weights of two-axle straight trucks are not wholly dependent on allowable g.v.w. limits and that any weight limit increase beyond 14,600 kg

FIGURE 6.19: GROSS VEHICLE WEIGHT DISTRIBUTION
VEHICLE TYPE: 2 AXLE STRAIGHT TRUCKS
GOVERNING LIMIT: 13700 kg. G.V.W. LIMIT
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 7817



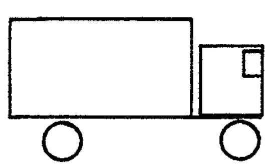
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 2500 u = 7650 PI = 3.14159

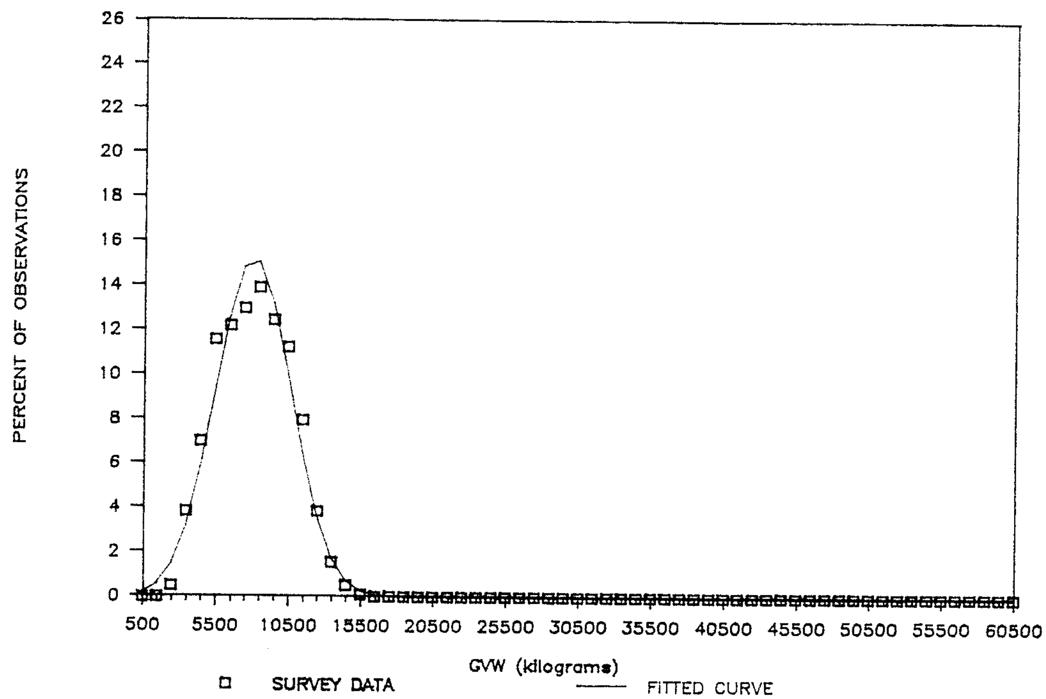
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits: 8200 + 5500 = 13700 kg.
G.V.W. Limit: 20000 TO 47600 = 20000+ kg.

Governing Limit: 13700 kg.

FIGURE 6.20: GROSS VEHICLE WEIGHT DISTRIBUTION
VEHICLE TYPE: 2 AXLE STRAIGHT TRUCKS
GOVERNING LIMIT: 14600 kg. G.V.W. LIMIT
COMMODITY GROUP: `ALL' NUMBER OF OBS: 5325



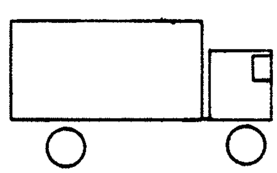
FITTED CURVE EQUATION:

$$p(x) = K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 2600 u = 8100 PI = 3.14159

GOVERNING REGULATORY LIMIT:



Axle Wt. Limits: 9100 + 5500 = 14600 kg.
G.V.W. Limit: 33600 TO 56500 = 33600+ kg.

Governing Limit: 14600 kg.

would probably result in an upward shift in the gvw curve of these vehicle much less than the limit increase.

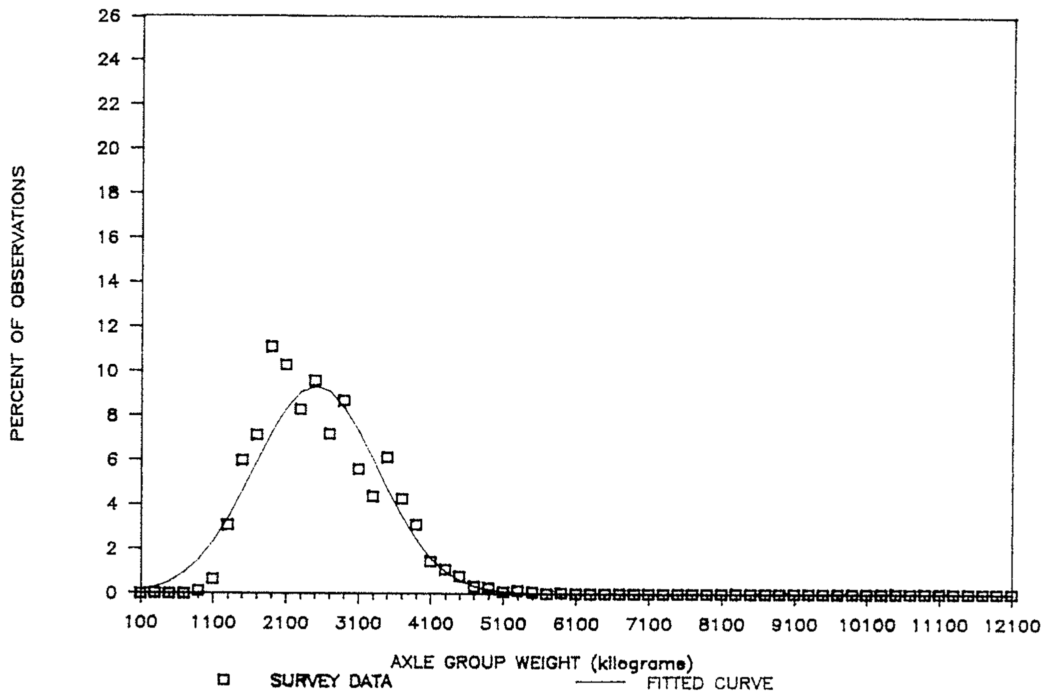
6.5.2 Axle Weight Distributions

Symmetrical bell-like shapes characterize the front steering axle weight distributions of these trucks (Figures 6.21 and 6.22). The curves are similar at both legislated weight limits, with the exception of an upward shift of approximately 300 kg in the steering axle weight distribution of trucks operating under the higher total axle weight. Under both limits the majority of trucks operated with steering axle weights well below the legislated maximum of 5,500 kg. Almost no trucks were found with overweight front axles. Mean steering axle weights were 2,557 kg and 2,771 kg for vehicles governed by total axle weight limits of 13,700 kg and 14,600 kg, respectively.

Like the steering axle weights of all observed truck configurations, the front axle weights of two axle straight trucks were approximated by normally distributed curves. The parameters of these curves are:

Parameter	13,700 kg Limit	14,600 kg Limit	Parameter Relationship
Mean (u)	2,500 kg	2,800 kg	u = .333 limit - 2,067 kg
Std. Deviation (S.D.)	850 kg	850 kg	S.D. = 850 kg

FIGURE 6.21: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 2 AXLE STRAIGHT TRUCKS
AXLE GROUP TYPE: STEERING
GOVERNING LIMIT: 13700 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 7817



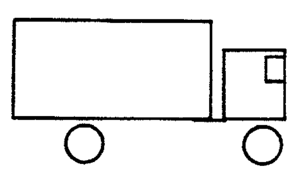
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 850 u = 2500 PI = 3.14159

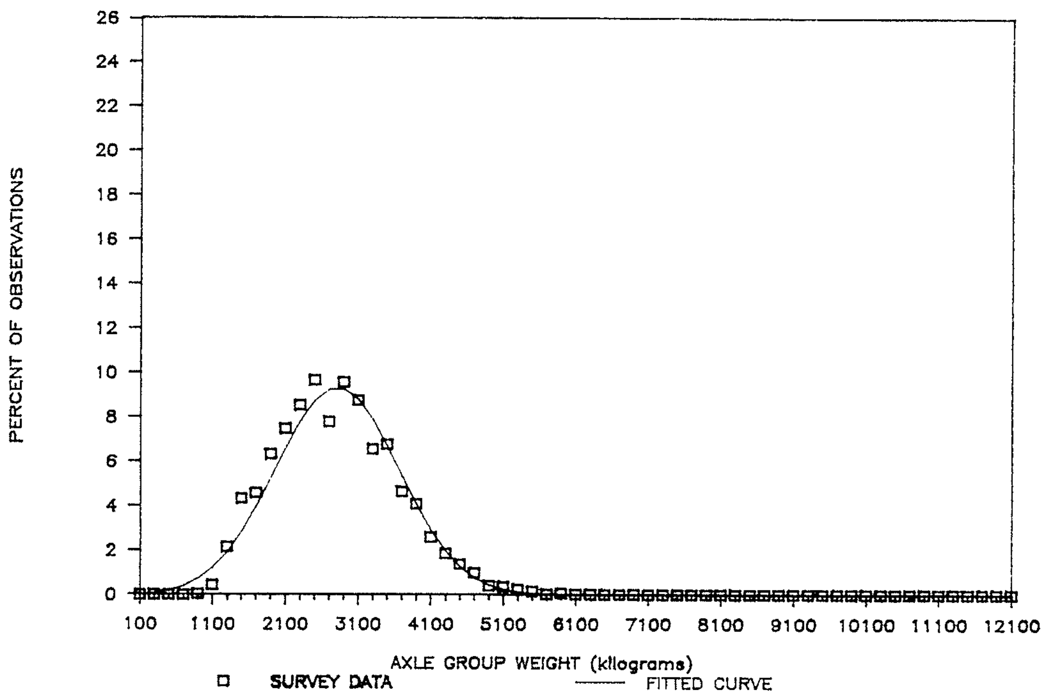
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits: 8200 + 5500 = 13700 kg.
G.V.W. Limit: 20000 TO 47600 = 20000+ kg.

Governing Limit: 13700 kg. limit to total axle weights.

FIGURE 6.22: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 2 AXLE STRAIGHT TRUCKS
AXLE GROUP TYPE: STEERING
GOVERNING LIMIT: 14600 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 5325



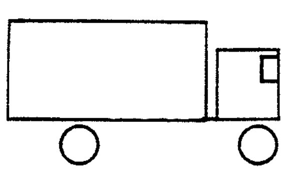
FITTED CURVE EQUATION:

$$p(x) = K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 850 u = 2800 PI = 3.14159

GOVERNING REGULATORY LIMIT:



Axle Wt. Limits: 9100 + 5500 = 14600 kg.
G.V.W. Limit: 33600 TO 56500 = 33600+ kg.

Governing Limit: 14600 kg. limit to total axle weights.

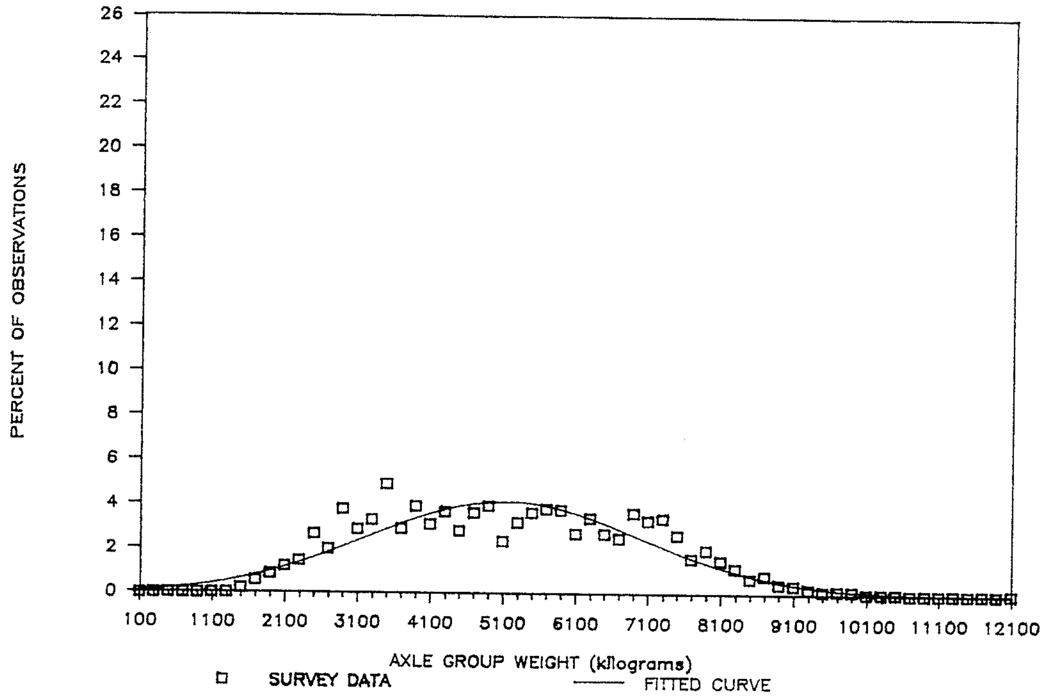
The standard deviation of these normal distributions remained constant despite the 900 kg increase in allowable axle weights while the mean rose by only a third of the legal limit increase.

The wide bell-shaped curves formed by the single rear axle weight distributions (Figures 6.23 and 6.24) have similar shapes with the exception of a slight upward shift of about 350 kg in the rear axle weights of trucks limited to 14,600 kg as opposed to those limited to 13,700 kg. Mean weights of these single axles were 5,178 kg and 5,338 kg, well below the applicable axle weight limits. Overweight axles accounted for under 5% of all observations in both cases.

Parameter	13,700 kg Limit	14,600 kg Limit	Parameter Relationship
Mean (u)	5,100 kg	5,450 kg	u = .389 limit - 228 kg
Std. Deviation (S.D.)	2,000 kg	2,100 kg	S.D. = .111 limit + 378 kg

The very wide distributions and low means of these axle weights suggest a variety of commodities, mostly of a cube-out nature, as well as a substantial number of partially loaded trucks among the observations.

FIGURE 6.23: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 2 AXLE STRAIGHT TRUCKS
AXLE GROUP TYPE: SINGLE
GOVERNING LIMIT: 13700 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: `ALL' NUMBER OF OBS: 7817



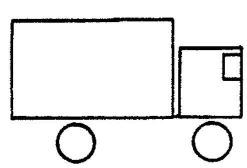
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 1900 u = 5100 PI = 3.14159

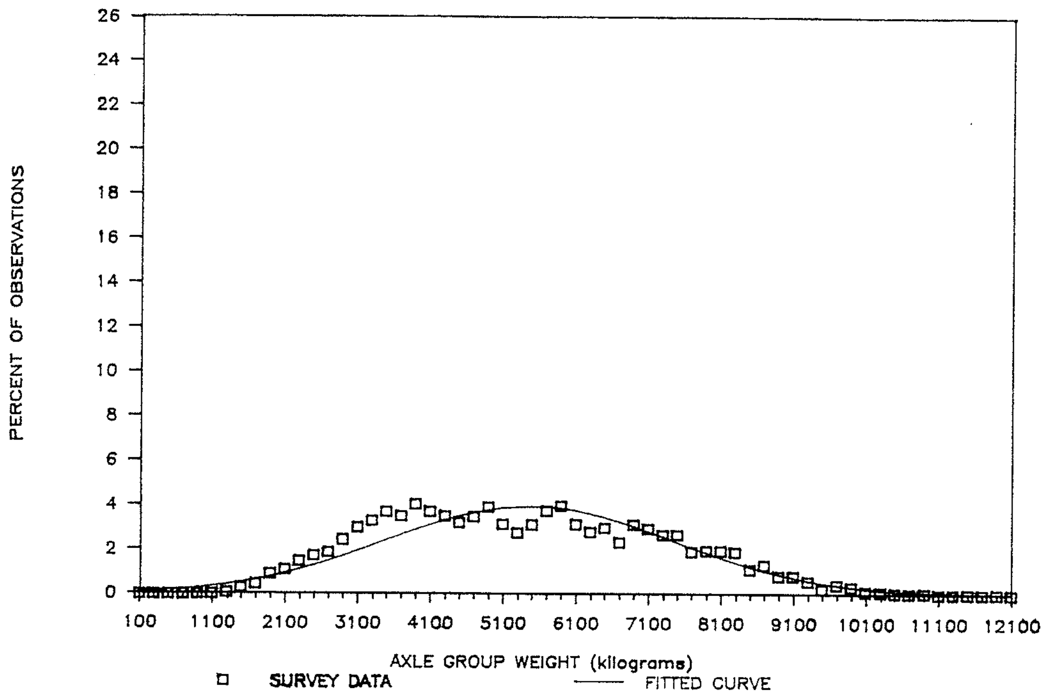
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits: 8200 + 5500 = 13700 kg.
G.V.W. Limit: 20000 TO 47600 = 20000+ kg.

Governing Limit: 13700 kg. limit to total axle weights.

```
FIGURE 6.24:        AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE:       2 AXLE STRAIGHT TRUCKS
AXLE GROUP TYPE:    SINGLE
GOVERNING LIMIT:    14600 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP:    `ALL'       NUMBER OF OBS: 5325
```



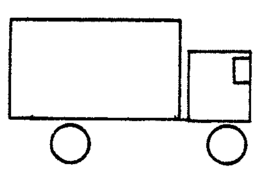
<u>FITTED CURVE EQUATION</u>:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 2000   u = 5450   PI = 3.14159

<u>GOVERNING REGULATORY LIMIT</u>:



Axle Wt. Limits: 9100 + 5500 = 14600 kg.
G.V.W. Limit: 33600 TO 56500 = 33600+ kg.

Governing Limit: 14600 kg. limit to total axle weights.

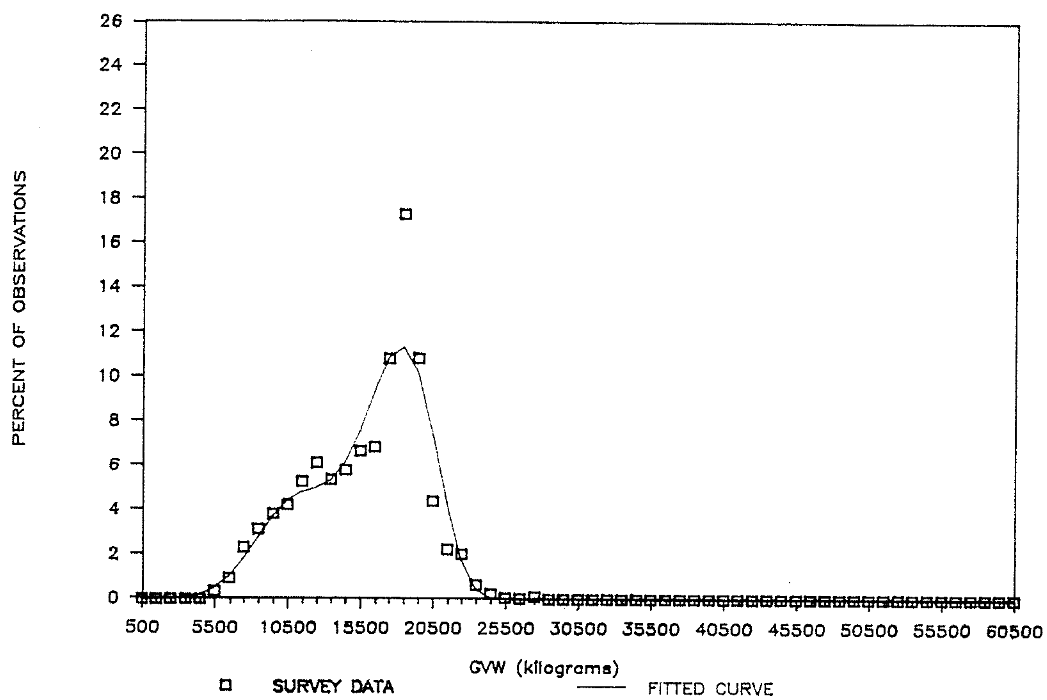
6.6 THREE AXLE STRAIGHT TRUCKS

6.6.1 G.V.W. Distributions

The g.v.w. distribution curves of three-axle straight trucks (Figure 6.25 and 6.26) show distributions which are skewed toward the heavy end of the scale and approach the legislated maximum g.v.w. limits (overweight trucks account for between 5 and 10% of all observations). Overall, the mean g.v.w. of three-axle straight trucks (15,782 kg and 16,638 kg for trucks legally limited to 20,000 kg and 21,500 kg) are much closer to the legal limits than are those of two-axle trucks. In addition, the curves are fundamentally different from those of two-axle straight trucks in that they show evidence that two distinct populations of vehicles are present. The majority, grouped at the heavy end of the scale, are loaded nearly to the legal limits. A smaller population of vehicles (partially loaded or loaded with low density commodities) is grouped around a point well below the weight limits.

The distributions were approximated by a combination of a log-normal curve comprising 75% of the truck population and a normal curve making up the remaining 25%. The fitted curve parameters are as follows:

FIGURE 6.25: GROSS VEHICLE WEIGHT DISTRIBUTION
VEHICLE TYPE: 3 AXLE STRAIGHT TRUCKS
GOVERNING LIMIT: 20000 kg. G.V.W. LIMIT
COMMODITY GROUP: `ALL' NUMBER OF OBS: 3262



FITTED CURVE EQUATION:

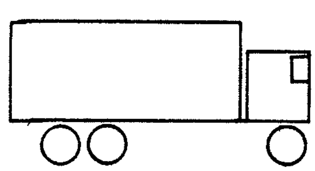
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

where $K = 1/(2PI)^{1/2}$, $w = [(\ln(SHIFT - x) - \ln(E))/SD2]^{2}$,

and $a = (x - u)^{2} / (2 * (SD1)^{2})$

SD1 = 2600 SD2 = .201 SHIFT = 31200
u = 10800 ln(E) = 9.5 PI = 3.14159

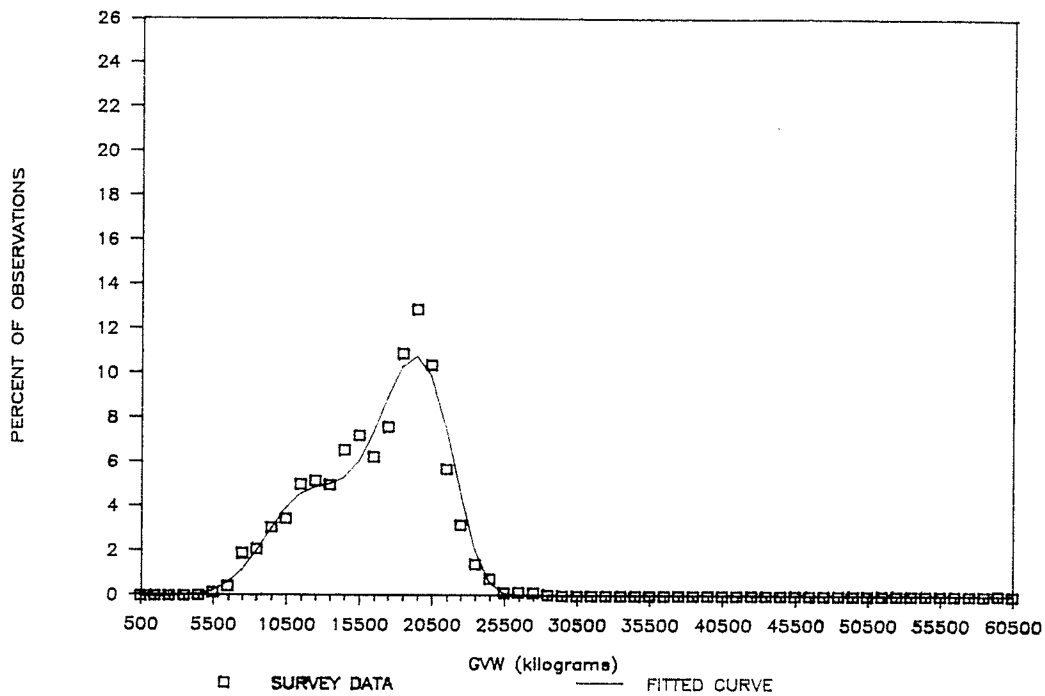
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits: 14500 + 5500 = 20000 kg.
G.V.W. Limit: 20000 TO 47600 = 20000+ kg.

Governing Limit: 20000 kg.

FIGURE 6.26: GROSS VEHICLE WEIGHT DISTRIBUTION
VEHICLE TYPE: 3 AXLE STRAIGHT TRUCKS
GOVERNING LIMIT: 21500 kg. G.V.W. LIMIT
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 2767



FITTED CURVE EQUATION:

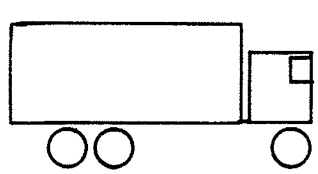
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

where $K = 1/(2PI)^{1/2}$, $w = [(\ln(SHIFT - x) - \ln(E))/SD2]^2$,

and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 2600 SD2 = .213 SHIFT = 32200
u = 11600 ln(E) = 9.5 PI = 3.14159

GOVERNING REGULATORY LIMIT:



Axle Wt. Limits: 16000 + 5500 = 21500 kg.
G.V.W. Limit: 33600 TO 56500 = 33600+ kg.

Governing Limit: 21500 kg.

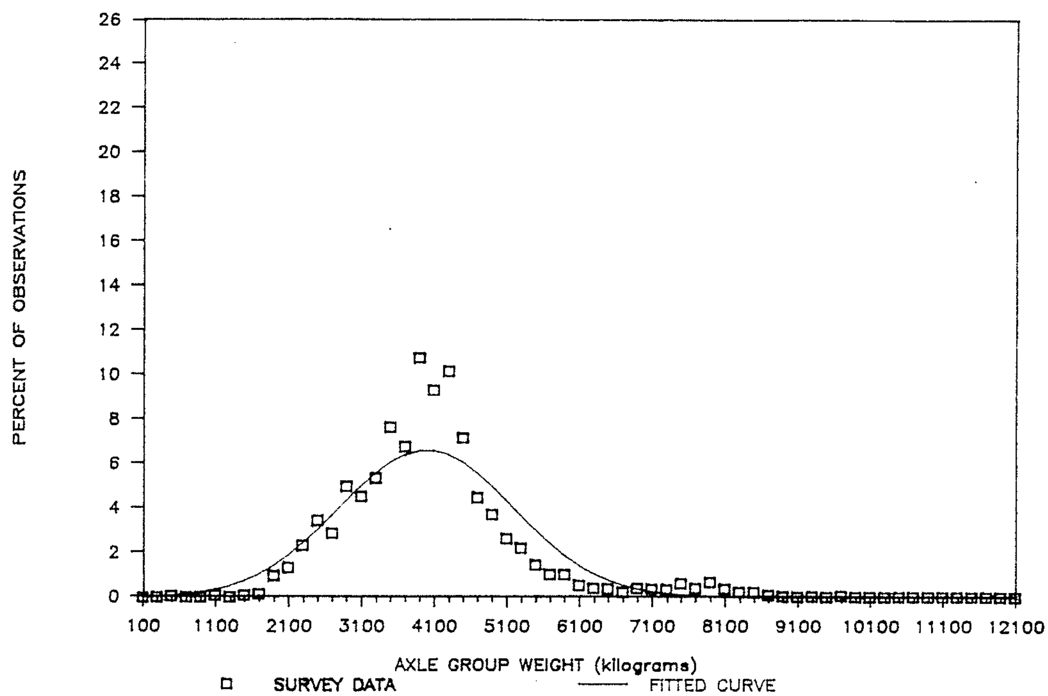
Parameter	20,000 kg Limit	21,500 kg Limit	Parameter Relationship
Ln (E)	9.5	9.5	Ln(E) = 9.5
Std. Deviation (log-normal)	.201	.213	SD2 = .00000800 Limit + .0410
SHIFT	31,200 kg	32,200 kg	SHIFT = .667 limit + 17,870 kg
MEAN (u) (normal curve)	10,800 kg	11,600 kg	u = .533 limit + 140 kg
Std. Deviation (normal curve)	2,600 kg	2,600 kg	SD1 = 2,600 kg

Of these variables, only Ln(E) and the standard deviation of the normally distributed portion of the combination curve remained constant during the increase in g.v.w. limit. SHIFT and MEAN, representing the position along the x-axis of the log-normal and normal curves, respectively, both increased along with the increase in the limit but in amounts between one-half and two-thirds of the limit increase. The standard deviation of the log-normal curve also increased under higher legal g.v.w. limits.

6.6.2 Axle Weight Distributions

The steering axle weight distribution curves of three axle straight trucks (Figures 6.27 and 6.28) are similar to those of two axle straight trucks in that they have nearly symmetrical, bell-like shapes. Overall, the mean weights of these axles (4,039 kg and 4,476 kg for trucks limited to gross vehicle weights of 20,000 kg and 21,500 kg, respectively) are much higher than front axle weights of two axle trucks. This fact, along with the presence of a small number of observations well above the legal axle weight of 5,500 kg indicates the tendency

FIGURE 6.27: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 3 AXLE STRAIGHT TRUCKS
AXLE GROUP TYPE: STEERING
GOVERNING LIMIT: 20000 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 3262



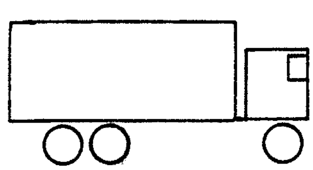
FITTED CURVE EQUATION:

$$p(x) = K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 1200 u = 4000 PI = 3.14159

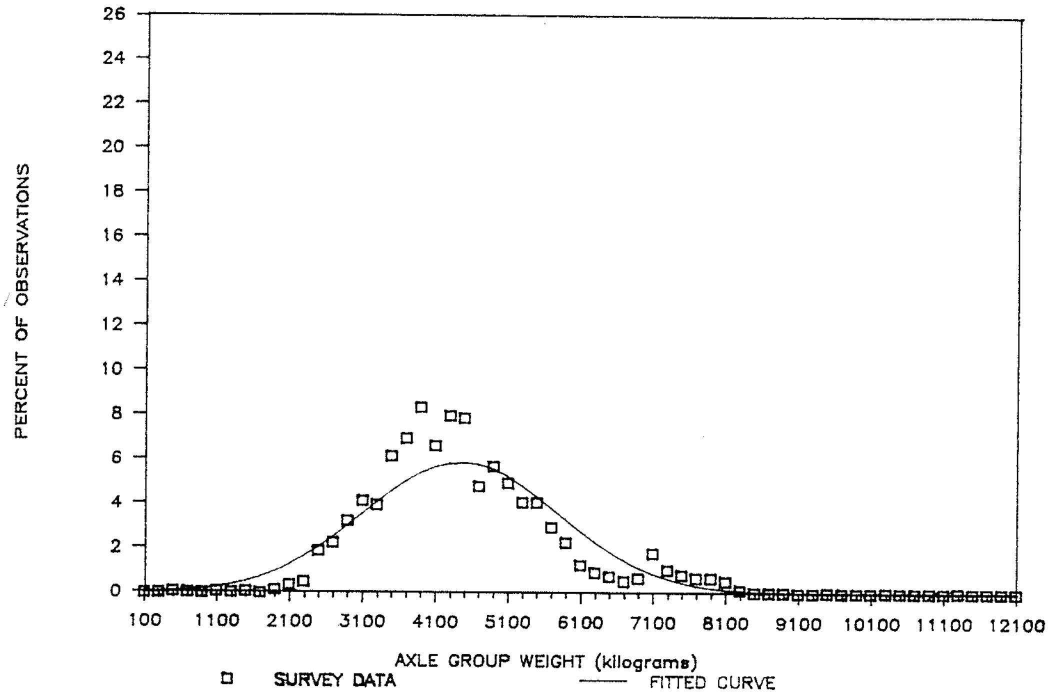
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits: 14500 + 5500 = 20000 kg.
G.V.W. Limit: 20000 TO 47600 = 20000+ kg.

Governing Limit: 20000 kg. limit to total axle weights.

FIGURE 6.28: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 3 AXLE STRAIGHT TRUCKS
AXLE GROUP TYPE: STEERING
GOVERNING LIMIT: 21500 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: `ALL' NUMBER OF OBS: 2767



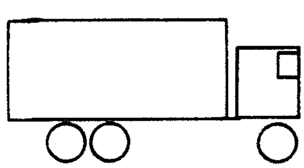
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 1350 u = 4450 PI = 3.14159

GOVERNING REGULATORY LIMIT:



Axle Wt. Limits: 16000 + 5500 = 21500 kg.
G.V.W. Limit: 33600 TO 56500 = 33600+ kg.

Governing Limit: 21500 kg. limit to total axle weights.

of these trucks to be used for hauling extremely dense commodities such as concrete and gravel.

The normal distribution curves used to approximate these axle weights have the following parameters.

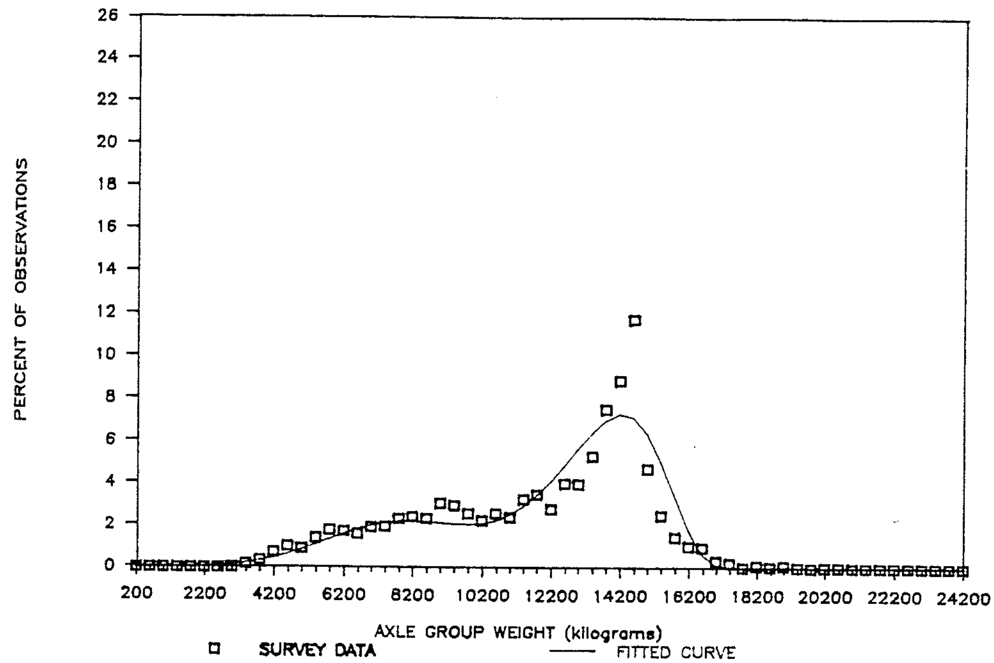
Parameter	20,000 kg Limit	21,500 kg Limit	Parameter Relationship
Mean (u)	4,000 kg	4,450 kg	u = .300 limit - 2,000 kg
Std. Deviation (S.D.)	1,200 kg	1,350 kg	S.D. = .100 limit - 800 kg

The increase of allowable total vehicle weight by 1,500 kg resulted in an upward shift of the steering axle weight fitted curves of 450 kg and an increase of 150 kg in their standard deviations.

The tandem axle group weight distributions of three-axle vehicles (Figures 6.29 and 6.30) are both skewed heavily toward the upper end of the weight range. Overall mean weights of these axle groups are 11,744 kg and 12,162 kg and overweight axles account for between 5 and 10% of all observations.

The elongated left side of the axle group weight distribution suggests the presence of two distinct populations of axle groups, one consisting of heavily laden axles with weights grouped near the legal limit and one of lighter axles loaded with less dense commodity

FIGURE 6.29: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 3 AXLE STRAIGHT TRUCKS
AXLE GROUP TYPE: TANDEM
GOVERNING LIMIT: 20000 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: `ALL' NUMBER OF OBS: 3262



FITTED CURVE EQUATION:

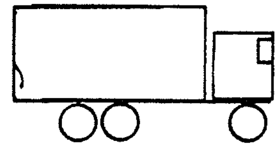
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

where $K = 1/(2PI)^{1/2}$, $w = [(\ln(SHIFT - x) - \ln(E))/SD2]^{2}$,

and $a = (x - u)^{2} / (2 * (SD1)^{2})$

SD1 = 2000 SD2 = .354 SHIFT = 18600
u = 7600 ln(E) = 8.5 PI = 3.14159

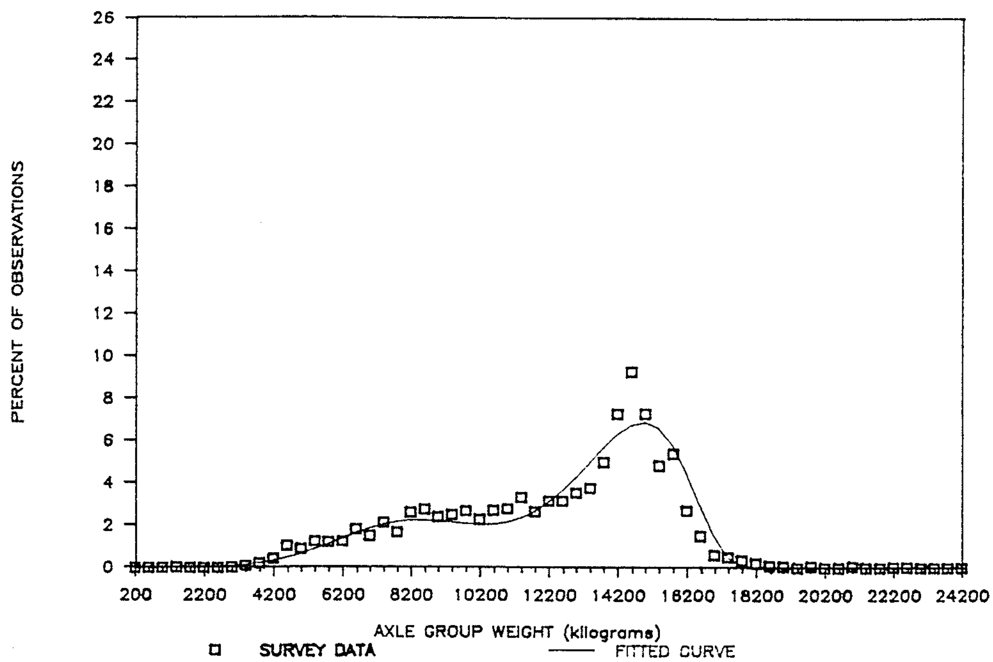
GOVERNING REGULATORY LIMIT:



Axle Wt.Limits: 14500 + 5500 = 20000 kg.
G.V.W. Limit: 20000 TO 47600 = 20000+ kg.

Governing Limit: 20000kg. limit to total axle weights.

FIGURE 6.30: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 3 AXLE STRAIGHT TRUCKS
AXLE GROUP TYPE: TANDEM
GOVERNING LIMIT: 21500 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 2767



FITTED CURVE EQUATION:

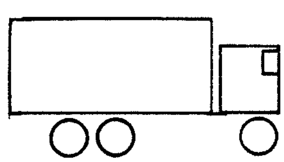
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

where $K = 1/(2PI)^{1/2}$, $w = [(\ln(SHIFT - x) - \ln(E))/SD2]^{2}$,

and $a = (x - u)^{2} / (2 * (SD1)^{2})$

SD1 = 2000 SD2 = .378 SHIFT = 19200
u = 8000 ln(E) = 8.5 PI = 3.14159

GOVERNING REGULATORY LIMIT:



Axle Wt.Limits: 16000 + 5500 = 21500kg.
G.V.W. Limit: 33600 TO 56500 = 33600+ kg.

Governing Limit: 21500kg. limit to total axle weights.

types and making up the elongated portion of the axle group weight distribution curve. A combination of normal and log-normal distributions provided the best fitting model. The parameters of these combination curves are as follows.

Parameter	20,000 kg Limit	21,500 kg Limit	Parameter Relationship
Ln (E)	8.5	8.5	Ln(E) = 8.5
Std. Deviation (log-normal)	.354	.378	SD2 = .0000160 Limit + .0340
SHIFT	18,600 kg	19,200 kg	SHIFT = .400 limit + 10,600 kg
MEAN (u) (normal curve)	7,600 kg	8,000 kg	u = .267 limit + 2,267 kg
Std. Deviation (normal curve)	2,000 kg	2,000 kg	SD1 = 2,000 kg

Only Ln(E) and the standard deviation of the normally distributed portion of the combination curve remain constant across the range of legal truck weight limits. All other parameters increased significantly as a result of the higher axle weight limits.

6.7 3-S2 TRACTOR SEMITRAILERS

6.7.1 G.V.W. Distributions

3-S2 tractor semitrailers were observed under these five different g.v.w. limits: 20,000 kg, 33,600 kg, 34,500 kg, 36,500 kg, and 37,500 kg (Figures 6.31 to 6.35). In all five cases, the distributions were skewed to the heavy end of the weight range and were similar in shape to the distributions of three axle straight trucks. Mean weights of these vehicles were as follows:

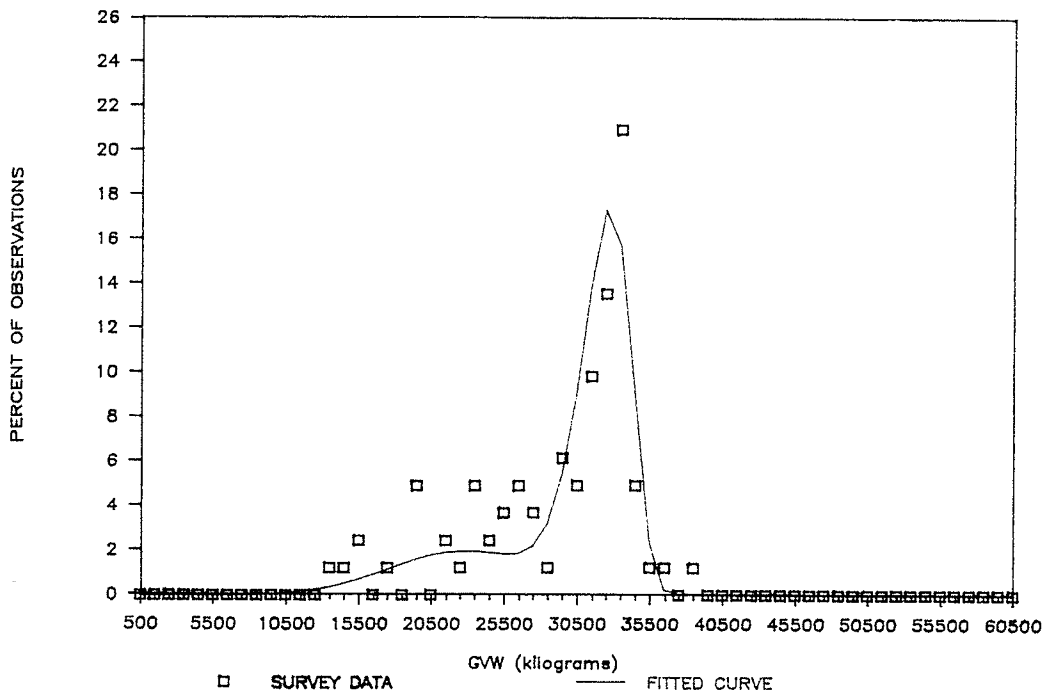
Limit	Mean Weight
20,000 kg	29,008 kg
33,600 kg	30,022 kg
34,500 kg	28,933 kg
36,500 kg	30,509 kg
37,500 kg	30,626 kg

It is surprising that these mean weights increased by less than 2,000 kg while the legal limits under which the trucks are allowed to operate increased by 17,500 kg. Furthermore, the percentage of overweight trucks among these observations ranges from less than 5% for those limited to 37,500 kg to almost 100% of those limited to 20,000 kg. Obviously, the 20,000 kg limit did not have any bearing at all on the weights at which trucks were being operated.

All five groups of trucks could be represented by combinations of normal and log-normal distributions. The curve parameters are as follows:

Parameter	20,000 kg Limit	33,600 kg Limit	34,500 kg Limit	36,500 kg Limit	37,500 kg Limit
Ln (E)	9.0	9.0	9.0	8.5	8.5
Std. Deviation (log-normal)	.218	.295	.502	.628	.570
SHIFT	40,500 kg	41,000 kg	40,900 kg	38,800 kg	38,600 kg
MEAN (u) (normal curve)	22,600 kg	23,300 kg	22,300 kg	23,900 kg	23,900 kg
Std. Deviation (normal curve)	5,000 kg	5,000 kg	5,000 kg	5,000 kg	5,000 kg

FIGURE 6.31: GROSS VEHICLE WEIGHT DISTRIBUTION
VEHICLE TYPE: 5 AXLE TRACTOR SEMITRAILERS
GOVERNING LIMIT: 20000 kg. G.V.W. LIMIT
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 81



<u>FITTED CURVE EQUATION</u>:

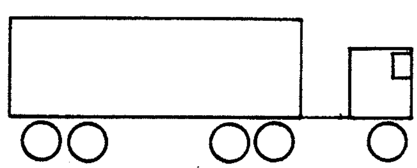
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

where $K = 1/(2PI)^{1/2}$, $w = [(\ln(SHIFT - x) - \ln(E))/SD2]^{2}$,

and $a = (x - u)^{2} / (2 * (SD1)^{2})$

SD1 = 5000 SD2 = .218 SHIFT = 40500
u = 22600 ln(E) = 9.0 PI = 3.14159

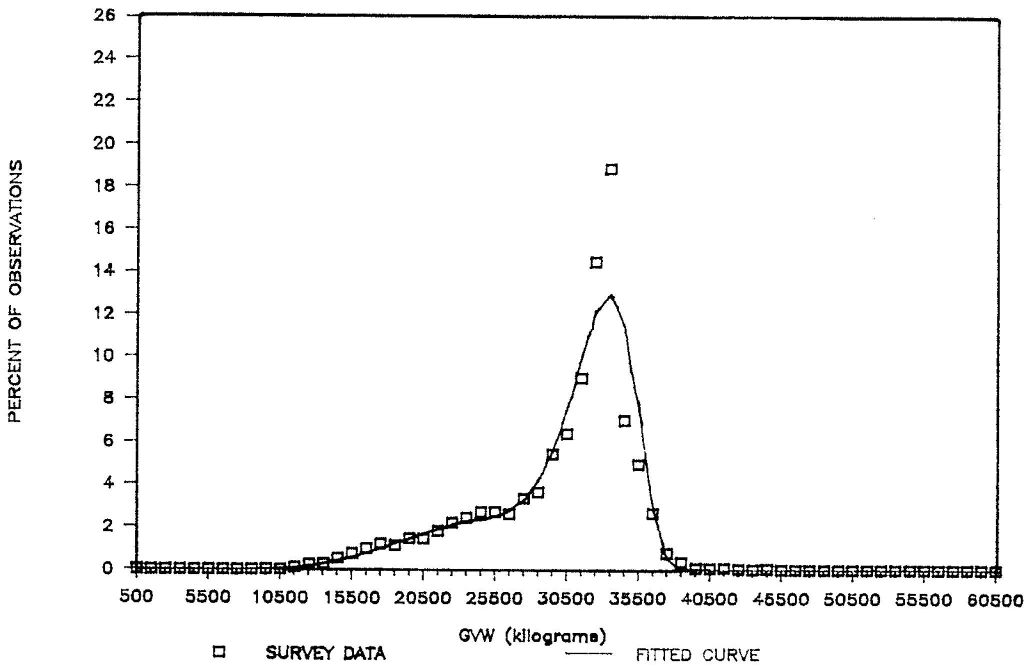
<u>GOVERNING REGULATORY LIMIT</u>:



Axle Wt. Limits: 14500 + 14500 + 5500 = 34500 kg.
G.V.W. Limit: 20000 = 20000 kg.

Governing Limit: 20000 kg.

FIGURE 6.32: GROSS VEHICLE WEIGHT DISTRIBUTION
VEHICLE TYPE: 5 AXLE TRACTOR SEMITRAILERS
GOVERNING LIMIT: 33600 kg. G.V.W. LIMIT
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 8808



<u>FITTED CURVE EQUATION</u>:

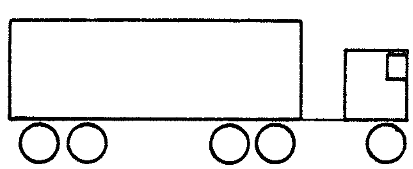
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

where $K = 1/(2PI)^{1/2}$, $w = [(\ln(SHIFT - x) - \ln(E))/SD2]^{2}$,

and $a = (x - u)^{2} / (2 * (SD1)^{2})$

SD1 = 5000 SD2 = .329 SHIFT = 42200
u = 23100 ln(E) = 9.0 PI = 3.14159

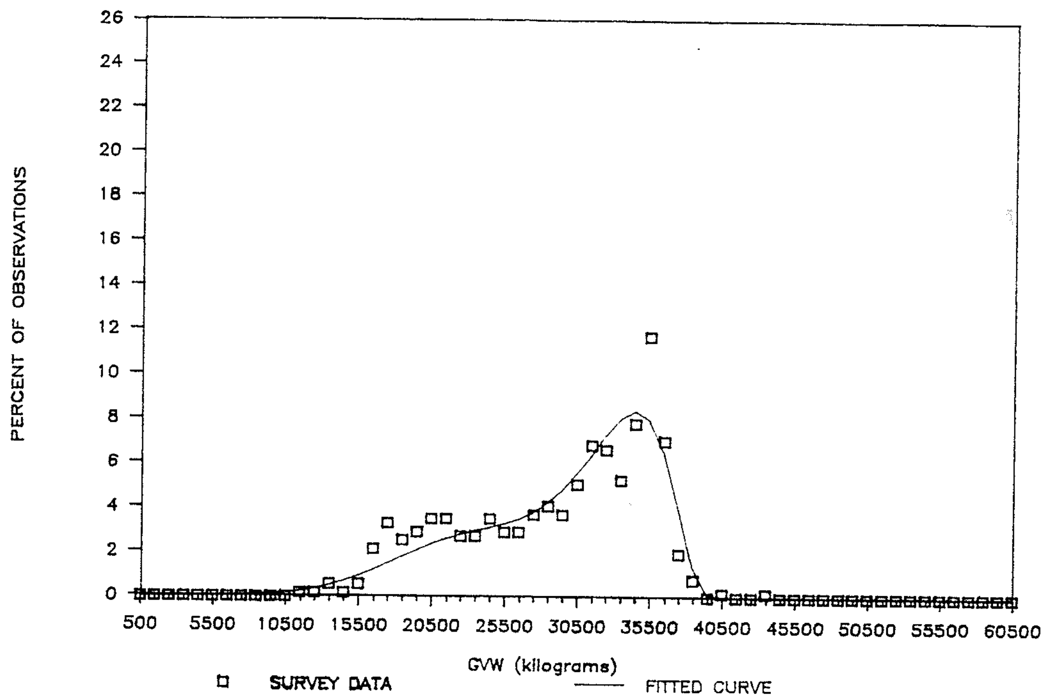
<u>GOVERNING REGULATORY LIMIT</u>:



Axle Wt. Limits: 14500 + 14500 + 5500 = 34500 kg.
G.V.W. Limit: 33600 = 33600 kg.

Governing Limit: 33600 kg.

FIGURE 6.33: GROSS VEHICLE WEIGHT DISTRIBUTION
VEHICLE TYPE: 5 AXLE TRACTOR SEMITRAILERS
GOVERNING LIMIT: 34500 kg. G.V.W. LIMIT
COMMODITY GROUP: `ALL' NUMBER OF OBS: 510



FITTED CURVE EQUATION:

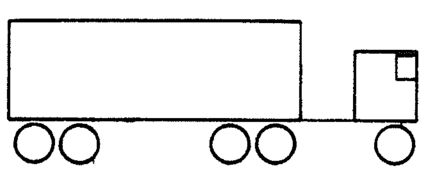
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

where $K = 1/(2PI)^{1/2}$, $w = [(\ln(SHIFT - x) - \ln(E))/SD2]^{2}$,

and $a = (x - u)^{2} / (2 * (SD1)^{2})$

SD1 = 5000 SD2 = .502 SHIFT = 40900
u = 22300 ln(E) = 9.0 PI = 3.14159

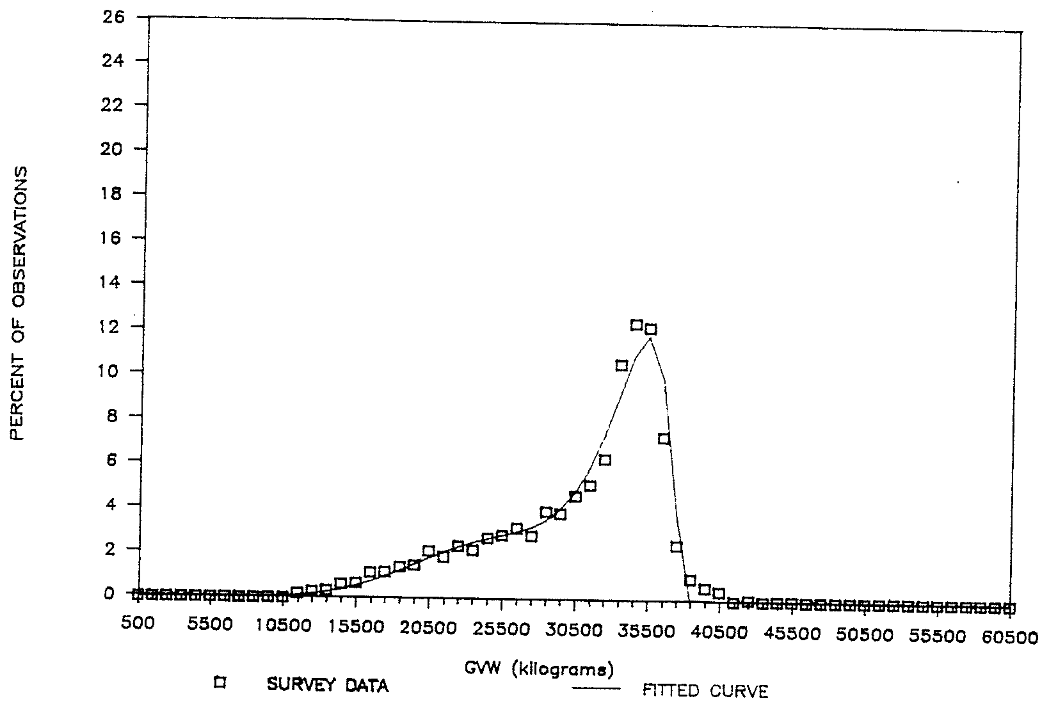
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits: 14500 + 14500 + 5500 = 34500 kg.
G.V.W. Limit: 47600 = 47600 kg.

Governing Limit: 34500 kg.

FIGURE 6.34: GROSS VEHICLE WEIGHT DISTRIBUTION
VEHICLE TYPE: 5 AXLE TRACTOR SEMITRAILERS
GOVERNING LIMIT: 36500 kg. G.V.W. LIMIT
COMMODITY GROUP: `ALL' NUMBER OF OBS: 3393



FITTED CURVE EQUATION:

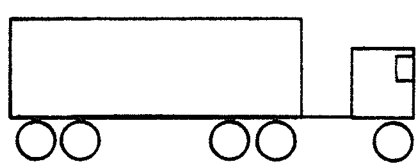
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

$$\text{where } K = 1/(2PI)^{1/2}, \quad w = [(\ln(SHIFT - x) - \ln(E))/SD2]^2,$$

$$\text{and } a = (x - u)^2 / (2 * (SD1)^2)$$

SD1 = 5000 SD2 = .628 SHIFT = 38800
u = 23900 ln(E) = 8.5 PI = 3.14159

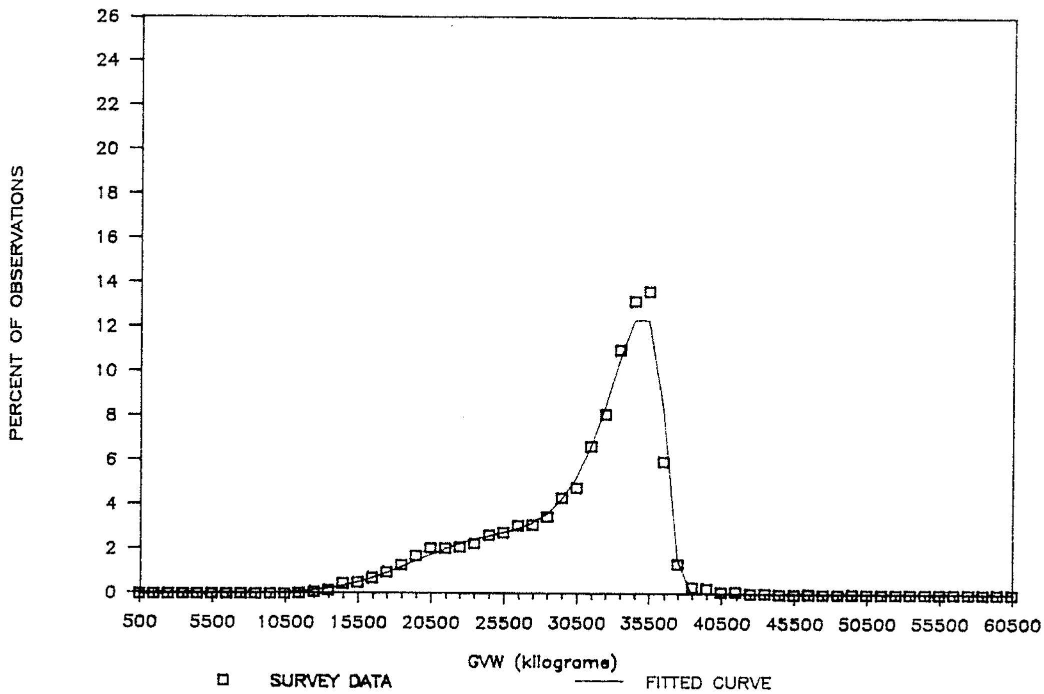
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits: 16000 + 16000 + 5500 = 37500 kg.
G.V.W. Limit: 36500 = 36500 kg.

Governing Limit: 36500 kg.

FIGURE 6.35: GROSS VEHICLE WEIGHT DISTRIBUTION
VEHICLE TYPE: 5 AXLE TRACTOR SEMITRAILERS
GOVERNING LIMIT: 37500 kg. G.V.W. LIMIT
COMMODITY GROUP: `ALL' NUMBER OF OBS: 9163



FITTED CURVE EQUATION:

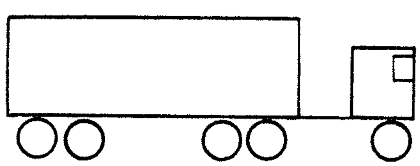
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

where $K = 1/(2PI)^{1/2}$, $w = [(\ln(SHIFT - x) - \ln(E))/SD2]^2$,

and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 5000 SD2 = .570 SHIFT = 38600
u = 23900 ln(E) = 8.5 PI = 3.14159

GOVERNING REGULATORY LIMIT:



Axle Wt. Limits: 16000 + 16000 + 5500 = 37500 kg.
G.V.W. Limit: 49900 TO 53500 = 49900+ kg.

Governing Limit: 37500 kg.

Obviously, none of the parameters could be related to the 20,000 kg limit. Therefore, that segment of the truck observations was useless in determining a relationship between the weight limits and the curve parameters. The other four weight groups display patterns of seeming randomness with respect to the weight limits. Despite the large increase in allowable gross vehicle weights (3,900 kg), the weight distribution parameters show very little substantial change to reflect that fact. (This is also true for the mean weights of these trucks which increased by only 700 kg despite the 3,900 kg increase in allowable gross vehicle weights).

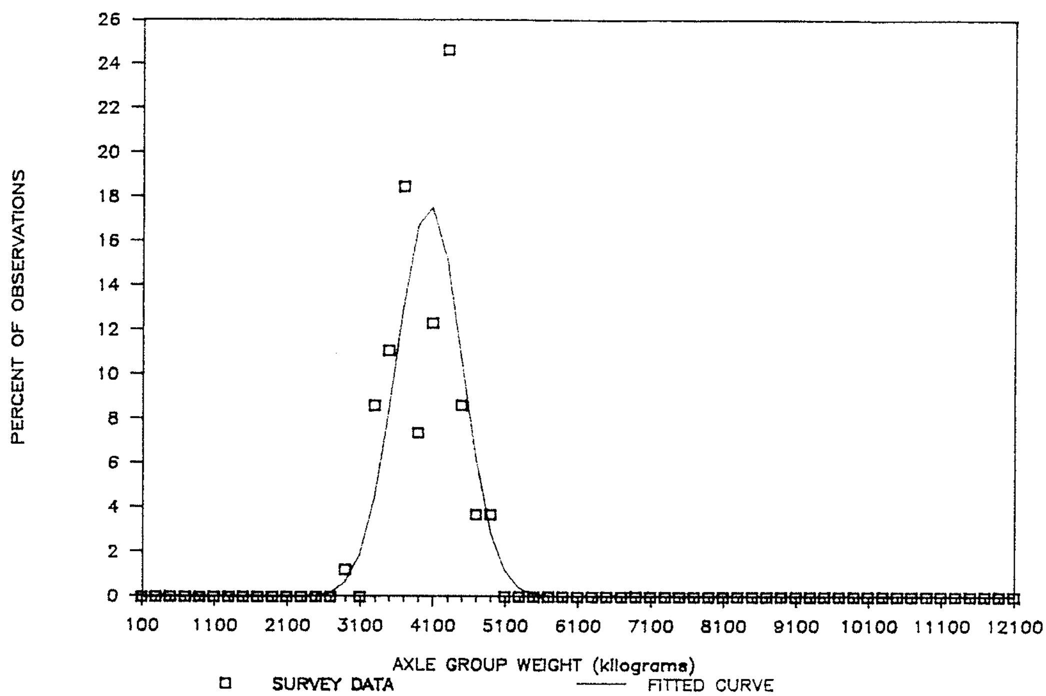
6.7.2 Axle Weight Distributions

Under all five different truck weight limits, the steering axle weight distributions of these trucks assumed relatively narrow and remarkably consistent bell-like shapes (Figures 6.36-6.40). The mean weights of these axles all fall within a range of only 350 kg. The number of overweight axles among them is negligible.

All five distributions were represented by normally distributed curves with parameters as follows.

Parameter	20,000 kg Limit	33,600 kg Limit	34,500 kg Limit	36,500 kg Limit	37,500 kg Limit
Mean (u)	4,050 kg	4,200 kg	4,350 kg	4,350 kg	4,350 kg
Std. Deviation	450 kg	450 kg	450 kg	500 kg	450 kg

```
FIGURE 6.36:        AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE:       5 AXLE TRACTOR SEMITRAILERS
AXLE GROUP TYPE:    STEERING
GOVERNING LIMIT:    20000 kg. G.V.W. LIMIT
COMMODITY GROUP:    `ALL'        NUMBER OF OBS: 81
```



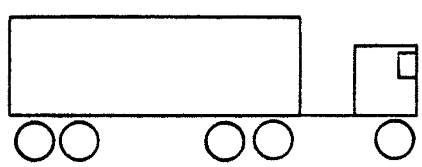
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 450   u = 4050   PI = 3.14159

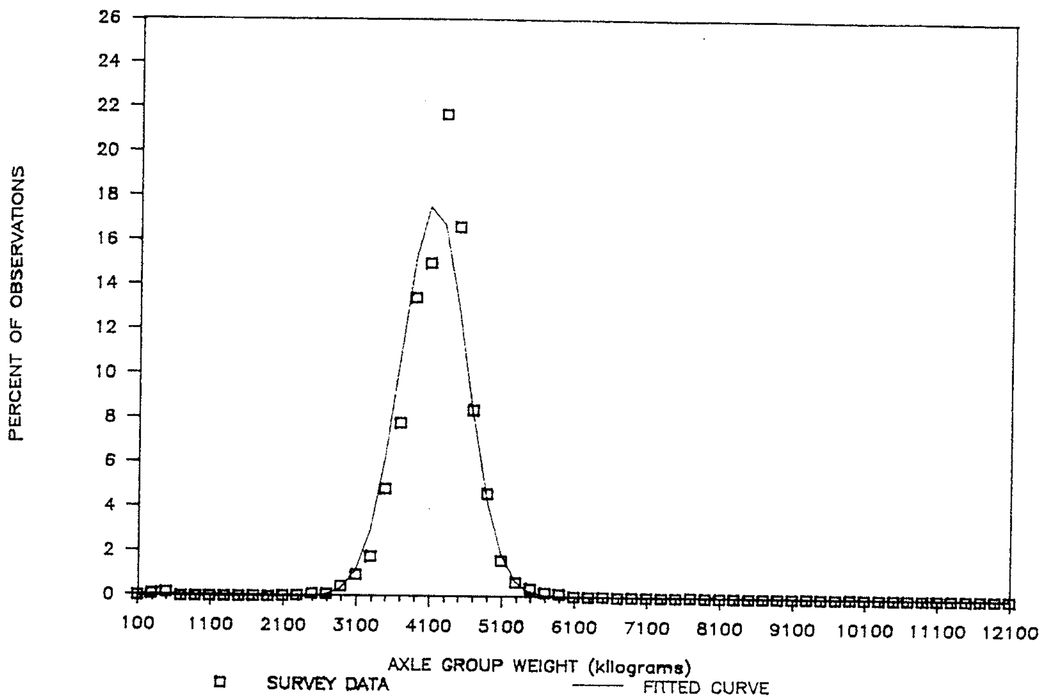
GOVERNING REGULATORY LIMIT:



```
Axle Wt. Limits:  14500   +  14500 + 5500 = 34500 kg.
   G.V.W. Limit:  20000 kg.
```

Governing Limit: 20000 kg. G.V.W. limit.

FIGURE 6.37: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 5 AXLE TRACTOR SEMITRAILERS
AXLE GROUP TYPE: STEERING
GOVERNING LIMIT: 33600 kg. G.V.W. LIMIT
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 8806



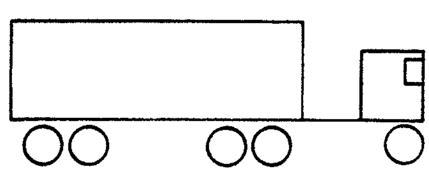
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 450 u = 4150 PI = 3.14159

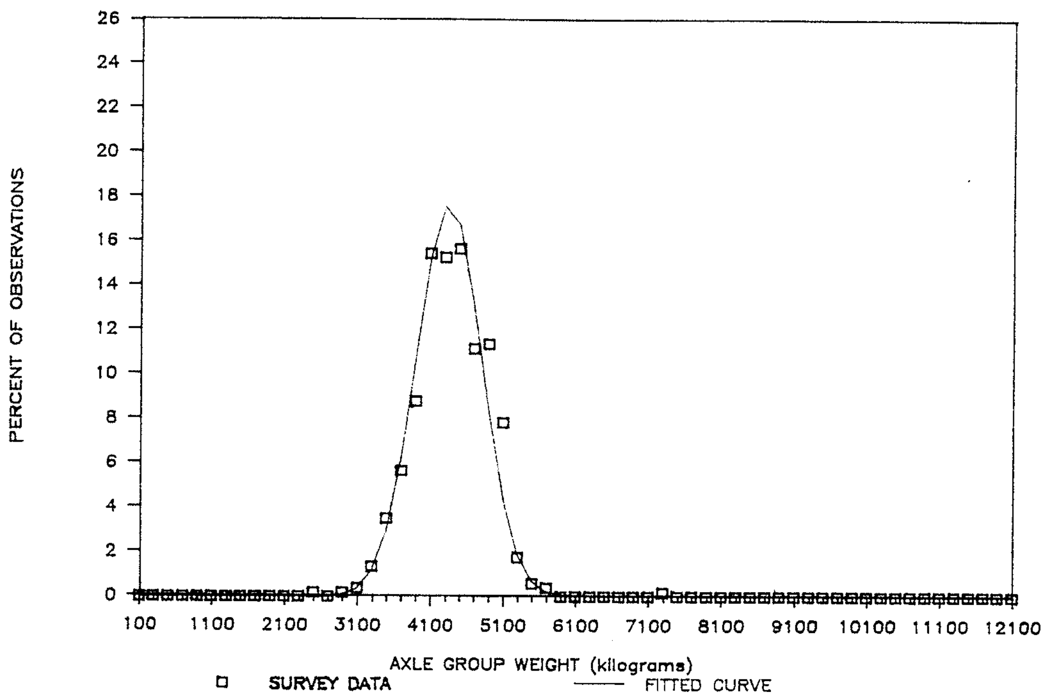
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits: 14500 + 14500 + 5500 = 34500 kg.
G.V.W. Limit: 33600 kg.

Governing Limit: 33600 kg. G.V.W. limit.

FIGURE 6.38: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 5 AXLE TRACTOR SEMITRAILERS
AXLE GROUP TYPE: STEERING
GOVERNING LIMIT: 34500 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: `ALL' NUMBER OF OBS: 510



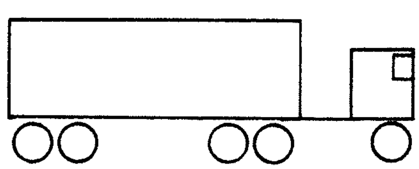
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^{2} / (2 * (SD1)^{2})$

SD1 = 450 u = 4350 PI = 3.14159

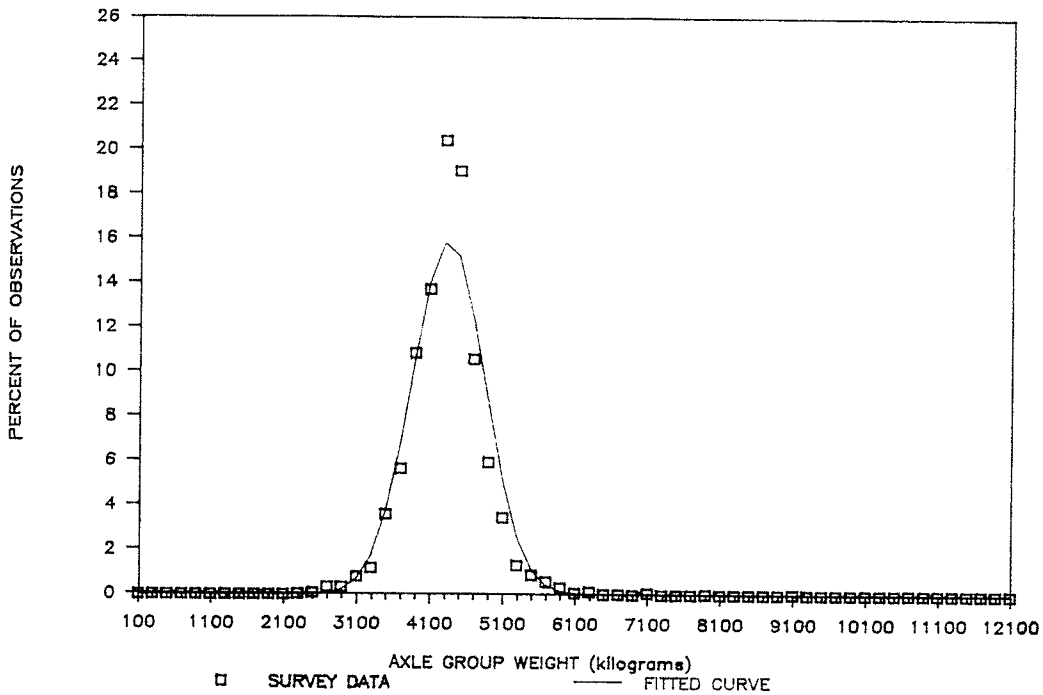
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits: 14500 + 14500 + 5500 = 34500 kg.
G.V.W. Limit: 47600 kg.

Governing Limit: 34500 kg. limit to total axle weight.

FIGURE 6.39: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 5 AXLE TRACTOR SEMITRAILERS
AXLE GROUP TYPE: STEERING
GOVERNING LIMIT: 36500 kg. G.V.W. LIMIT
COMMODITY GROUP: `ALL' NUMBER OF OBS: 3393



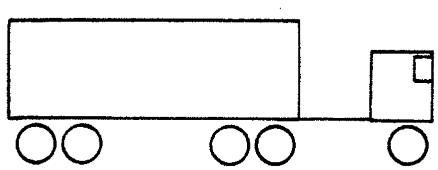
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 500 u = 4350 PI = 3.14159

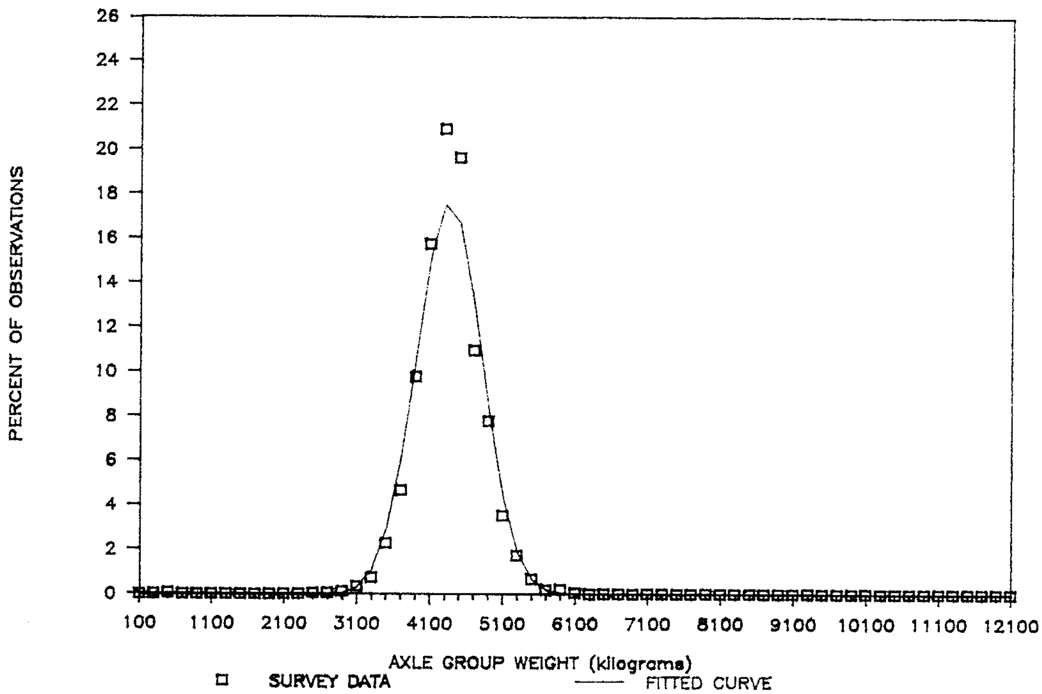
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits: 16000 + 16000 + 5500 = 37500 kg.
G.V.W. Limit: 36500 kg.

Governing Limit: 36500 kg. G.V.W. limit.

FIGURE 6.40: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 5 AXLE TRACTOR SEMITRAILERS
AXLE GROUP TYPE: STEERING
GOVERNING LIMIT: 37500 kg. G.V.W. LIMIT
COMMODITY GROUP: `ALL' NUMBER OF OBS: 9163



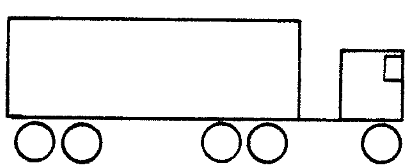
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 450 u = 4350 PI = 3.14159

GOVERNING REGULATORY LIMIT:



Axle Wt. Limits: 16000 + 16000 + 5500 = 37500 kg.
G.V.W. Limit: 49900 TO 53500 = 49900+ kg.

Governing Limit: 37500 kg. limit to total axle weight.

A general upward trend in the value of the mean which tends to flatten out after weight limits exceed 34,500 kg is apparent while the standard deviation remains relatively constant at 450 kg. Both parameters seem independent of the weight limits at levels above 33,600 kg.

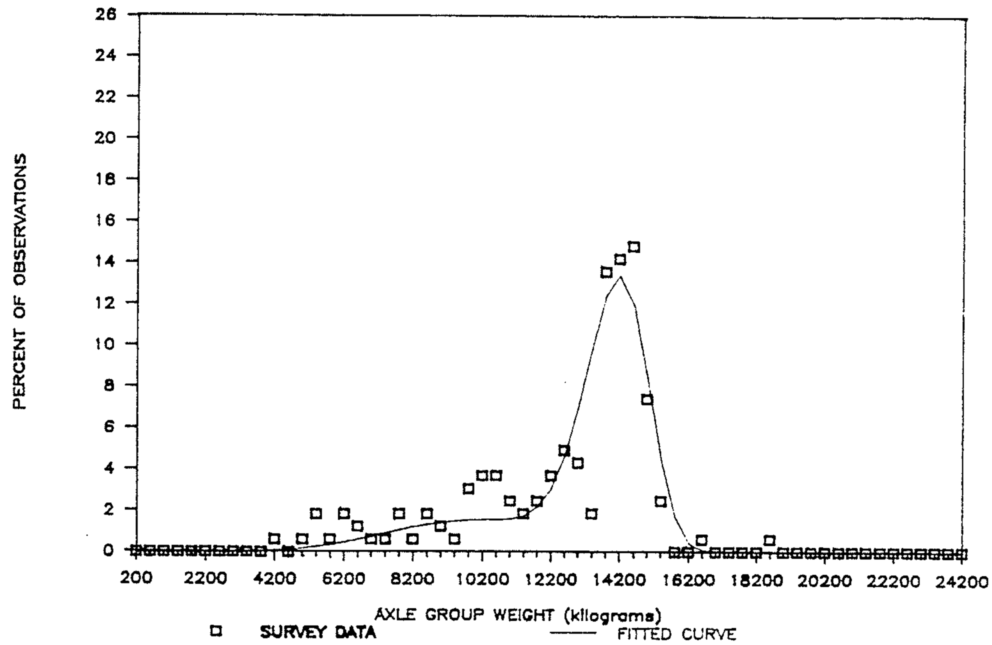
The tandem axle group weight distributions of these vehicles (Figures 6.41-6.45) are all skewed toward the heavy end of the scale with mean values falling between 12,300 kg and 13,100 kg. The percentage of axle groups weighing above the legal limits range from 5% to 30% of all observations.

Combination curves with the following parameters were used to represent these distributions.

Parameter	20,000 kg Limit	33,600 kg Limit	34,500 kg Limit	36,500 kg Limit	37,500 kg Limit
Ln (E)	8.8	8.8	9.1	8.8	8.8
Std. Deviation (log-normal)	.139	.160	.204	.223	.213
SHIFT	20,700 kg	20,900 kg	23,300 kg	21,300 kg	21,300 kg
MEAN (u) (normal curve)	9,900 kg	9,300 kg	8,700 kg	9,200 kg	9,600 kg
Std. Deviation (normal curve)	2,500 kg	2,500 kg	2,500 kg	2,500 kg	2,500 kg

Trends in parameters such as the SHIFT variable and the standard deviation of the log-normal part of the curve are generally upward but stop or reverse themselves at the 37,500 kg weight limit. This pattern suggests that other factors (besides the 1,000 kg increase in allowable vehicle weight) influenced the tandem axle group weights of these trucks.

FIGURE 6.41: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 5 AXLE TRACTOR SEMITRAILERS
AXLE GROUP TYPE: TANDEM
GOVERNING LIMIT: 20000 kg. G.V.W. LIMIT
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 162



FITTED CURVE EQUATION:

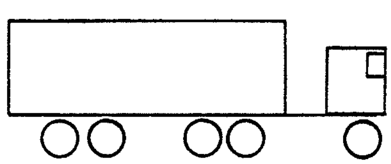
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

where $K = 1/(2PI)^{1/2}$, $w = [(\ln(SHIFT - x) - \ln(E))/SD2]^{2}$,

and $a = (x - u)^{2} / (2 * (SD1)^{2})$

SD1 = 2500 SD2 = .139 SHIFT = 20700
u = 9900 ln(E) = 8.8 PI = 3.14159

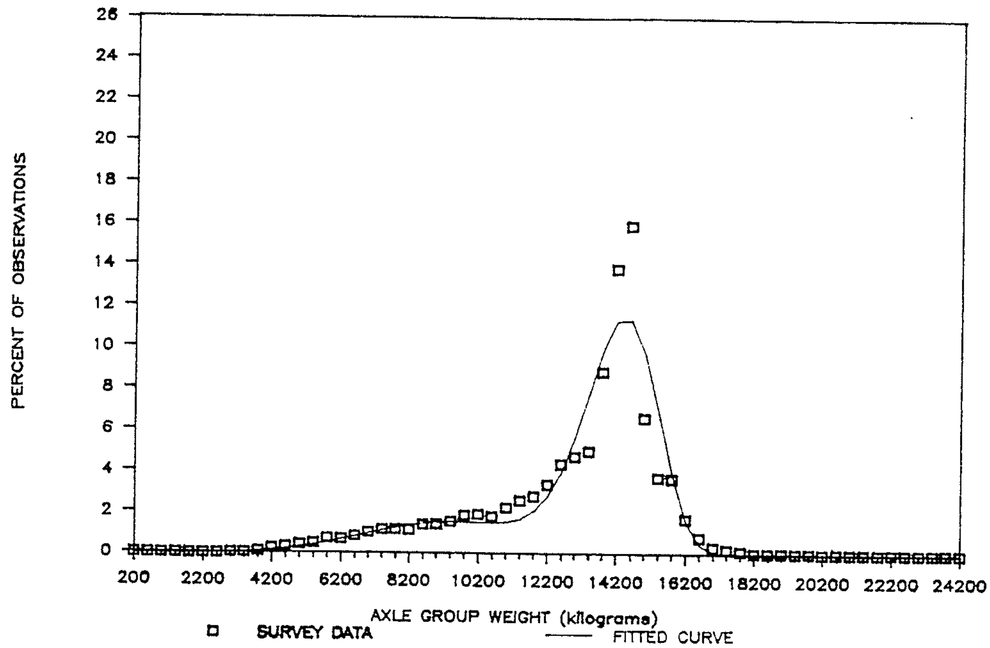
GOVERNING REGULATORY LIMIT:



Axle Wt.Limits: 14500 + 14500 + 5500 = 34500kg.
G.V.W. Limit: 20000 kg.

Governing Limit: 20000kg. G.V.W. limit.

FIGURE 6.42: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 5 AXLE TRACTOR SEMITRAILERS
AXLE GROUP TYPE: TANDEM
GOVERNING LIMIT: 33600 kg. G.V.W. LIMIT
COMMODITY GROUP: `ALL' NUMBER OF OBS: 17612



FITTED CURVE EQUATION:

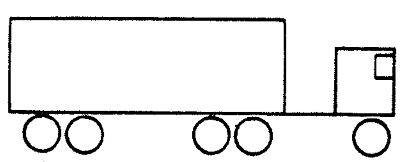
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

where $K = 1/(2PI)^{1/2}$, $w = [(\ln(SHIFT - x) - \ln(E))/SD2]^{2}$,

and $a = (x - u)^{2} / (2 * (SD1)^{2})$

SD1 = 2500 SD2 = .160 SHIFT = 20900
u = 9300 ln(E) = 8.8 PI = 3.14159

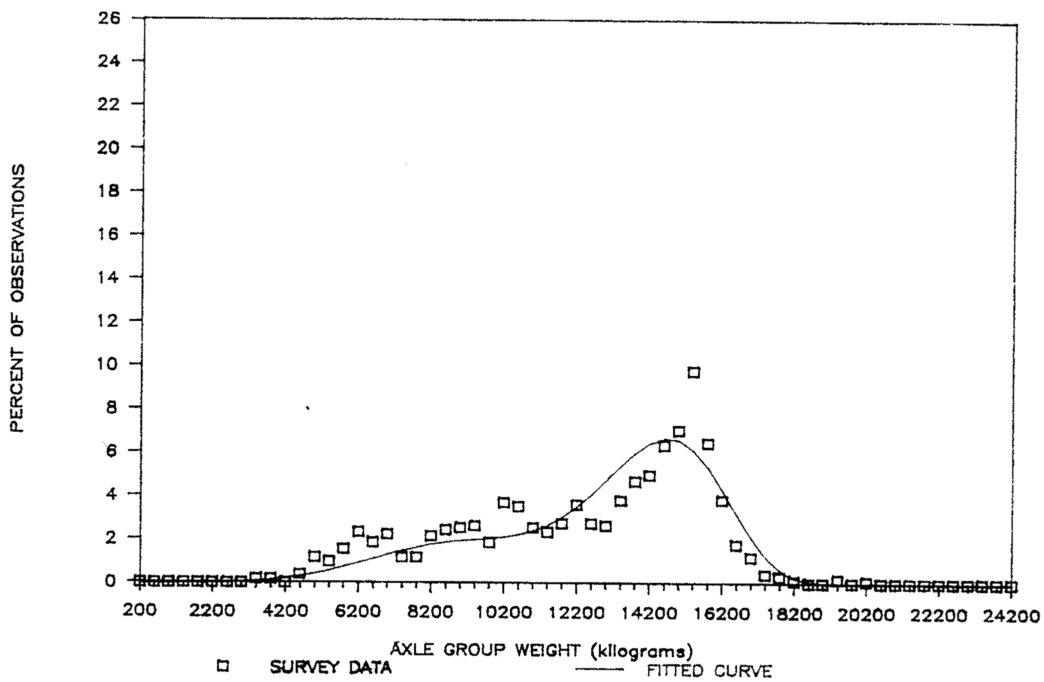
GOVERNING REGULATORY LIMIT:



Axle Wt.Limits: 14500 + 14500 + 5500 = 34500kg.
G.V.W. Limit: 33600 kg.

Governing Limit: 33600 kg. G.V.W. limit.

FIGURE 6.43: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 5 AXLE TRACTOR SEMITRAILERS
AXLE GROUP TYPE: TANDEM
GOVERNING LIMIT: 34500 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 1020



FITTED CURVE EQUATION:

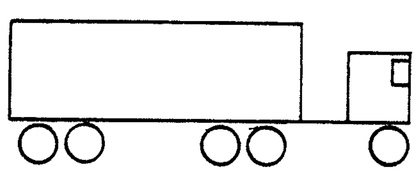
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

$$\text{where } K = 1/(2PI)^{1/2}, \quad w = [(\ln(SHIFT - x) - \ln(E))/SD2]^{2},$$

$$\text{and } a = (x - u)^{2} / (2 * (SD1)^{2})$$

SD1 = 2300 SD2 = .204 SHIFT = 23300
u = 8700 ln(E) = 9.1 PI = 3.14159

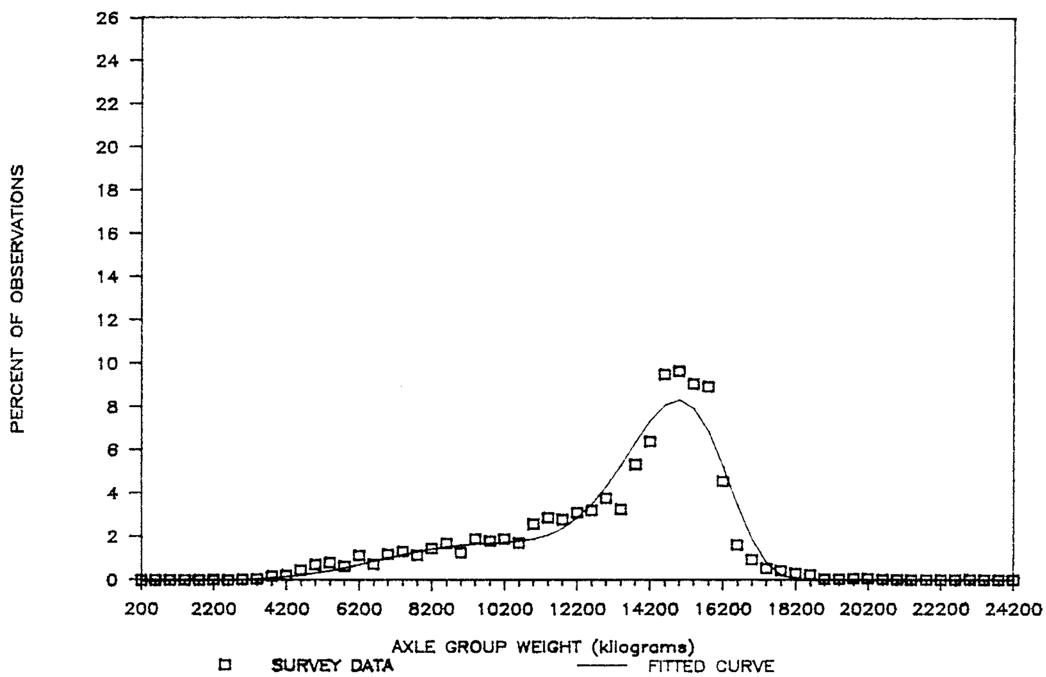
GOVERNING REGULATORY LIMIT:



Axle Wt.Limits: 14500 + 14500 + 5500 = 34500kg.
G.V.W. Limit: 47600 kg.

Governing Limit: 34500 kg. limit to total axle weights.

FIGURE 6.44: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 5 AXLE TRACTOR SEMITRAILERS
AXLE GROUP TYPE: TANDEM
GOVERNING LIMIT: 36500 kg. G.V.W. LIMIT
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 6786



FITTED CURVE EQUATION:

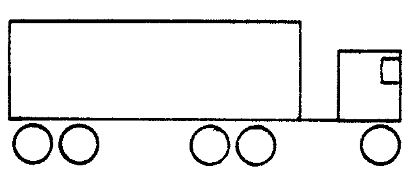
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

$$\text{where } K = 1/(2PI)^{1/2}, \quad w = [(\ln(SHIFT - x) - \ln(E))/SD2]^2,$$

$$\text{and } a = (x - u)^2 / (2 * (SD1)^2)$$

SD1 = 2500 SD2 = .223 SHIFT = 21300
u = 9200 ln(E) = 8.8 PI = 3.14159

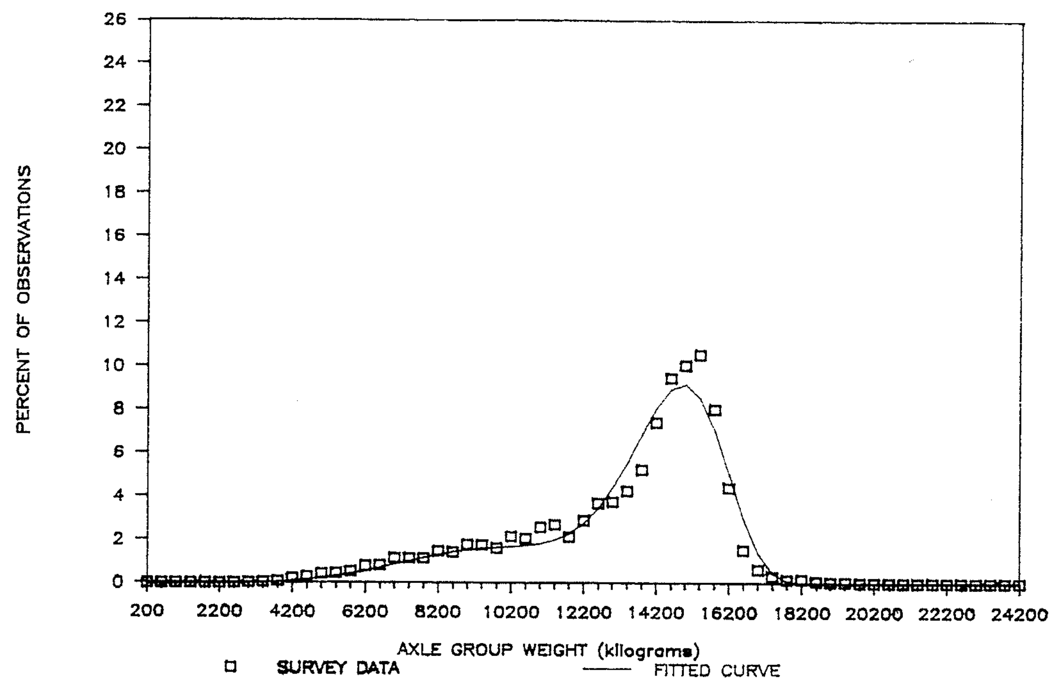
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits:16000 + 16000 + 5500 = 37500kg.
G.V.W. Limit: 36500 kg.

Governing Limit: 36500 kg. G.V.W. limit.

FIGURE 6.45: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 5 AXLE TRACTOR SEMITRAILERS
AXLE GROUP TYPE: TANDEM
GOVERNING LIMIT: 37500 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: `ALL' NUMBER OF OBS: 18326



FITTED CURVE EQUATION:

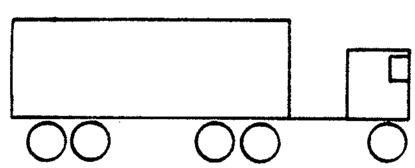
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

where $K = 1/(2PI)^{1/2}$, $w = [(\ln(SHIFT - x) - \ln(E))/SD2]^{2}$,

and $a = (x - u)^{2} / (2 * (SD1)^{2})$

SD1 = 2500 SD2 = .213 SHIFT = 21300
u = 9600 ln(E) = 8.8 PI = 3.14159

GOVERNING REGULATORY LIMIT:



Axle Wt. Limits:16000 + 16000 + 5500 = 37500kg.
G.V.W. Limit: 50000 TO 56500 = 50000+ kg.

Governing Limit: 37500 kg. limit to total axle weights.

6.8 SIX-AXLE A-TRAINS

6.8.1 G.V.W. Distributions

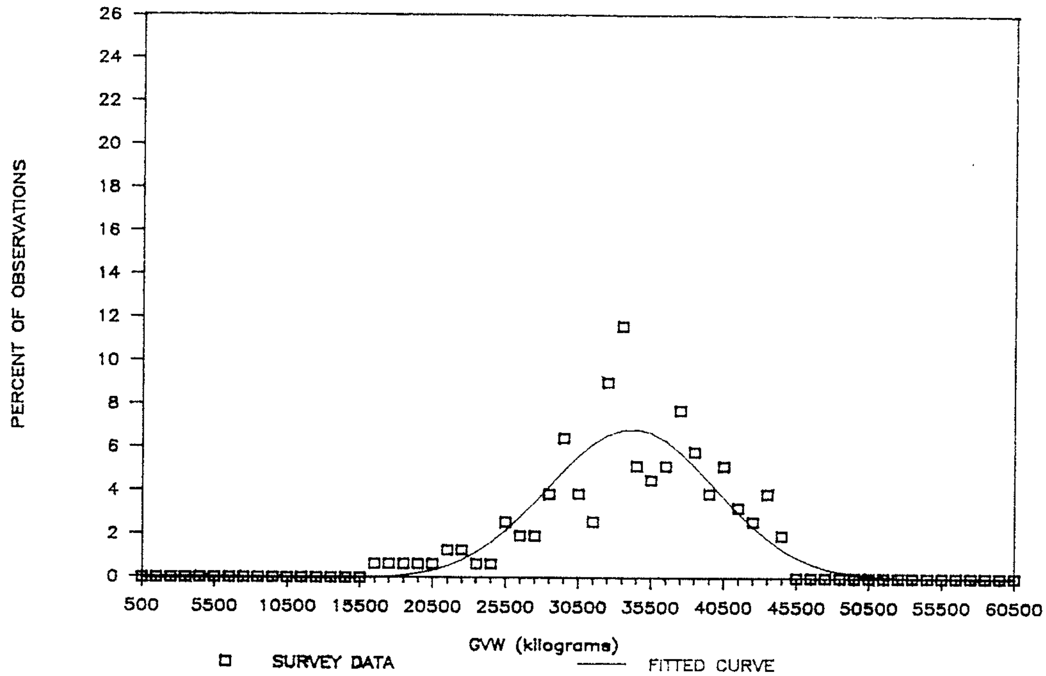
The distribution curve of these vehicles (Figure 6.46) is bell-shaped with no skew. The mean weight of these trucks (33,973 kg) is substantially less than the mean of any other types of trains and well below the legal maximum of 48,800 kg. There were no observations of overweight trucks among these A-trains.

The distribution could be approximated by a normal distribution curve. The fitted curve parameters are as follows:

Parameter	48,800 kg Limit
Mean (u)	34,100 kg
Std. Deviation	5,750 kg

This distribution curve does not resemble those of tractor semitrailers or of any other A-trains in that it is positioned well below the legal limits and lacks any apparent skew. These facts support the conclusion that six-axle A-train weights are affected mainly by factors other than legislated weight limits, the most likely being cubic capacity limits.

FIGURE 6.46: GROSS VEHICLE WEIGHT DISTRIBUTION
VEHICLE TYPE: 6 AXLE A-TRAINS
GOVERNING LIMIT: 48800 kg. G.V.W. LIMIT
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 155



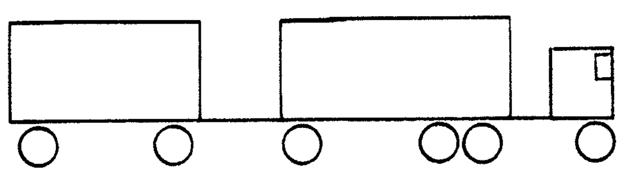
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $a = (x - u)^2 / (2 *(SD1)^2)$ and $K = 1/(2PI)^{1/2}$

SD1 = 5750 u = 34100 PI = 3.14159

GOVERNING REGULATORY LIMIT:



Axle Wt.Limits:9100 + 9100 + 9100 + 16000 + 5500 = 48800kg.
G.V.W. Limit: 50000 TO 56500 = 48800kg.

Governing Limit: 48800 kg.

6.8.2 Axle Weight Distributions

It was found that weight distributions of all three axle group types (steering, single, and tandem) of six axle A-trains formed the distinctive bell shape of a normally distributed curve (Figures 6.47-6.49). Mean weights of these axle groups are as follows:

Axle Group Type	Mean Weight
Steering	4,284 kg
Single	6,099 kg
Tandem	11,391 kg

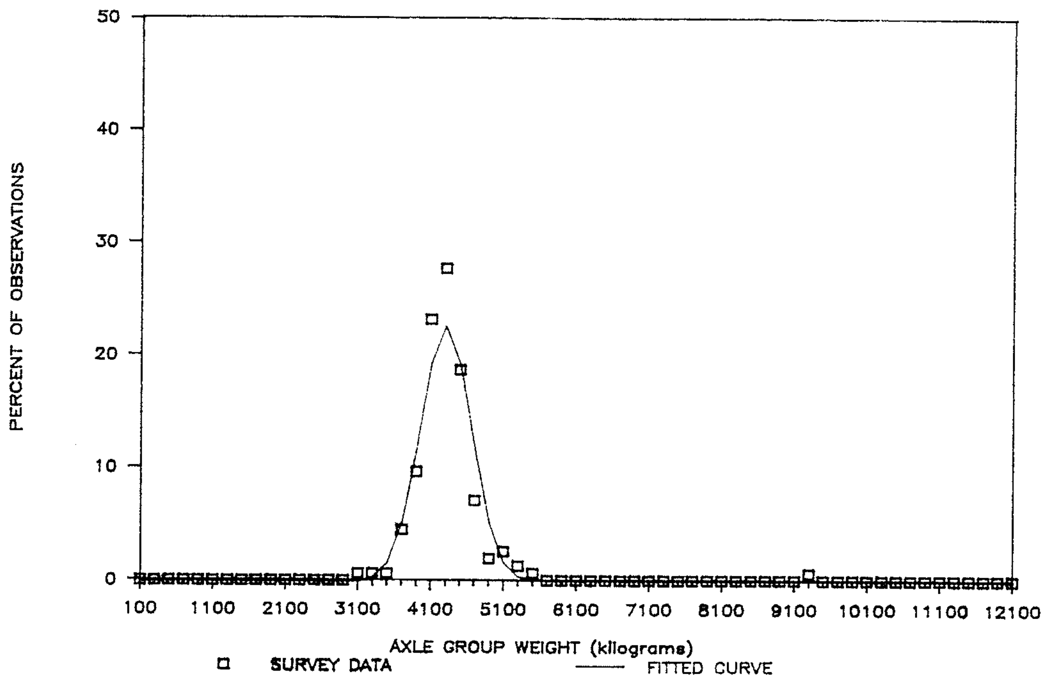
The number of overweight axle groups was negligible in each case. The normal distributions used in modelling these axle weight curves have the following parameters.

	48,800 kg limit		
Parameter	Steering	Single	Tandem
Mean (u)	4,300 kg	6,200 kg	11,500 kg
Std. Deviation	350 kg	1,600 kg	2,300 kg

The lack of any skew in the curves suggests an absence of dense commodities among the loads hauled by this configuration.

The relative scarcity of six-axle A-train observations meant that axle weight distributions of this truck configuration type were not available except for the case in which they were limited to 48,800 kg in g.v.w.

FIGURE 6.47: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 6 AXLE A-TRAINS
AXLE GROUP TYPE: STEERING
GOVERNING LIMIT: 48800 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 155



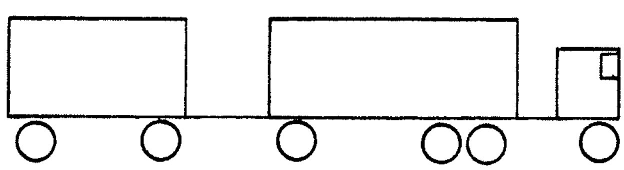
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 350 u = 4300 PI = 3.14159

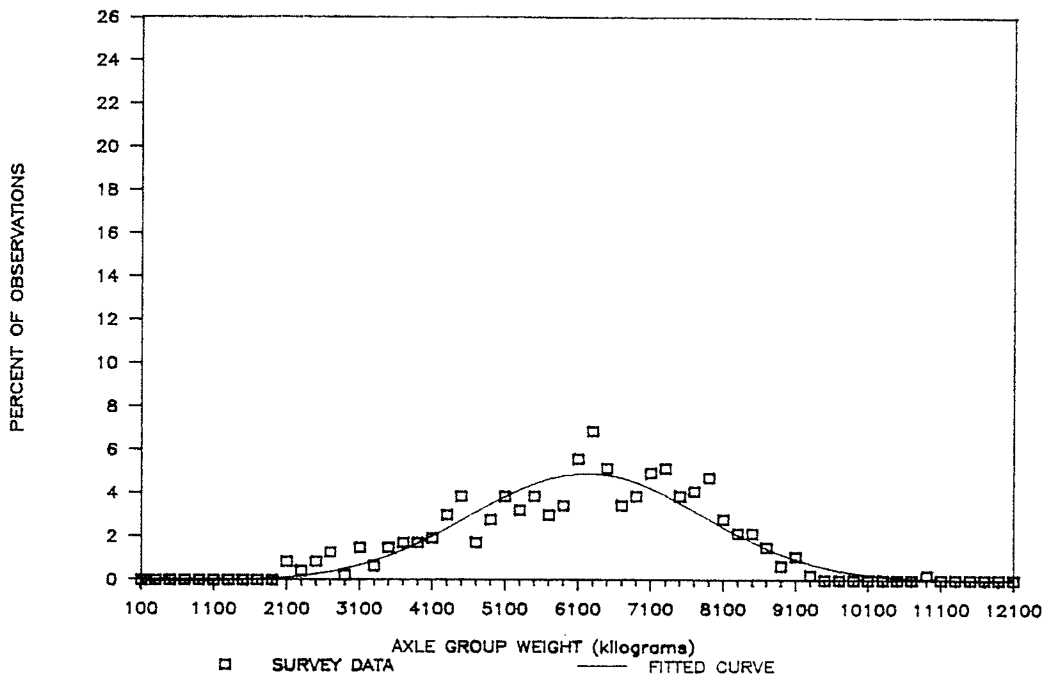
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits:9100 + 9100 + 9100 + 16000 + 5500 = 48800 kg
G.V.W. Limit: 50000 TO 56500 = 50000+ kg.

Governing Limit: 48800 kg. limit to total axle weight.

FIGURE 6.48: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 6 AXLE A-TRAINS
AXLE GROUP TYPE: SINGLE
GOVERNING LIMIT: 48800 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 465



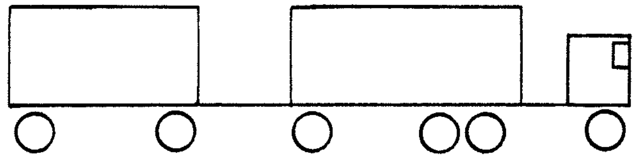
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 1600 u = 6200 PI = 3.14159

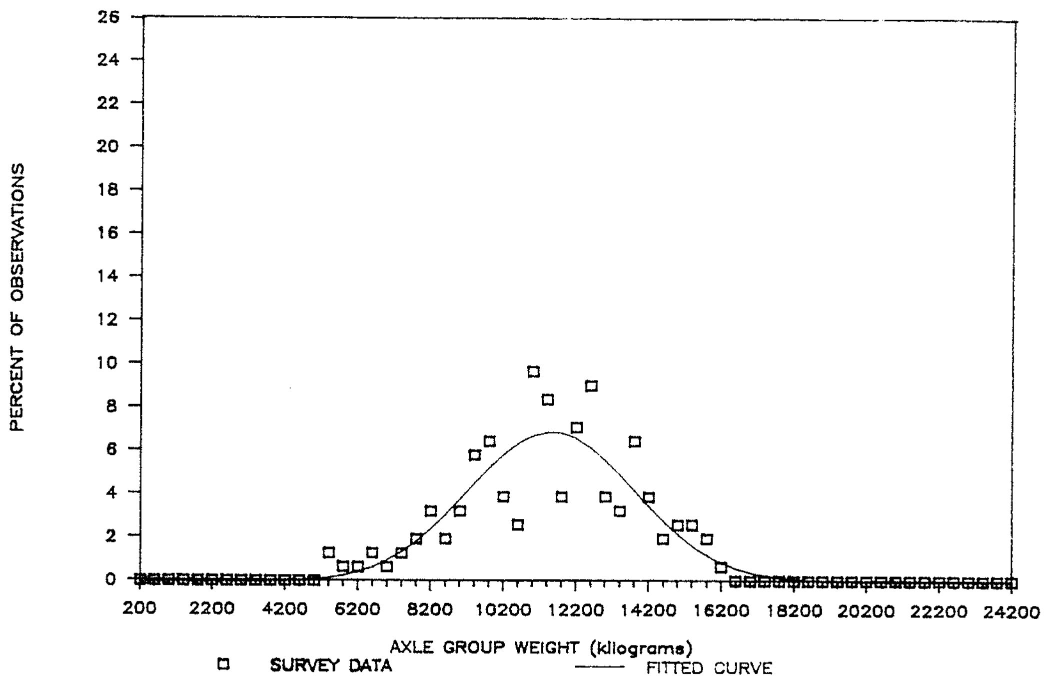
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits:9100 + 9100 + 9100 + 16000 + 5500 = 48800 kg
G.V.W. Limit: 50000 TO 56500 = 50000+ kg.

Governing Limit: 48800 kg. limit to total axle weights.

FIGURE 6.49: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 6 AXLE A-TRAINS
AXLE GROUP TYPE: TANDEM
GOVERNING LIMIT: 48800 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 155



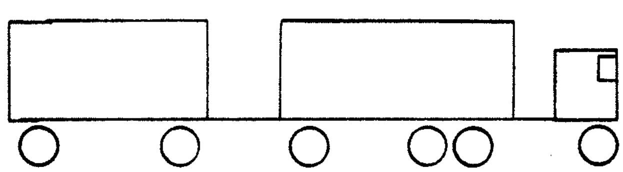
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^{2} / (2 * (SD1)^{2})$

SD1 = 2300 u = 11500 PI = 3.14159

GOVERNING REGULATORY LIMIT:



Axle Wt. Limits:9100 + 9100 + 9100 + 16000 + 5500 = 48800 kg
G.V.W. Limit: 50000 TO 56500 = 50000+ kg.

Governing Limit: 48800 kg. limit to total axle weights.

6.9 SEVEN AXLE A-TRAINS

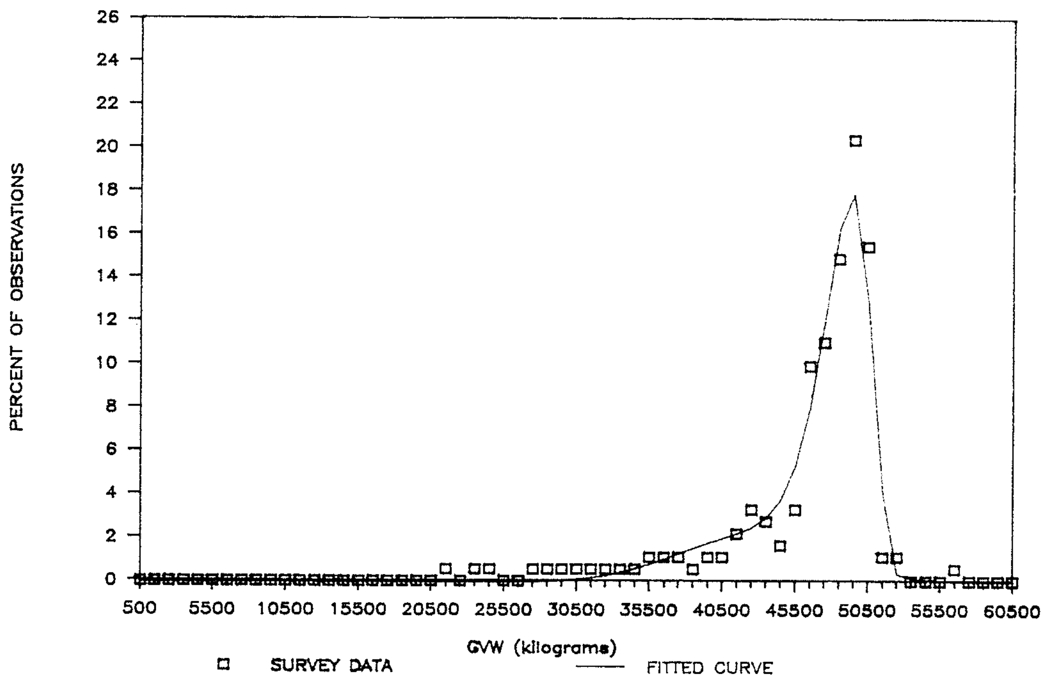
6.9.1 G.V.W. Distributions

At weight limits of both 50,000 kg and 55,700 kg, the g.v.w. distribution curves of seven-axle A-trains (Figures 6.50 and 6.51) show a pattern of truck weights heavily skewed to the high end of the scale and approaching very near to the maximum legal limits. The overall mean weights of these trucks were found to be 46,314 kg and 47,796 kg when operating on highways with maximum legislated g.v.w. limits of 50,000 kg and 55,700 kg, respectively.

Overweight vehicles made up over 15% at the lower weight limits but only 1% of all observations at the higher one. Another significant difference between the two distributions is the width of the weight ranges over which the observations are spread. When limited to 50,000 kg, the majority of the trucks operated at weights between 46,000 kg and 51,000 kg. This range increased to between 46,000 and 55,000 kg at the higher g.v.w. limit.

In both cases, the distribution curves showed evidence of being composed of two populations in much the same manner as three axle straight trucks and five axle tractor semitrailers. They are different, however, in that it appears that the normally distributed portion of the trucks seems to be much smaller among the A-trains than among either of the two smaller truck configurations, probably because A-trains are used more exclusively for high density commodity hauls.

FIGURE 6.50: GROSS VEHICLE WEIGHT DISTRIBUTION
VEHICLE TYPE: 7 AXLE A-TRAINS
GOVERNING LIMIT: 50000 kg. G.V.W. LIMIT
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 181



FITTED CURVE EQUATION:

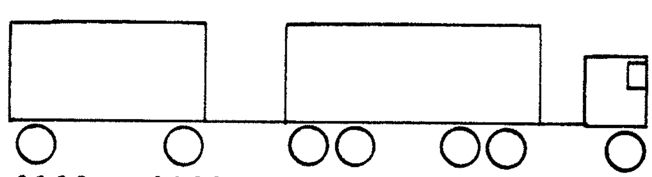
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

$$\text{where } K = 1/(2PI)^{1/2}, \quad w = [(\ln(SHIFT - x) - \ln(E))/SD2]^{2},$$

$$\text{and } a = (x - u)^{2} / (2 * (SD1)^{2})$$

SD1 = 5000 SD2 = .335 SHIFT = 54200
u = 42000 ln(E) = 8.6 PI = 3.14159

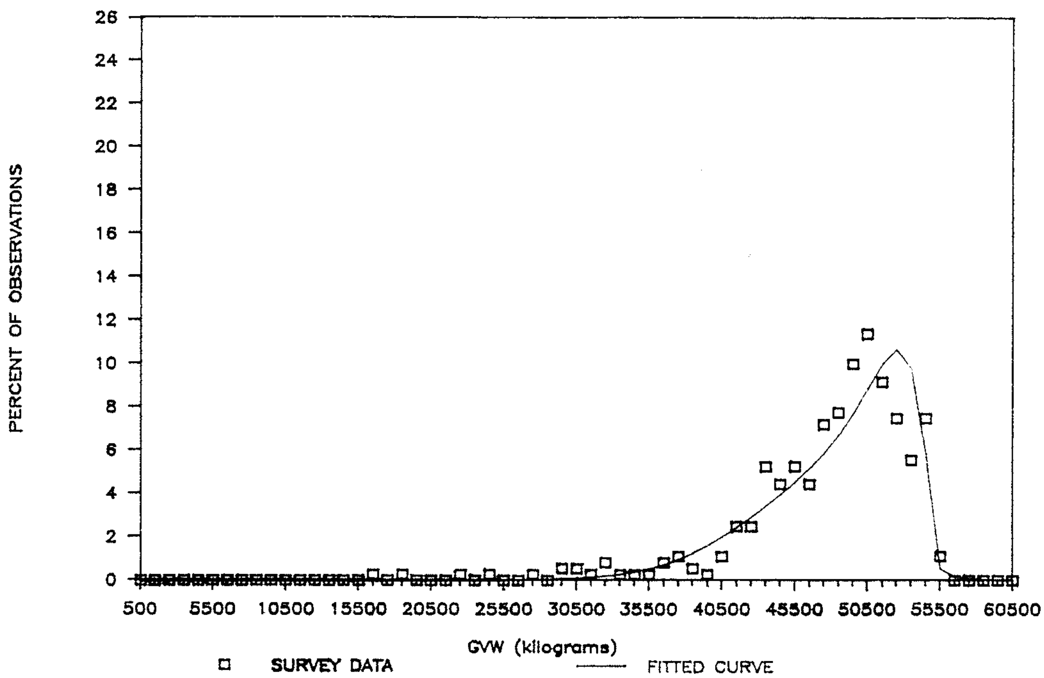
GOVERNING REGULATORY LIMIT:



Axle Wt.Limits: 9100 + 9100 + 16000 + 16000 + 5500 = 55700kg.
G.V.W. Limit: 50000 = 50000kg.

Governing Limit: 50000kg.

FIGURE 6.51: GROSS VEHICLE WEIGHT DISTRIBUTION
VEHICLE TYPE: 7 AXLE A-TRAINS
GOVERNING LIMIT: 55700 kg. G.V.W. LIMIT
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 360



FITTED CURVE EQUATION:

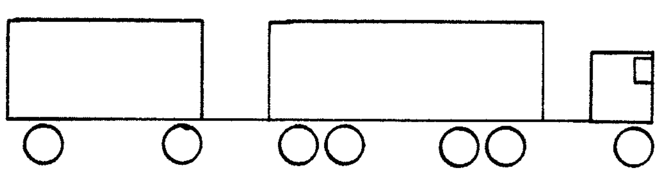
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

$$\text{where } K = 1/(2PI)^{1/2}, \quad w = [(\ln(SHIFT - x) - \ln(E))/SD2]^2,$$

$$\text{and } a = (x - u)^2 / (2 * (SD1)^2)$$

SD1 = 5000 SD2 = .710 SHIFT = 56000
u = 45700 ln(E) = 8.6 PI = 3.14159

GOVERNING REGULATORY LIMIT:



Axle Wt.Limits:9100 + 9100 + 16000 + 16000 + 5500 = 55700kg.
G.V.W. Limit: 56500 = 56500kg.

Governing Limit: 55700kg.

The fitted curve parameters are as follows.

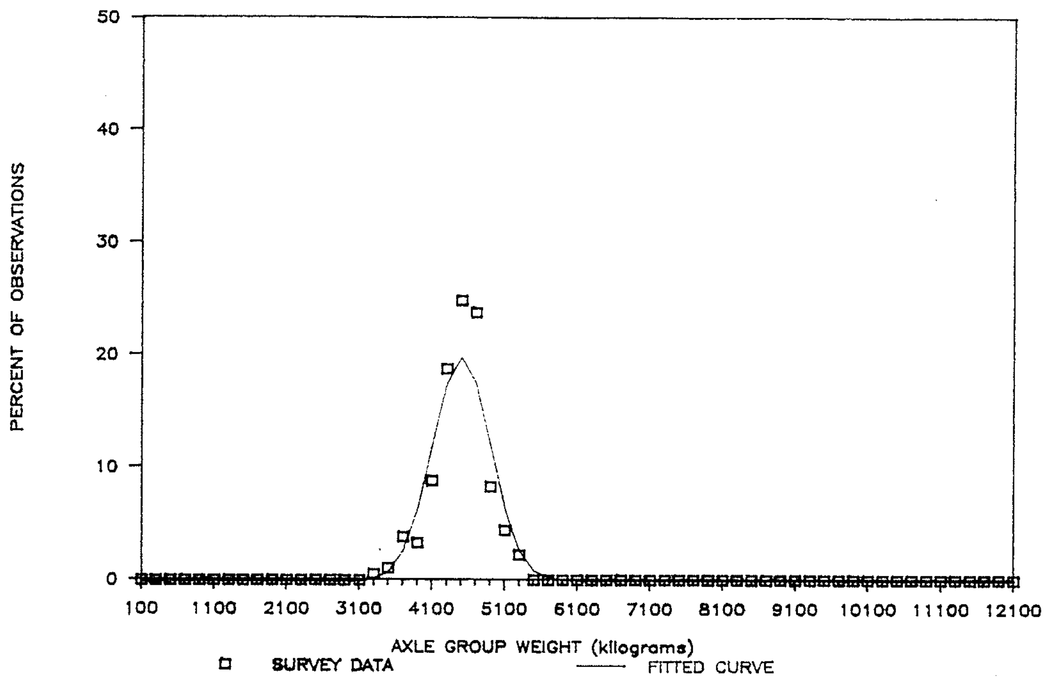
Parameter	50,000 kg Limit	55,700 kg Limit	Parameter Relationship
Ln (E)	8.6	8.6	Ln(E) = 8.6
Std. Deviation (log-normal)	.335	.710	SD2 = .0000657 Limit - 2.95
SHIFT	54,200 kg	56,000 kg	SHIFT = .316 limit + 38,400 kg
MEAN (u) (normal curve)	42,000 kg	45,700 kg	u = .649 limit + 9,550 kg
Std. Deviation (normal curve)	5,000 kg	5,000 kg	SD1 = 5,000 kg

The increase in the maximum legal g.v.w. resulted in an increase in both the SHIFT and MEAN variables (affecting the x-axis placement of the log-normal and normal portions of the fitted distribution). The increases were both only a portion of the weight limit increase. Unexpectedly, the standard deviation of the log-normal distribution curve increased substantially (more than doubling).

6.9.2 Axle Weight Distributions

Figures 6.52 and 6.53 show the bell-shaped curves formed by steering axle weight distributions of these vehicles under legislated total axle weights of 50000 kg and 55700 kg, respectively. Mean weights of these axles are 4,458 kg and 4,565 kg. Overweight axles make up less than 5% of observations at both weight levels.

FIGURE 6.52: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 7 AXLE A-TRAINS
AXLE GROUP TYPE: STEERING
GOVERNING LIMIT: 50000 kg. G.V.W. LIMIT
COMMODITY GROUP: `ALL' NUMBER OF OBS: 181



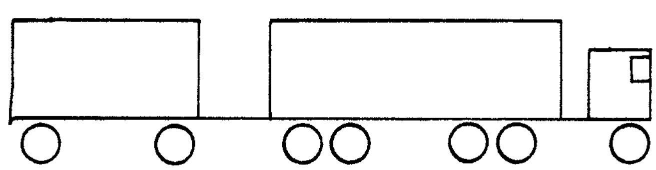
FITTED CURVE EQUATION:

$$p(x) = K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 400 u = 4500 PI = 3.14159

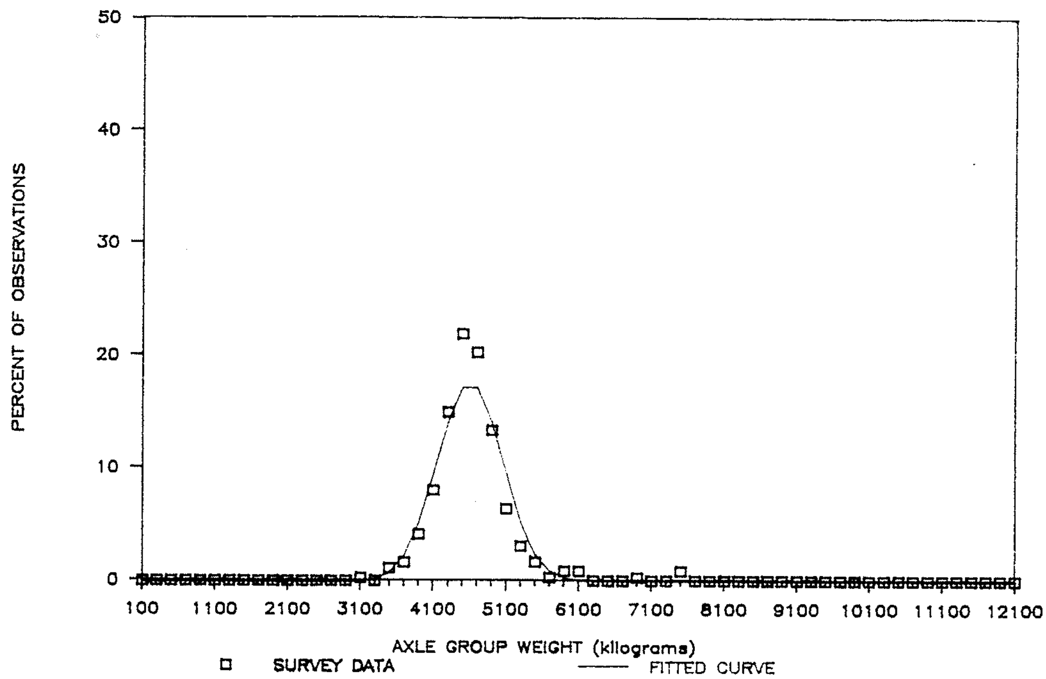
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits:9100 + 9100 + 16000 + 16000 + 5500 =55700 kg
G.V.W. Limit: 50000 kg.

Governing Limit: 50000 kg. G.V.W. limit.

FIGURE 6.53: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 7 AXLE A-TRAINS
AXLE GROUP TYPE: STEERING
GOVERNING LIMIT: 55700 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: `ALL' NUMBER OF OBS: 360



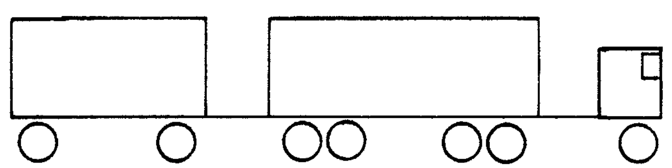
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 450 u = 4600 PI = 3.14159

GOVERNING REGULATORY LIMIT:



Axle Wt. Limits:9100 + 9100 + 16000 + 16000 + 5500 =55700 kg
G.V.W. Limit: 56500 kg.

Governing Limit: 55700 kg. limit to total axle weights.

The parameters of the normally distributed fitted curves are as follows.

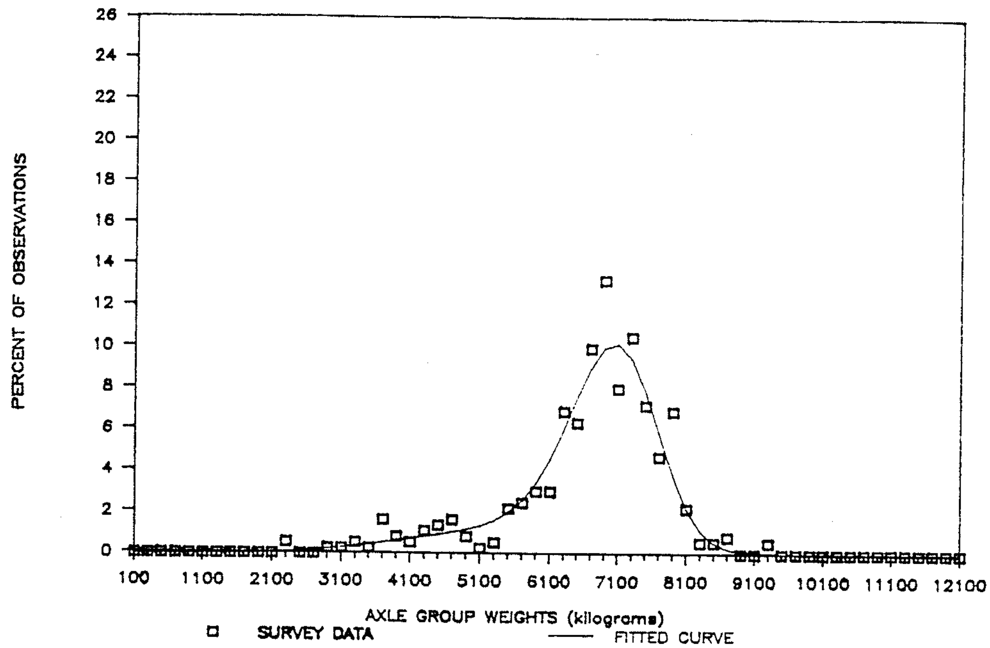
Parameter	50,000 kg Limit	55,700 kg Limit	Parameter Relationship
Mean (u)	4,500 kg	4,600 kg	u = .0175 Limit + 3,623 kg
Std. Deviation (S.D.)	400 kg	450 kg	S.D. = .00877 Limit - 38.0 kg

Both parameters showed small increases as the legal weight limits were raised.

Single axle weights (Figures 6.54 and 6.55) showed a pattern similar to that displayed by the g.v.w. curves of these trucks, i.e., heavily skewed to the upper end of the weight scale and suitable for representation by combination of normal and log-normal distribution curves. The single axles were seldom overweight (<5%) and averaged 6,651 kg and 7,106 kg at the legal weight limits. Interestingly, the single axle observations at the higher weight limit tended to be spread over a wider weight range (standard deviations were 1,129 kg and 1,421 kg),. Curve parameters are as follows.

Parameter	50,000 kg Limit	55,700 kg Limit	Parameter Relationship
Ln (E)	8.7	8.7	Ln(E) = 8.7
Std. Deviation (log-normal)	.106	.150	SD2 = .00000772 Limit - .279
SHIFT	13,000 kg	13,700 kg	SHIFT = .123 limit + 6,860 kg
MEAN (u) (normal curve)	5,600 kg	5,600 kg	u = 5,600 kg
Std. Deviation (normal curve)	1,600 kg	1,600 kg	SD1 = 1,600 kg

FIGURE 6.54: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 7 AXLE A-TRAINS
AXLE GROUP TYPE: SINGLE
GOVERNING LIMIT: 50000 kg. G.V.W. LIMIT
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 362



FITTED CURVE EQUATION:

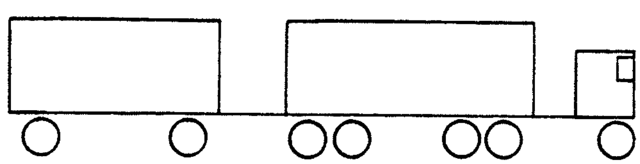
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

$$\text{where } K = 1/(2PI)^{1/2}, \quad w = [(\ln(SHIFT - x) - \ln(E))/SD2]^2,$$

$$\text{and } a = (x - u)^2 / (2 * (SD1)^2)$$

SD1 = 1600 SD2 = .106 SHIFT = 13000
u = 5600 ln(E) = 8.7 PI = 3.14159

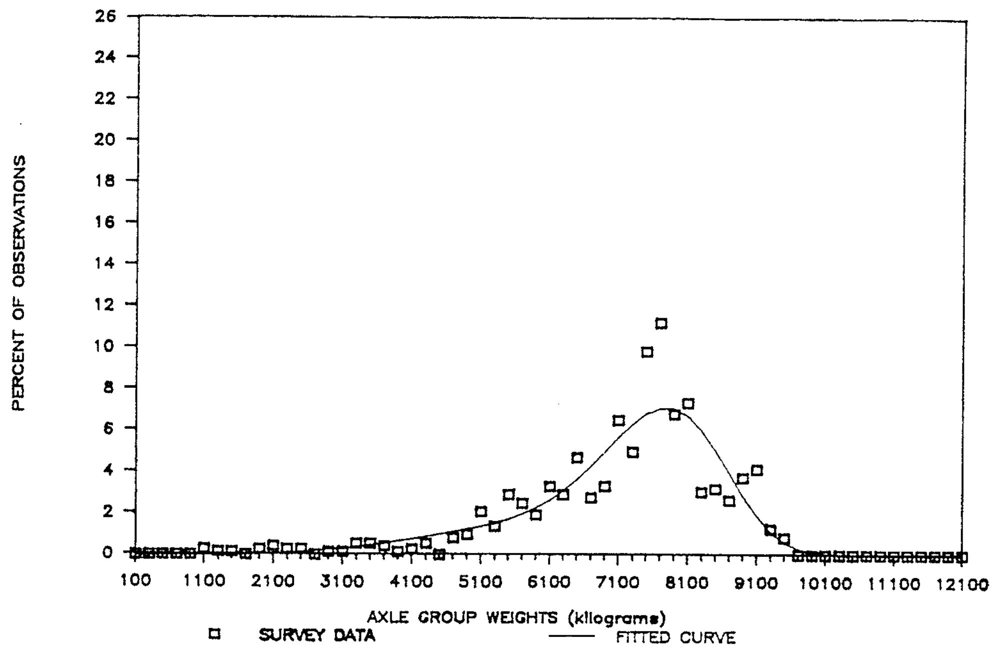
GOVERNING REGULATORY LIMIT:



Axle Wt.Limits:9100 + 9100 + 16000 + 16000 + 5500 = 55700kg.
G.V.W. Limit: 50000kg.

Governing Limit: 50000kg. G.V.W. limit.

FIGURE 6.55: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 7 AXLE A-TRAINS
AXLE GROUP TYPE: SINGLE
GOVERNING LIMIT: 55700 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: `ALL' NUMBER OF OBS: 720



FITTED CURVE EQUATION:

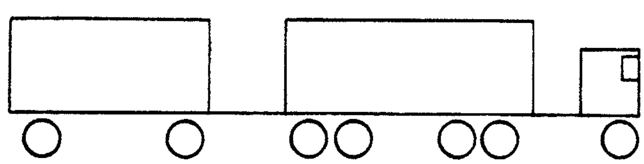
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

where $K = 1/(2PI)^{1/2}$, $w = [(\ln(SHIFT - x) - \ln(E))/SD2]^2$,

and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 1600 SD2 = .150 SHIFT = 13700
u = 5600 ln(E) = 8.7 PI = 3.14159

GOVERNING REGULATORY LIMIT:



Axle Wt.Limits:9100 + 9100 + 16000 + 16000 + 5500 = 55700kg.
G.V.W. Limit: 56500kg.

Governing Limit: 56500kg. limit to total axle weights.

The parameters of the normal portion of the distribution curve remained constant while the log-normal curve shifted upwards along with the upward shift in weight limit. The standard deviation of this curve also increased.

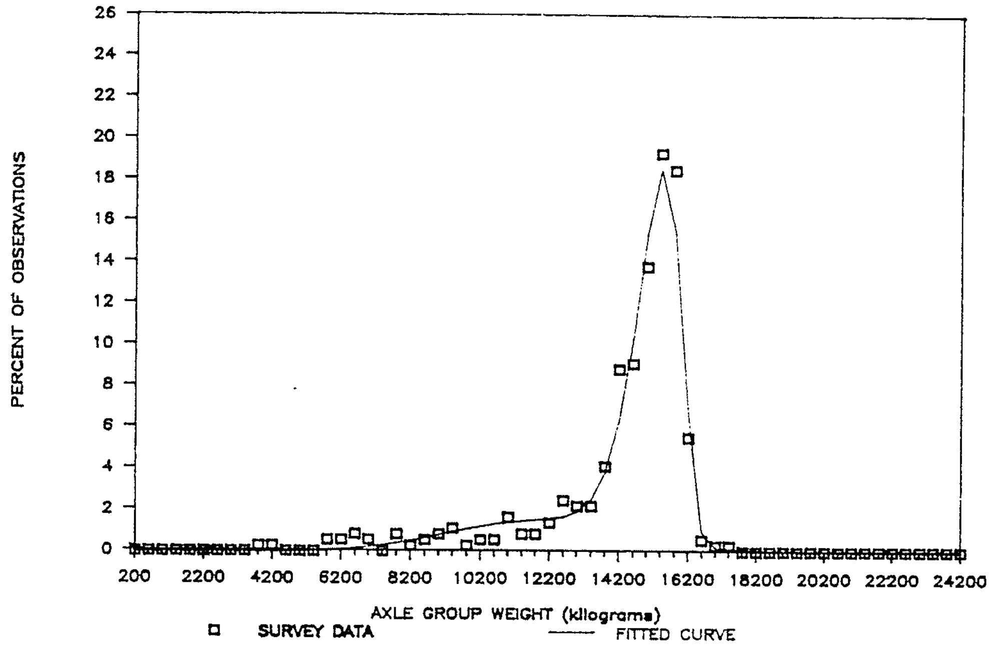
Tandem axle weight distribution curves (Figures 6.56 and 6.57) display characteristics similar to those of the single axle weight curves. They are heavily skewed to the right, with the majority of axles at or near the maximum legislated weight limit. Overweight axles were found to be less than 5% of the total observations and mean axle weights were 14,277 kg and 14,509 kg for trucks limited to 50,000 kg and 55,700 kg in total axle weights, respectively.

The combination curves used in modelling these axle weight distributions have these parameters:

Parameter	50,000 kg Limit	55,700 kg Limit	Parameter Relationship
Ln (E)	7.8	7.8	Ln(E) = 7.8
Std. Deviation (log-normal)	.282	.349	SD2 = .0000117 Limit - .303
SHIFT	17,700 kg	17,800 kg	SHIFT = .0175 limit + 16,823 kg
MEAN (u) (normal curve)	11,800 kg	12,500 kg	u = .123 Limit + 5,660 kg
Std. Deviation (normal curve)	2,600 kg	2,600 kg	SD1 = 2,600 kg

Both portions of the combination curve shifted upwards coincident with the upward shift in the vehicle weight limits. In addition, the standard deviation of the log-normal portion of the curve also increased along with the limit increase.

FIGURE 6.56: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 7 AXLE A-TRAINS
AXLE GROUP TYPE: TANDEM
GOVERNING LIMIT: 50000 kg. G.V.W. LIMIT
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 362



FITTED CURVE EQUATION:

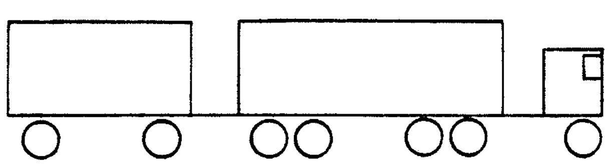
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

where $K = 1/(2PI)^{1/2}$, $w = [(\ln(SHIFT - x) - \ln(E))/SD2]^2$,

and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 2600 SD2 = .282 SHIFT = 17700
u = 11800 ln(E) = 7.8 PI = 3.14159

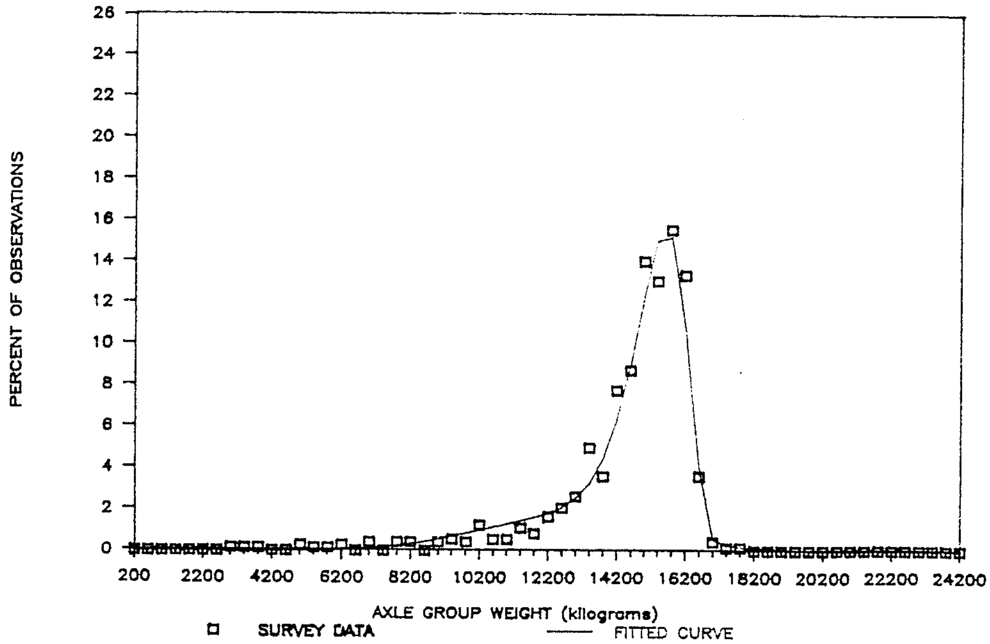
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits:9100 + 9100 + 16000 + 16000 + 5500 = 55700 kg
G.V.W. Limit: 50000 kg.

Governing Limit: 50000 kg. G.V.W. Limit.

FIGURE 6.57: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 7 AXLE A-TRAINS
AXLE GROUP TYPE: TANDEM
GOVERNING LIMIT: 55700 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 720



FITTED CURVE EQUATION:

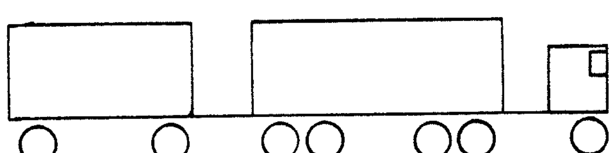
$$p(x) = .25K/(SD1) * e^{-a} + .75K/(SD2 * (SHIFT - x)) * e^{-w/2}$$

where $K = 1/(2PI)^{1/2}$, $w = [(\ln(SHIFT - x) - \ln(E))/SD2]^2$,

and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 2600 SD2 = .349 SHIFT = 17800
u = 12500 ln(E) = 7.8 PI = 3.14159

GOVERNING REGULATORY LIMIT:



Axle Wt. Limits:9100 + 9100 + 16000 + 16000 + 5500 = 55700 kg
G.V.W. Limit: 56500 kg.

Governing Limit: 55700 kg. Limit to total axle weights.

6.10 SEVEN-AXLE B-TRAINS

6.10.1 G.V.W. Distributions

The g.v.w. distribution of these vehicles under a legislated gvw limit of 53500 kg is bell-shaped and relatively narrow, with almost all observations concentrated between 42,000 kg and 54,000 kg (see Figure 6.58). The mean weight of these vehicles was relatively high at 48,632 kg and almost 10% were overweight. The distribution was approximated by a normally distributed curve with parameters as follows:

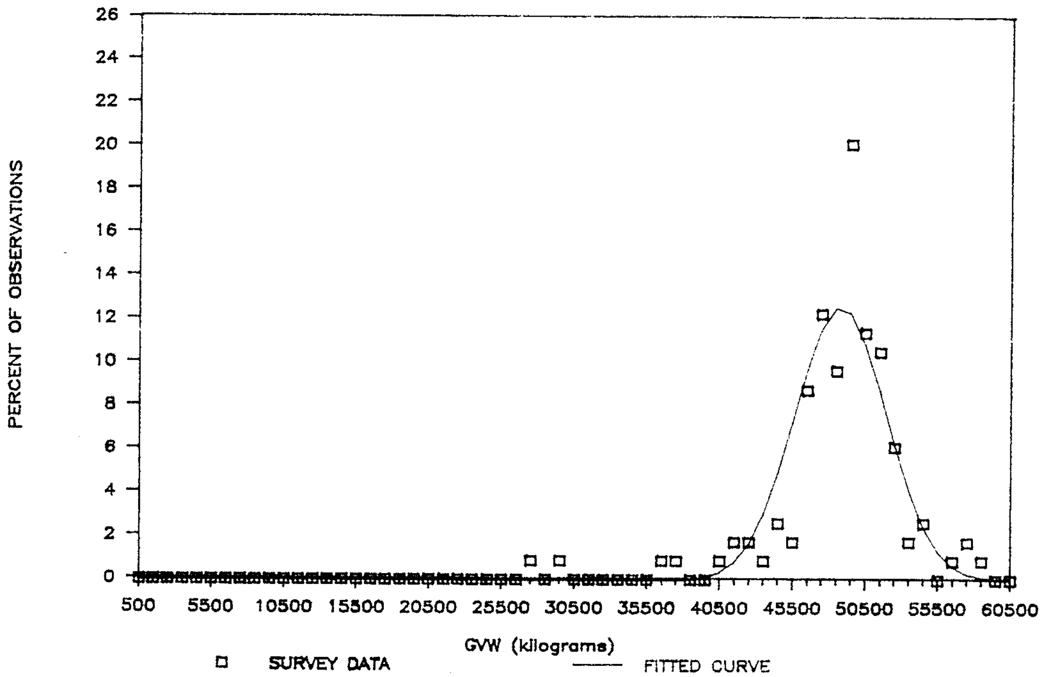
Parameter	53,500 kg Limit
Mean (u)	48,800 kg
Std. Deviation	3,200 kg

The absence of any significant numbers of observations below 40,000 kg suggests that these vehicles were almost exclusively used for the transport of high density commodities.

6.10.2 Axle Weight Distributions

The shape of steering axle weight distribution curves for seven-axle B-trains are, like those for most other truck configurations, symmetrical, bell-like, and concentrated between 4,000 kg and 5,000 kg (see Figures 6.59 and 6.60). Overweight axles accounted for a negligible part of the total body of observations under both weight limits. Mean axle weights under

FIGURE 6.58: GROSS VEHICLE WEIGHT DISTRIBUTION
VEHICLE TYPE: 7 AXLE B-TRAINS
GOVERNING LIMIT: 53500 kg. G.V.W. LIMIT
COMMODITY GROUP: `ALL' NUMBER OF OBS: 114



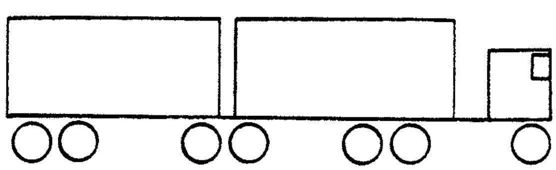
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^{2} / (2 * (SD1)^{2})$

SD1 = 3200 u = 48800 PI = 3.14159

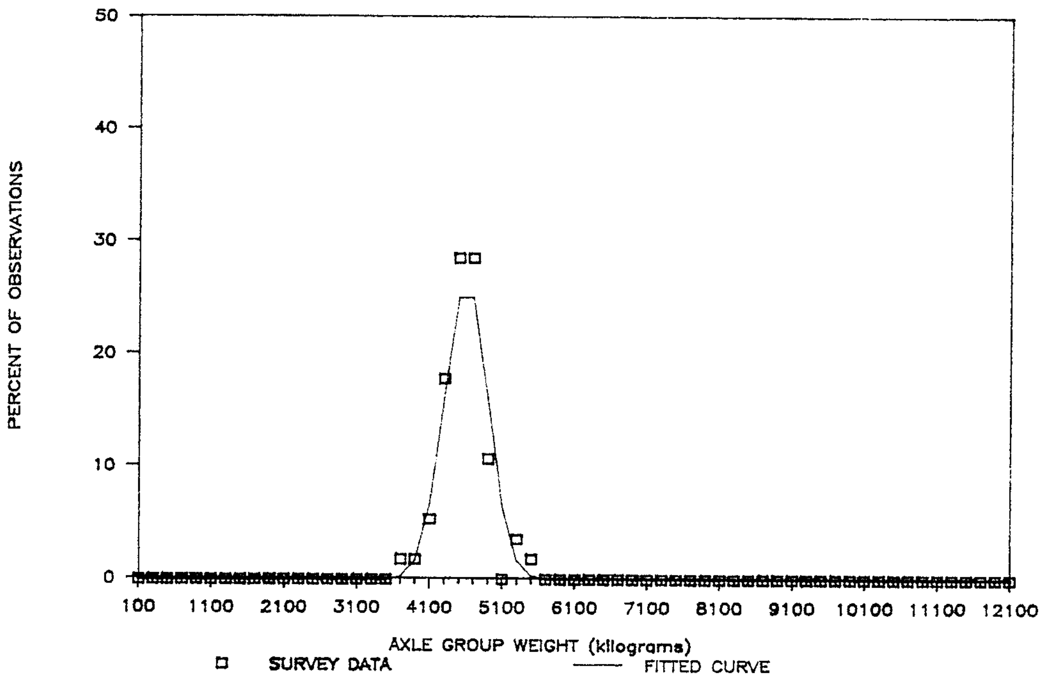
GOVERNING REGULATORY LIMIT:



Axle Wt.Limits:16000 + 16000 + 16000 + 5500 = 53500 kg.
G.V.W. Limit: 56500 = 56500 kg.

Governing Limit: 53500 kg.

FIGURE 6.59: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 7 AXLE B-TRAINS
AXLE GROUP TYPE: STEERING
GOVERNING LIMIT: 47600 kg. G.V.W. LIMIT
COMMODITY GROUP: `ALL' NUMBER OF OBS: 56



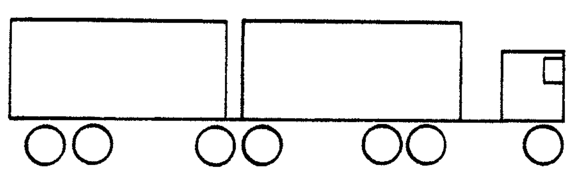
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 300 u = 4600 PI = 3.14159

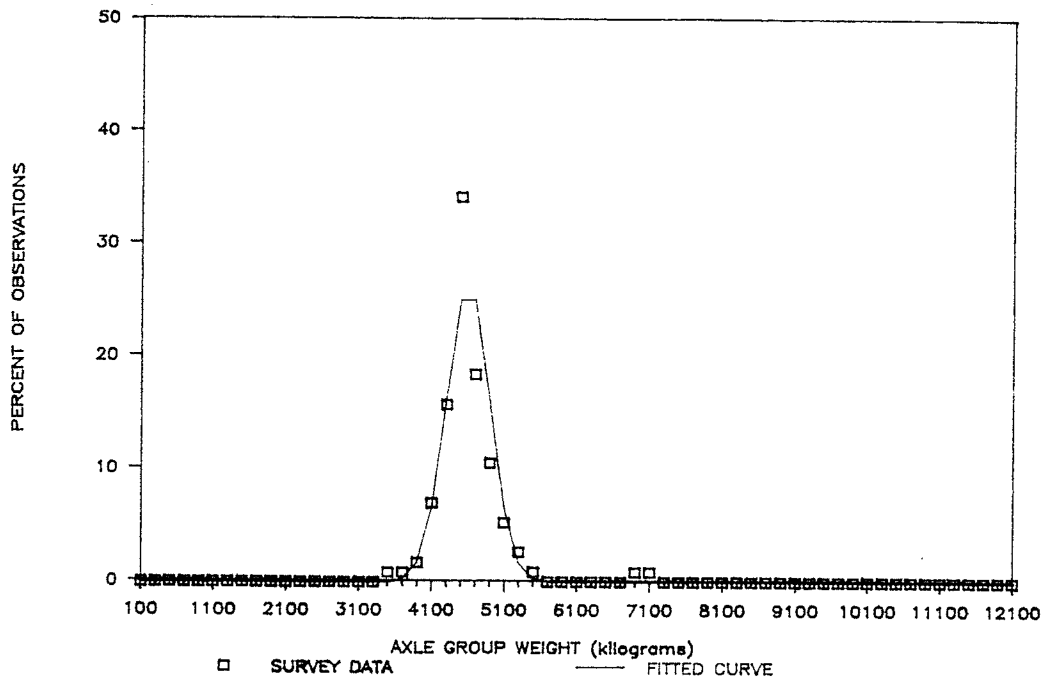
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits:14500 + 14500 + 14500 + 5500 = 49000 kg.
G.V.W. Limit: 47600 kg.

Governing Limit: 47600 kg. G.V.W. limit.

FIGURE 6.60: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 7 AXLE B-TRAINS
AXLE GROUP TYPE: STEERING
GOVERNING LIMIT: 53500 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 114



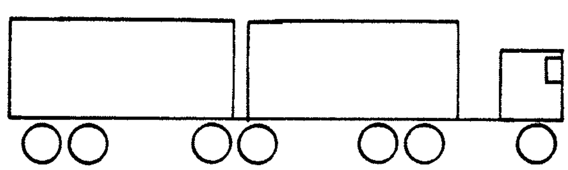
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 300 u = 4600 PI = 3.14159

GOVERNING REGULATORY LIMIT:



Axle Wt. Limits:16000 + 16000 + 16000 + 5500 = 53500 kg
G.V.W. Limit: 56500 kg.

Governing Limit: 53500 kg. limit to total axle weights.

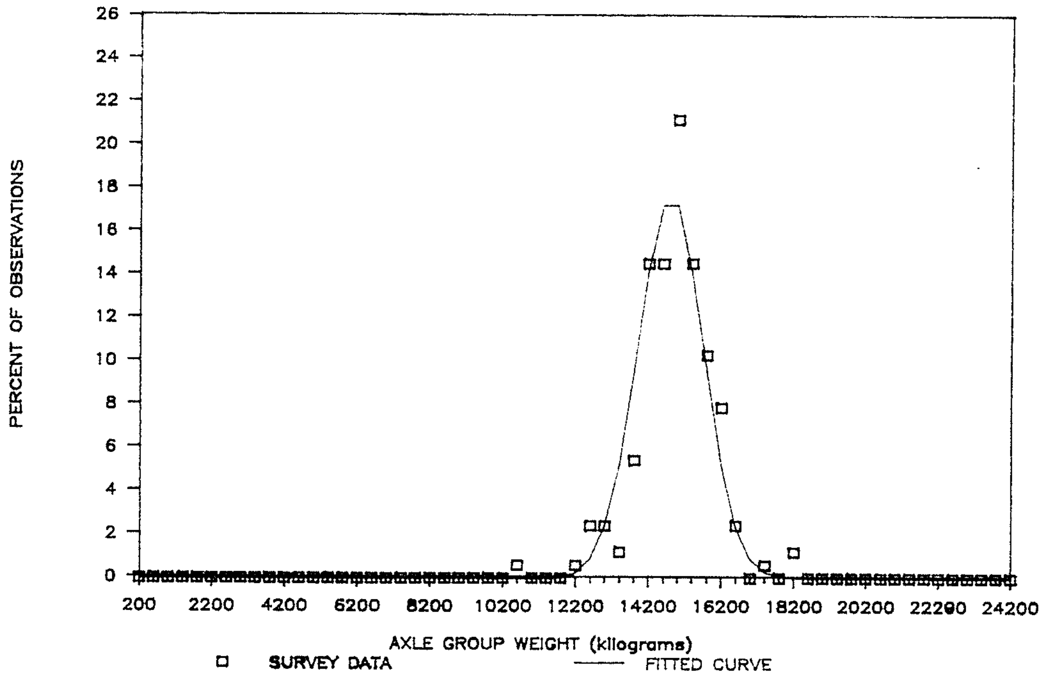
the limits of 47,600 kg and 53,500 kg were 4,523 kg and 4,542 kg, respectively; the difference was only 19 kg--an insignificant amount.

The parameters of the normal curve used to model these steering axle weight distributions reflect the similarity of the two groups of observations. Both parameters remain unchanged despite the 5,900 kg increase in allowable vehicle weight. The parameters are as follows.

Parameter	47,600 kg Limit	53,500 kg Limit	Parameter Relationship
Mean (u)	4,600 kg	4,600 kg	u = 4,600 kg
Std. Deviation (S.D.)	300 kg	300 kg	S.D. = 300 kg

Figures 6.61 and 6.62 show tandem axle group weight distributions for seven-axle B-trains under gvw limits of 47600 kg and 53500 kg, respectively differ from those of most other truck types in that they lack any significant numbers of observations well below the maximum axle group weight limit. The majority of observations are concentrated between 12,000 kg and 18,000 kg, with mean weights of 14,870 kg and 14,697 kg for trucks limited to g.v.w.'s of 47,600 kg and 53,500 kg, respectively. Overweight axle groups account for between 10 and 20% of all observations. These distributions differ from those of most other truck types in that they lack any significant number of observations at low axle weight levels, suggesting that these vehicles are used predominantly for high density commodities.

FIGURE 6.61: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 7 AXLE B-TRAINS
AXLE GROUP TYPE: TANDEM
GOVERNING LIMIT: 47600 kg. G.V.W LIMIT
COMMODITY GROUP: 'ALL' NUMBER OF OBS: 56



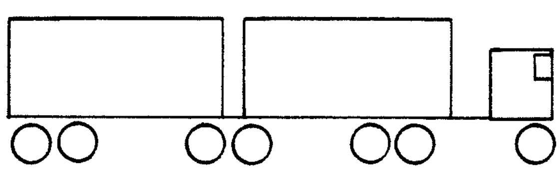
FITTED CURVE EQUATION:

$$p(x) = K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 900 u = 14800 PI = 3.14159

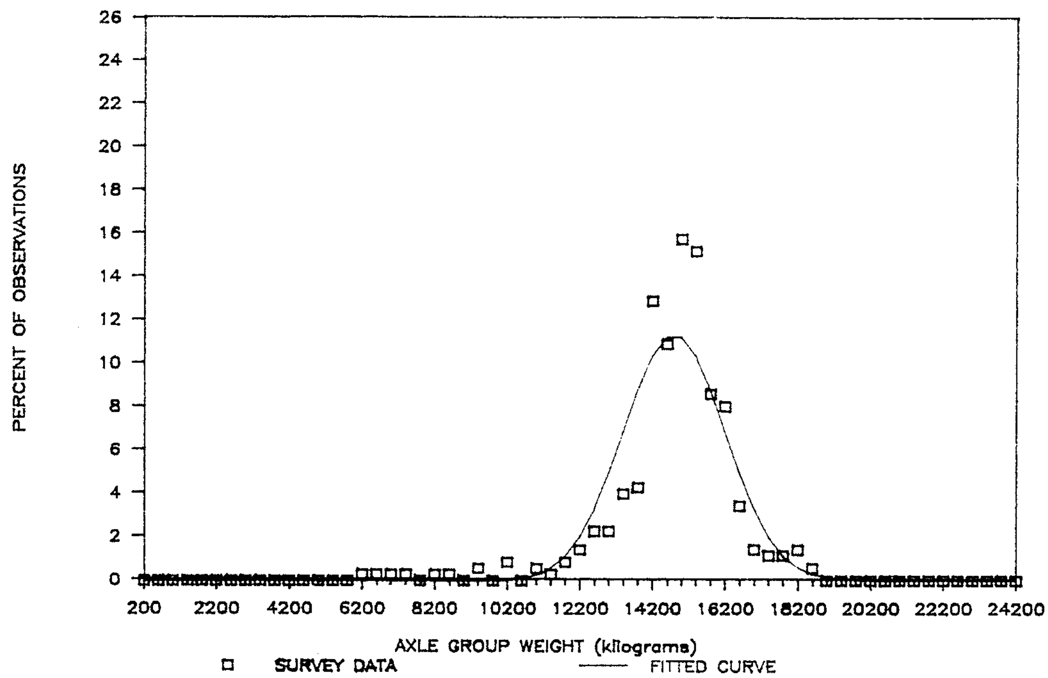
GOVERNING REGULATORY LIMIT:



Axle Wt. Limits:14500 + 14500 + 14500 + 5500 = 49000 kg.
G.V.W. Limit: 47600 kg.

Governing Limit: 47600 kg. G.V.W. limit.

FIGURE 6.62: AXLE GROUP WEIGHT DISTRIBUTION
VEHICLE TYPE: 7 AXLE B-TRAINS
AXLE GROUP TYPE: TANDEM
GOVERNING LIMIT: 53500 kg. LIMIT TO TOTAL AXLE WEIGHTS
COMMODITY GROUP: `ALL' NUMBER OF OBS: 342



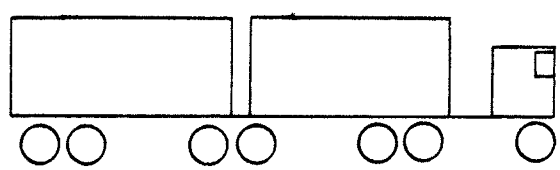
FITTED CURVE EQUATION:

$$p(x)=K/(SD1) * e^{-a}$$

where $K = 1/(2PI)^{1/2}$ and $a = (x - u)^2 / (2 * (SD1)^2)$

SD1 = 1400 u = 14800 PI = 3.14159

GOVERNING REGULATORY LIMIT:



Axle Wt. Limits:16000 + 16000 + 16000 + 5500 = 53500 kg.
G.V.W. Limit: 56500 kg.

Governing Limit: 53500 kg. limit to total axle weights.

The normal distribution curve parameters are as follows.

Parameter	47,600 kg Limit	53,500 kg Limit	Parameter Relationship
Mean (u)	14,800 kg	14,800 kg	u = 14,800 kg
Std. Deviation (S.D.)	900 kg	1,400 kg	S.D. = .0847 Limit - 3,134 kg

The mean did not increase despite an increase of 5,900 kg in the g.v.w. limit of these vehicles. The standard deviation increased substantially, although the fact that only 56 trucks were observed operating under a limit of 47,600 kg may have resulted in a misleading standard deviation figure for this particular weight limit.

CHAPTER 7

DIMENSIONAL CHARACTERISTICS

7.1 AXLE GROUP SPREADS

The spacing of axles within a tandem axle group affects the relative pavement damage attributable to that particular axle group. It is generally known that, all other factors being equal, narrow axle spacings result in increased stresses within pavements (Yoder and Witczak, 1975).

The AASHO road tests, on which most methods of E.S.A.L. calculations are based, were performed with axle spreads ranging from 48" (1.22 m) to 54" (1.37 m). The majority of tandem axle group spreads were set at 50" (1.27 m) (Highway Research Board, 1961). The possibility exists for a systematic over (or under) estimation of E.S.A.L. figures if the spreads of tandem axle groups used in recent years differ significantly from the 1.27 m figure on which the AASHTO equations are based.

The Manitoba data confirms the non-existence of any significant number of vehicles with axle group spreads of less than 1.3 m (comparable to the 1.27 m AASHTO average). Figures 7.1 through 7.4 are based on this data. A majority of axle groups are within the range of 3 cm and 13 cm greater than the AASHTO road test axle spreads, while a minority are more than 13 cm wider. Axle group spreads set at less than 1.3 m are almost nonexistent in Manitoba. Furthermore, the larger and heavier vehicles tend to use wider

FIGURE 7.1: TANDEM AXLE GROUP SPREADS
THREE AXLE STRAIGHT TRUCKS

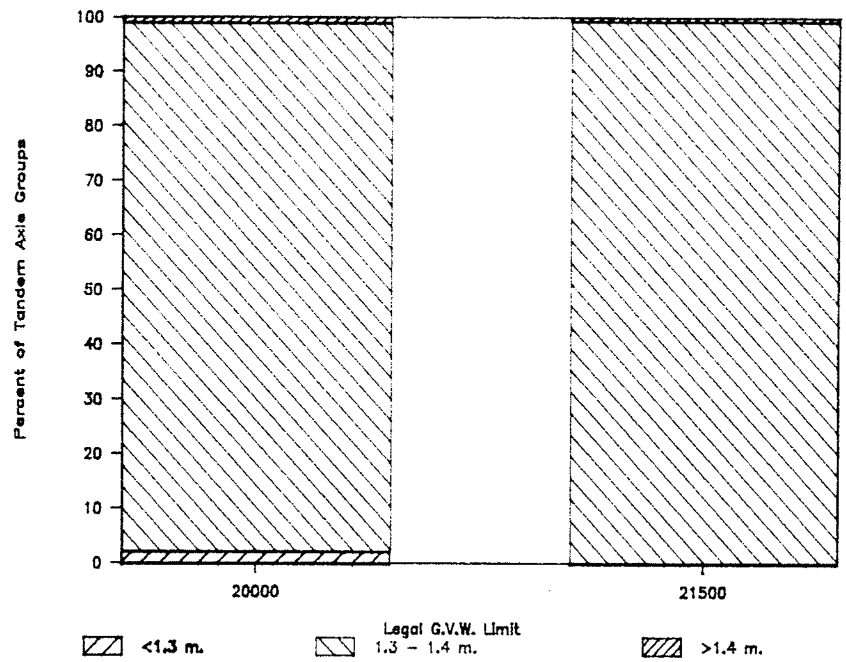


FIGURE 7.2: TANDEM AXLE GROUP SPREADS
TRACTOR SEMITRAILERS

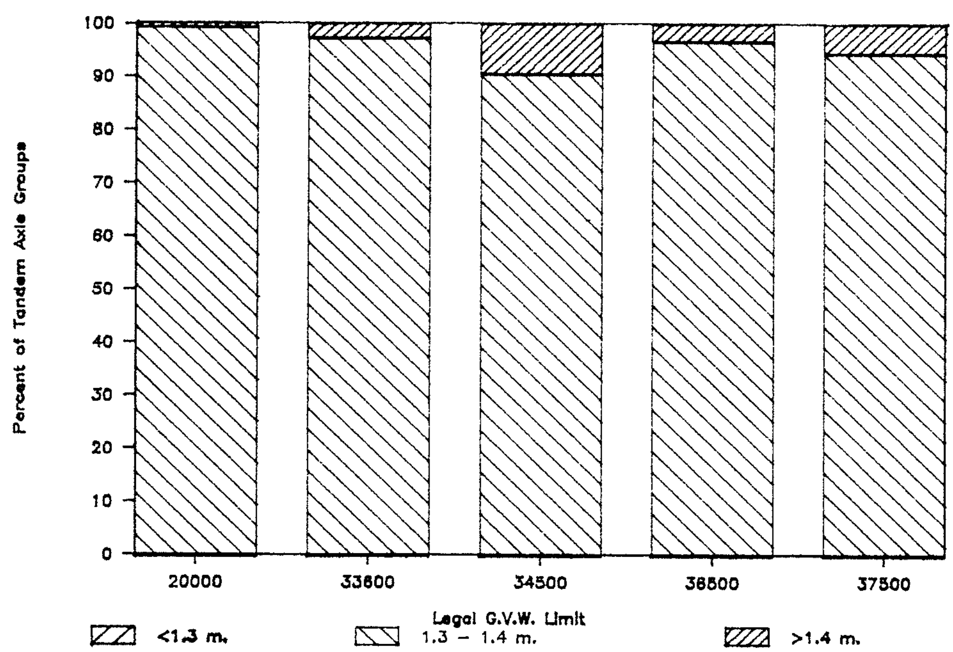


FIGURE 7.3: TANDEM AXLE GROUP SPREADS
A-TRAINS

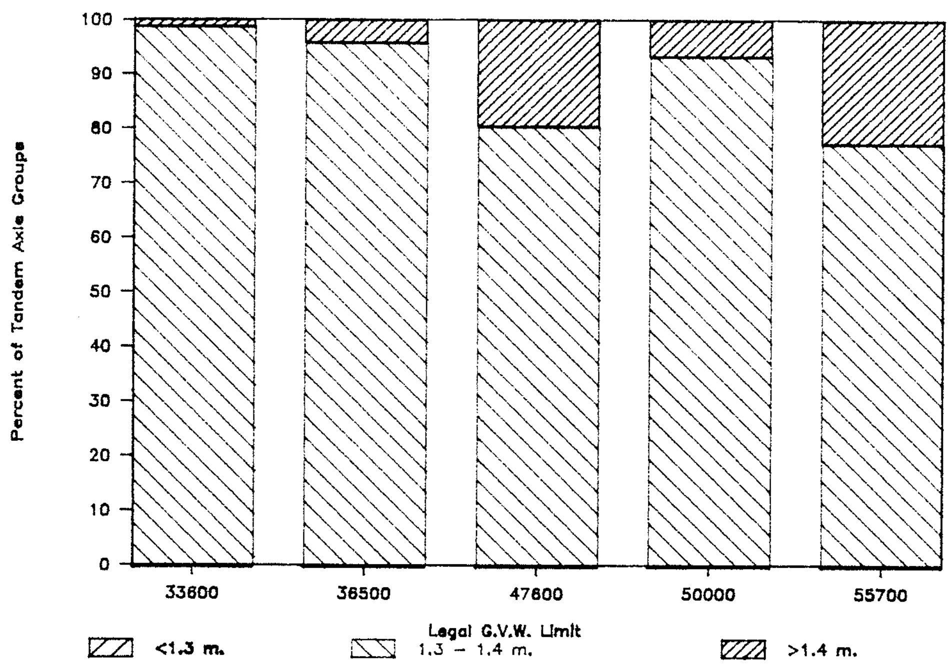
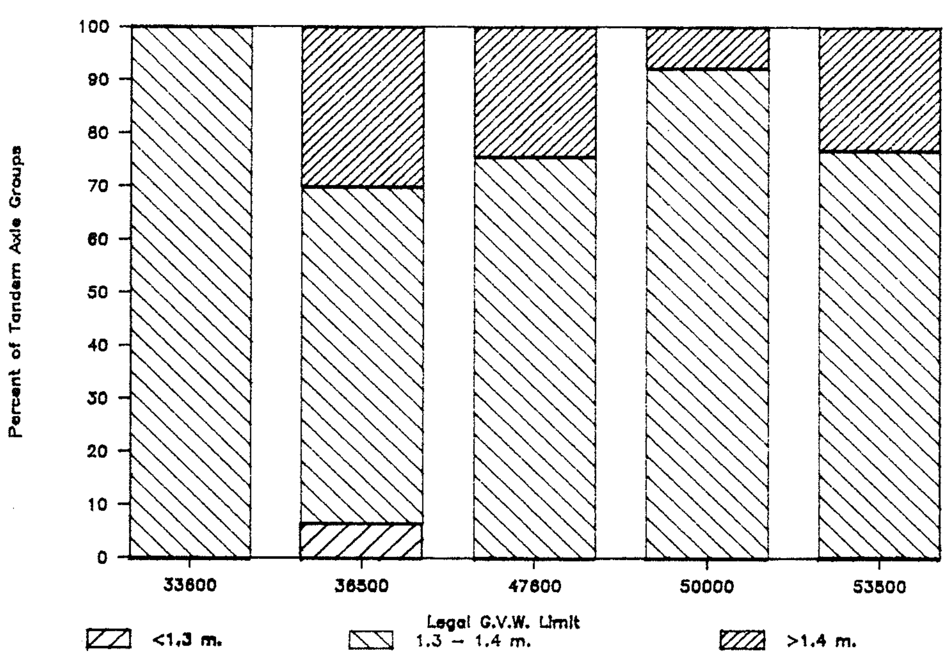


FIGURE 7.4: TANDEM AXLE GROUP SPREADS
B-TRAINS

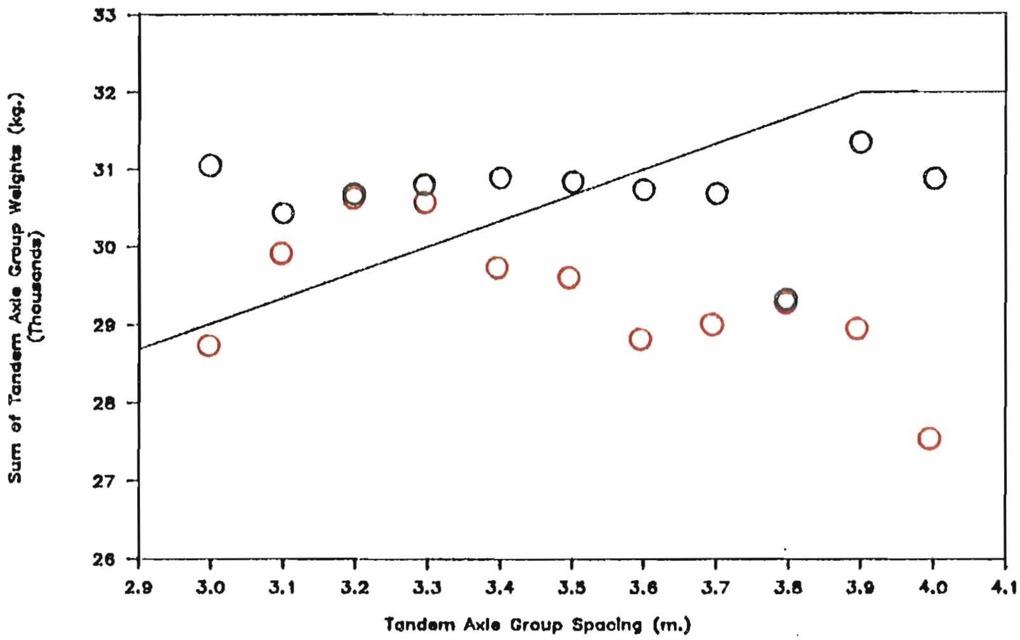


axle groups more frequently than smaller vehicles. For example, on primary highways with g.v.w. limits of 125,000 lb (56,500 kg), the percentage of tandem axles spread wider than 1.4 m is 15% and 24% for A- and B-trains, respectively, while the corresponding figures for straight trucks and tractor semitrailers are only 1% and 6%. Since increases in axle spreads result in decreased pavement damage given similar loads, it is apparent that the direct application of equivalency factors based on the AASHO road test to Manitoba truck traffic may result in an over-estimation of E.S.A.L.'s, particularly for larger combinations.

Due to the extremely heavy and dense nature of some commodities, most notably gravel, the semitrailers designed to haul this material are normally much shorter than most others. Long semitrailers are unnecessary, since the volume of gravel required to bring the vehicle to its maximum legal weight limit is relatively small. Shorter vehicles are preferred, because they are lighter, less expensive, and put less stress on their frame members than do longer ones.

The short wheelbases of these vehicles can cause pavement stress problems, since they are typically loaded to their maximum legal weights, and the tandem axle groups are sometimes placed within three or four metres of each other. On November 7, 1982, gravel hauling 3-S2 units were required to operate with a minimum of four metres separating the two inner axles of the pair of tandems. Any pair of tandems spaced at less than this limit are now subject to a reduction of 330 kg in their combined legislated weight limit for every 10 cm below 4.0 metres which they are spaced. The purpose of this legislation is to reduce

FIGURE 7.5: MEAN TANDEM AXLE GROUP WEIGHTS OF TRACTOR SEMITRAILERS HAULING GRAVEL



○ BEFORE NOV.7/82 ○ AFTER NOV.7/82 —— LEGISLATED MAX.

the numbers of these vehicles with short wheelbases and to reduce the weights of those which continued to operate with spacings of less than 4.0 m.

Figure 7.5 is based on Manitoba Department of Highways Truck Weight and Dimension survey results from 1972 to 1986, inclusive, and shows similar patterns of non-compliance with the 1982 regulation, both prior to and after its introduction on November 7 of that year. Both graph lines display similar mean axle weights at spacings ranging from 3.0 to 4.0 metres, i.e., there is no sign of weight reductions for axle spacings under 4.0 m as required by the 1982 regulation. Clearly, gravel truck operators do not load short wheelbase equipment any differently than they do semitrailers with wheelbases exceeding 4.0 m, possibly because they are either unaware of the legislation, or feel that low levels of enforcement do not warrant the cost of compliance.

7.2 OFFTRACKING PERFORMANCE

In Manitoba, geometric design of urban and rural streets and highways is based on the set of AASHTO geometric design vehicles (AASHTO, 1984). The WB-50 design vehicle (Figure 3.6) is used in the design of roadways on which the largest of truck combinations commonly operate. The swept path of this vehicle in a 180 degree turn with a 45 ft (13.9 m) turning radius is 27.7 ft (8.45 m). Comparative swept paths of vehicle combinations presently in use in Manitoba are found within Table 7.2.

Table 7.2. Swept paths of vehicle combinations in Manitoba*
(180 degree turn with a 45 ft (139 m) radius)

Combination Type	Mean Swept Path
5-axle Tractor Semi	8.52 m
7-axle A-train	6.91 m
7-axle B-train	8.98 m
8-axle A-train	6.47 m
WB-50 Vehicle	8.45 m

* Calculations of swept paths are based on Woodrooffe, Morisset & Smith, 1983

In terms of offtracking performance, 3-S2 vehicles and B-train vehicles place the largest demand on the geometric design of roadways. A highway designed to accommodate the WB-50 design vehicle may not be wholly adequate, particularly if B-trains make up a large percentage of the truck traffic.

7.3 TIRE WIDTHS

Truck tire widths are generally measured in inches and range from about 7 to 18 inches per tire, the most common widths being 9, 10, 11, and 12 inches. On examination of the Manitoba Weight and Dimension survey data, it was found that 4 tire axles (most drive and trailer axles) of 3-S2 and larger vehicles were most commonly equipped with 10 and 11 inch tires (typically over 95%). Nine and 10 inch tires were most often used on three axle straight trucks (over 90%). A number of smaller sizes were used on two axle straight trucks, the most common being 7.5, 8.25, 9, and 10 inches.

The widths of tires on steering axles were generally consistent with those on four tire axles with the exception of a number of very wide tires on 3-S2 vehicles as well as on straight trucks. These tires (13 inches or wider) made up less than 2% of the total on tractor semitrailer and two axle straight truck steering axles but almost 16% of those on three axle straight trucks.

The legislated maximum weight limit with respect to tire widths is set at 9.0 kg/mm, meaning that the weight limits on axles equipped with common tire sizes are as follows:

Table 7.3. Axle weight limits with respect to tire widths.

Width	2-tire axle	4-tire axle
10 inch	4540 kg	9080 kg
11 inch	5000 kg	10000 kg
12 inch	5550 kg	11100 kg

Since the maximum legal weight on a 4-tire axle, regardless of tire width, is set at 9,100 kg on primary highways, there is little incentive for truck operators to use tires larger than 10 inches in width. The situation with respect to steering axles is quite different. The 5,500 kg axle weight limit means that the full weight potential of this axle can be utilized only with tire widths of 12 inches or more. Difficulties in loading steering axles to this level without overloading drive axles can effectively limit many trucks to steering axle weights well below the 5,500 kg maximum, making 12 inch tires unnecessary.

CHAPTER 8

CONCLUSIONS

Data from the Manitoba Department of Highways and Transportation Weight and Dimension Surveys shows a pattern of gross vehicle weight distribution changes coinciding with, or closely following, changes in the legislated vehicle weight limits. This correlation led to the development of mathematical models which link the set of regulatory limits under which large trucks operate to the gross vehicle weight distributions of these trucks for a number of specific vehicle configurations.

Mathematical models were successfully formulated for laden trucks in these configurations:

(i) straight trucks with two axles,
(ii) straight trucks with three axles, and
(iii) A-trains with seven axles.

Upon fitting models to the 3-S2 g.v.w. distribution data, it was found that these distribution curves did not always reflect the changes in the regulated weight limits, particularly in the case of the 1000 kg upward shift in g.v.w. limit for those vehicles from 36,500 kg to 37,500 kg. It is felt that the almost total lack of change in actual weights of 3-S2's following this g.v.w. limit shift was a result of these factors:

(i) 3-S2's could be loaded to the new limit only by raising the front axle weight, which is not always practical without overloading the drive axle group. Hence, for many operations, maximum practical loads did not change.

(ii) the increasing use of A- and B-trains for the hauling of high density commodities affected the loading patterns of 3-S2's.

The reaction of B-train gross vehicle weights to changes in legal weight limits could not be determined with any degree of certainty, since significant numbers of B-train survey observations were not available.

Similar models linking axle weight distributions of laden trucks to regulatory limits were developed from the same truck survey results. As in the case with g.v.w.'s, axle weights and provincial weight regulations tend to be correlated. Mathematical models of the relationships between legal weight limits and axle (or axle group) weight distributions for laden trucks were formulated for all axle group types (steering, single and tandem) of these truck configurations:

(i) Straight trucks with two axles,
(ii) Straight trucks with three axles,
(iii) A-trains with seven axles, and
(iv) B-trains with seven axles.

The correlation did not hold in the case of 3-S2 limits and no models were formulated for this truck type, since, in at least one case, factors other than weight regulations played the most important role in determining axle weights. As with g.v.w.'s, axle weights of these vehicles remained relatively constant despite the increase in regulated g.v.w. limits.

The mean ESAL per truck as well as the average payload per truck are both dependent on truck weight characteristics which are, in turn, dependent on truck weight regulations. Means of estimating these two derivative quantities were presented. ESAL's/truck can be calculated quite simply by applying AASHTO axle load equivalency factors (AASHTO 86) to the estimated axle weight distributions. Payload distributions are found by subtracting estimates of vehicle tare weights from the g.v.w. distributions.

SAS (Statistical Analysis System) data files were created from the previously unsorted raw data files. The new computer files incorporate a number of changes, which greatly simply programming requirements for sorting, tabulating, and graphing the survey data. These changes include:

(i) the conversion of all Imperial units (with the exception of tire widths which remained in inches) to their metric equivalents,

(ii) the categorization of the 300+ commodity codes, among which loads were divided prior to 1980, into the 35 larger categories currently used by the Department of Highways and Transportation,

(iii) the creation of new variables to facilitate manipulation of the data, and

(iv) the creation of a combined file of all survey observations from 1972 to 1986. In this file, the deletion of certain stations led to a uniform commodity mix throughout the file without the distortions caused by the homogeneous type of commodity distributions found at some locations.

The observations made concerning the size and make-up of Manitoba's large truck fleet confirm the existence of two main trends. First, the fleet size has shown steady growth since 1974, and secondly, the relative percentages of each truck configuration type within the fleet have shifted over the same time period, straight trucks becoming fewer in number and larger twin trailer combinations becoming more numerous. Overall, the average size of the individual trucks within the fleet has grown in the wake of weight and dimension regulation liberalization.

Several observations concerning vehicle characteristics resulted from the study of survey data. They include:

(i) Inner axle spacings of gravel hauling 3-S2 units are consistently below 4.0 metres without the reduction in axle weights which has been the legal requirement since 1982.

(ii) The off-tracking performance of a typical tractor semitrailer as well as that of a typical B-train combination are both worse than that of the WB-50 design vehicle use din the geometric design of major highways in Manitoba.

(iii) The most common tire widths on combinations with one or more trailers are 10 and 11 inches. Three axle straight trucks generally use 9 or 10 in tires while those trucks with only two axles are most commonly surveyed with tire widths anywhere from 7.5 to 10 inches. Since 10 inch tires are required before the full 9,100 kg allowable single axle load can legally be carried, it follows that potential loads of many smaller trucks are limited by tire widths rather than by axle load limitations.

(iv) Tandem axle spreads, particularly those of larger combinations, are consistently wider than those used in the AASHTO road tests of 1962, from which most ESAL calculation equations are based.

(v) Since 1972, tare weights of 3-S2 and straight trucks have been rising. The evidence suggests that this is due mainly, though not entirely, to increases in legal weight limits during this period. In general, the mean tare weight of a particular vehicle configuration can be approximated with this formula:

$$\text{Tare Weight} = -3{,}650 \text{ kg} + 4{,}350(x) - 160\,(x)^2$$

where x = number of axles

(vi) Upward trends in laden vehicle weights as well as axle weights were observed in every instance where the legal weight limits were raised with only one exception. Tractor semitrailers decreased in weight following the increase in allowable g.v.w. from 36,500 kg to 37,500 kg in 1982.

(vii) Payloads of 3-S2's did not increase following the increase in allowable g.v.w. from 36,500 kg to 37,500 kg. The lack of any significant change in gross vehicle weight, combined with a slight increase in mean tare weight, resulted in a net drop in payload capacity despite the 1000 kg increase in the g.v.w. limit.

REFERENCES

Agarwal, A.C. and Billing, J.R. (1986) "Some Effects of Ontario's Weight Regulations on Commercial Vehicle Design", *Proceedings of the International Symposium on Heavy Vehicle Weights and Dimensions*, Roads and Transportation Association of Canada, Kelowna, June.

American Association of State Highway and Transportation Officials (1984) "A Policy on Geometric Design of Highways and Streets".

American Association of State Highway and Transportation Officials (1986) "AASHTO Guide for the Design of Pavement Structures".

American Association of State Highway and Transportation Officials (1983) "Standard Specifications for Highway Bridges", Thirteenth Edition.

American Association of State Highway and Transportation Officials (1982), "A Review of Effects of Truck Weights on Pavement Deterioration", Prepared by the Texas Transportation Institute, published by AASHTO.

Benthin, K. (1984) "Bridge Life Facts", *Proceedings of the Second Northstar Workshop: A Bold New Look at Minnesota's Roads and Loads*, Minnesota Department of Transportation, Office of Research and Development, November.

Bussard, D. (1978) "Axle Weight Control of Highway Loads in Alberta", presented at the WACHO Conference, Victoria, April.

Canroad Transportation Research Corporation (1986) "Vehicle Weight and Dimension Study: Technical Steering Committee Report", published by the Canroad Transportation Research Corporation, Ottawa, November.

Cherwenuk, A. (1986) "Extended Length Truck Combinations Demonstration Testing in Alberta", RTAC Annual Conference, Toronto.

Clayton, A. and Lai, M. (1985) "Data Requirements and Problems Respecting Truck Transportation in Manitoba", *Canadian Society for Civil Engineering Annual Conference Proceedings*, Saskatoon, May.

Clayton, A. and Lai, M. (1986) "Characteristics of Large Truck-Trailer Combinations Operating on Manitoba's Primary Highways: 1974-1984", *Canadian Journal of Civil Engineering*, December.

Clayton, A. and Nix, F. (1986) "Truck Transportation Data--Reflections on the Canadian Experience", *Proceedings of the World Conference on Transport Research*, Volume 1, Vancouver, May.

Clayton, A. and Nix, F. (1986) "Assessing the Impact of Weight and Dimension Regulations: Methodological Considerations", *Proceedings of the International Symposium on Heavy Vehicle Weights and Dimensions*, Roads and Transportation Association of Canada, Kelowna, June.

Clayton, A. and Nix, F. (1986) "Effects of Weight and Dimension Regulations: Some Evidence from Canada", *Transportation Research Record 1061*, Transportation Research Board.

Clayton, A., Nix, F., and Sparks, G. (1982) "Aspects of the Commercial Trucking of Grain: Prairie Region: Fall 1982", Canadian Transport Commission, Research Branch, *Report No. 1984/06E*, May 1983.

Clayton, A., Sparks, G., and Mak, R. (1983) "Truck Industry Technological Response to the Western Canada Highway Strengthening Program", presented at the Roads and Transportation Association of Canada Annual Conference, Edmonton, September.

Corcoran, P., Glover, M. and Shane, B. (1980) "Higher Gross Weight Goods Vehicles -- Operating Costs and Road Damage Factors", Transport and Road Research Laboratory, *TRRL Supplementary Report 590.*

Csagoly, P. and Dorton, R. (1978) "Truck Weights and Bridge Design Loads in Canada", presented at the AASHTO Annual Meeting, Louisville Kentucky, November, 1987, and reprinted by the Ontario Ministry of Transportation and Communications, Research and Development Division, October, 1979.

Ervin, R. (1984) "RTAC Study on Weights and Dimensions: Report on Task 1: A Survey of the Characteristics of Equipment in the Canadian Trucking Fleet", published by the Roads and Transportation Association of Canada, Ottawa.

Federal Highways Administration (1985) "The Highway Monitoring Guide".

French, A. and Solomon, D. (1986) "Traffic Data Collection and Analysis: Methods and Procedures", *NCHRP Synthesis 130.*

Girling, R. (1988) "Overweight/Overdimension Trucking in Manitoba and Western Canada", M.Sc. Thesis, University of Manitoba, Civil Engineering Department.

Good, D. and Bisson, B. (1986) "Impacts of Changes in Vehicle Mass and Dimensions on Trucking Activity in the Atlantic Provinces", *Canadian Transportation Research Forum Annual Conference Proceedings*, Vancouver, May.

Haas, R. and Hudson, W. (1978) *Pavement Management Systems*, McGraw-Hill, Inc.

Hald, A. (1952) *Statistical Theory with Engineering Application*, published by John Wiley & Sons, Inc.

Highway Research Board (1961) "Special Report 61A, The AASHTO Road Test: History and Description of Project", *Publication No. 816*, National Research Council.

Highway Research Board (1962) "Special Report 61C, The AASHTO Road Test: Traffic Operations and Pavement Maintenance", *Publication No. 952*, National Research Council.

Hutchinson, B. and Haas, R. (1986) "The Impacts of Large Trucks on the Highway Transportation System", presented at the Workshop on Trucking Issues: The Railway Association of Canada, published by the Transport Group, Department of Civil Engineering, University of Waterloo, February.

Krames, R.A. and Crowley, K.W. (1986) "Passenger Car Equivalents for Trucks on Level freeway Segments", *Transportation Research Record 1091*, Transportation Research Board.

Lill, R. (1986) "Geometric Design for Large Trucks -- An Overview of the Issues from the Perspective of the American Trucking Associations, Inc.", *Transportation Research Record 1052*, Transportation Research Board.

Mason, J. and Driscoll, V. (1986) "Consideration of Larger Trucks in Pavement Design and Management", *Transportation Research Record 1952*, Transportation Research Board.

Manheim, M.L. (1979) *Fundamentals of Transportation Systems Analysis*, MIT Press.

Mendenhall, W. and Reinmuth, J. (1982) *Statistics for Management and Economics*, published by Prindle, Weber and Schmidt Publishers.

NCHRP (1973) "Changes in Legal Weights and Dimensions: Some Economic Effects on Highways", National Research Council, Report No. 141.

Nix, F. and Clayton, A. (1985) "Study of Vehicle Weight and Dimension Regulations and Canada's Trucking Industry: Background Paper #3: AVAILABILITY OF PROVINCIAL DATA", Published by University of Toronto-York University Joint Program in Transportation, November.

Nix, F., Clayton, A. and Bisson, B. (1987) "Study of Vehicle Weight and Dimension Regulations and Canada's Trucking Industry: Volume II: THE REGULATIONS", Published by University of Toronto-York University Joint Program in Transportation, February.

Nix, F., Clayton, A., Bisson, B. and Sparks, G. (1986) "Study of Vehicle Weight and Dimension Regulations and Canada's Trucking Industry: Background Paper #6: CASE HISTORIES", Published by University of Toronto-York University Joint Program in Transportation, December.

Organization for Economic Cooperation and Development (1979) "Evaluation of Load-Carrying Capacity of Bridges".

Packard, R.G. (1984) "Thickness Design for Concrete Highway and Street Pavements", published by the Canadian Portland Cement Association.

SAS Institute, Inc. (1985) "SAS User's Guide, Version 5", Cary N.C.

Shapiro, S. and Gross, A. (1981) *Statistical Modelling Techniques*, published by Marcel Dekker, Inc.

Skok, E. (1984) "Pavement Life Facts", *Proceedings of the Second Northstar Workshop: A Bold New Look at Minnesota's Roads and Loads*, Minnesota Department of Transportation, Office of Research and Development, November.

Sparks, G. and Neudorf, R. (1987) "Productivity Implications of Vehicle Weight and Dimension Regulations in the Transportation of Petroleum Products", *Canadian Transportation Research Forum Annual Conference Proceedings.*

Stehr, R. (1984) "Minnesota's Road Usage Trends", *Proceedings of the Second Northstar Workshop: A Bold New Look at Minnesota's Roads and Loads*, November.

Transportation Research Board (1985) "Special Report #209: Highway Capacity Manual", National Research Council.

Transportation Research Board (1986) "Special Report #211: Twin Trailer Trucks", National

Research Council.

Wyatt, J. and Hassan, M. (1985) "Some Tentative Findings about the Effects of Level of Enforcement on Compliance with Truck Weight Regulations", CTRF.

Yoder, E.J. and Witczak, M.W. (1975) *Principles of Pavement Design*, Second Edition, published by John Wiley & Sons, Inc.

Young, F. (1982) "Manitoba Asphalt Pavement Design Methods", presented at the RTAC National Conference, Halifax, Nova Scotia.

Yu, C., Walton, C.M. and Ng, P. (1983) "Procedure for Assessing Truck Weight Shifts that Result from Changes in Legal Limits", *Transportation Research Record 920*, Transportation Research Board.

Yu, C. and Walton, C.M. (1983) "Truck Size and Weight Enforcement: A Case Study", *Transportation Research Record 920*, Transportation Research Board.

Yu, C. and Walton, C.M. (1984) "Characteristics of Double and Triple Trailer Truck Combinations Operating in the United States", *Transportation Research Record 966*, Transportation Research Board.

APPENDIX A: MANITOBA DEPARTMENT OF HIGHWAYS & TRANSPORTATION TRUCK SURVEY FORM

MANITOBA

TRUCK SURVEY

STATION ____ YEAR ____ MONTH ____ DAY ____ TIME ____

LICENCE ____ FUEL (Circle one) DIESEL 2 PROPANE 3 GASOHOL 4 OTHER 5

PROVINCE OF LICENCE

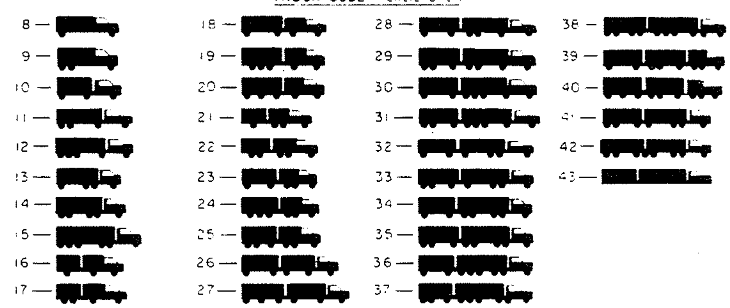
ORIGIN ____ RESTRICTION (Circle) YES

DESTINATION ____ FLOATING (Axle No.) ____

NOTE: ABOVE CITIES TO BE FILLED ONLY FOR MANITOBA, SASKATCHEWAN, ONTARIO, NORTH DAKOTA, MINNESOTA. PERMIT (Circle) YES

ORIG	DEST	PROVINCE OR STATE (CIRCLE)	
01	01	MAN	01
02	02	MINN	02
03	03	N DAK	03
04	04	ONT	04
05	05	SASK	05
06	06	ALA	06
07	07	ALASKA	07
08	08	ALTA	08
09	09	ARIZ	09
10	10	ARK	10
11	11	B.C.	11
12	12	CALIF	12
13	13	COLO	13
14	14	CONN	14
15	15	DEL	15
16	16	FLA	16
17	17	GEORGIA	17
18	18	IDAHO	18
19	19	ILL.	19
20	20	IND	20
21	21	IOWA	21
22	22	KANSAS	22
23	23	KY	23
24	24	LOUIS	24
25	25	MAINE	25
26	26	MARYLAND	26
27	27	MASS	27
28	28	MEXICO	28
29	29	MICH	29
30	30	MISS	30
31	31	MO	31
32	32	MONT	32
33	33	N.B.	33
34	34	NEBR	34
35	35	NEVADA	35
36	36	N.C.	36
37	37	NFLD	37
38	38	N.H.	38
39	39	N.J.	39
40	40	N MEX	40
41	41	N.S.	41
42	42	N.Y.	42
43	43	N.W.T.	43
44	44	OHIO	44
45	45	OKLA.	45
46	46	ORE	46
47	47	P.E.I.	47
48	48	PENN.	48
49	49	QUÉBEC	49
50	50	RHODE IS.	50
51	51	S.C.	51
52	52	S. DAK.	52
53	53	TENN.	53
54	54	TEXAS	54
55	55	UTAH	55
56	56	VERMONT	56
57	57	VA	57
58	58	WASH	58
59	59	W VA	59
60	60	WISC	60
61	61	WYO.	61
62	62	YUKON	62

TRUCK CODE (Circle One)



COMMODITY (CIRCLE ONE)

01 ANIMAL BY PRODUCTS	19 FUEL - VEHICLES, ENGINES
02 BEVERAGES	20 HOUSE-HOLD GOODS, APPLIANCES
03 BUILDING MAT'LS - GRAVEL	21 LIVE - POULTRY
04 BUILDING MAT'LS - OTHER	22 LIVE - STOCK
05 CHEMICALS	23 LIVE - OTHER
06 COMPRESSED GASES	24 MEDICAL SUPPLIES & EQUIPMENT
07 CONTAINERS EMPTY	25 MINING PRODUCTS
08 EARTH ORGANIC FERTILIZER	26 MISC GOODS, UNKNOWN COMM
09 EMPTY (NO COMMODITY)	27 PAPER PRODUCTS
10 EQUIPMENT - AUTOMOTIVE	28 PETROLEUM PRODUCTS
11 EQUIPMENT - CONSTRUCTION	29 PLANTS
12 EQUIPMENT - FARM	30 SERVICE VEHICLES
13 EQUIPMENT - OTHER	31 SCRAP
14 FOOD - FOR ANIMALS	32 SPORTING GOODS & SUPPLIES
15 FOOD - FOR HUMANS	33 TIMBER
16 FARM CROP - GRAIN	34 VEHICLES CAMPERS, TRAILERS
17 FARM CROP - OTHER	35 WEARING APPAREL
18 FUEL - HEATING, LIGHT	

ENTRY - (CIRCLE) N E S W EXIT - (CIRCLE) N E S W

OVERALL DIMENSIONS (METERS 2 DECIMALS)

LENGTH ____ WIDTH ____ HEIGHT ____

AXLE TIRE WIDTH (MILLIMETERS)	AXLE LOADS (IN HUNDREDS OF KILOGRAMS)	AXLE SPACING (METERS 2 DEC.)
1	1	
2	2	1-2
3	3	2-3
4	4	3-4
5	5	4-5
6	6	5-6
7	7	6-7
8	8	7-8
9	9	8-9
10	10	9-10

APPENDIX B:
Truck Weight and Dimension Survey
Commodity Code Listings

CODES 72-79	80-86	DESCRIPTION
100	14	Animal Food and Bedding
101		Fodder (Alfalfa, Clover, etc.)
102		Hay, Grass
103		Prepared Animal or Poultry Food
104		Soy Bean Meal
105		Straw
200	02	Beverages (Non-Alcoholic)
201		Soft Drinks
202		Water
300		Beverages (Alcoholic)
301		Liquor
302		Beer
303		Wine
304		Brewery Mash
400	32	Boating Equipment
401		Boats
402		Canoes
403		Launches, Sailboats, Yachts
404		Fishing Equipment
405		Boat Rigging, Oars, Paddles
406		Outboard Motors
407		Boat Trailers
500	03	Building Materials (Road)
501		Asphalt
502		Calcium Chloride
503		Clay
504		Concrete
505		Gravel, Crushed Rock
506		Sand
507		Cinders
508		Shale
600	04	Building Materials (Structural)
601		Cement
602		Building Blocks, Bricks, Stone Slabs
603		Gypsum, Lime or Plaster Compounds, Gyprock
604		Insulating Materials
605		Pitch
606		Roofing Materials and Sheeting
607		Steel and Steel Beams, Iron Rods
608		Concrete and Concrete Products
609		Bridge Timbers, Laminated Wood Beams, Rafters
700	32	Canvas Products
701		Bags, Sacks
702		Bolting

CODES 72-79	80-86	DESCRIPTION
703		Tents, Awnings
704		String and Twine
705		Camping Supplies
800	05	Chemicals
801		Caustic Soda, Alum
802		Acids (Liquid Carbonic)
803		Alcohol, Methyl Hydrate
804		Anti-Freeze (Glycole)
805		Arsenic
806		Benzine
807		Insecticide (DDT)
808		Weed Killer (2-4-D)
809		Dry Ice (Carbon Dioxide)
810		Cleaning Fluids or Compounds for Liquid Solvents
900	35	Clothing
901		Blankets
902		Wearing Apparel or Personal Effects (Luggage)
903		Fabrics (Oilcloth)
904		Wool
905		Laundry and Dry Cleaning
1000	07	Containers (Empty)
1001		Barrels, Kegs or Drums, Cans, Tanks, Pails
1002		Bottles, Jars
1003		Boxes, Cases Cartons, Crates, Pallets
1004		Gas Cylinders
1005		Plastic Bags and Products
1006		Jute Bags
1100	11	Construction Equipment (Heavy Machinery)
1101		Bulldozer, Tractor, Compressor, Packer, Etc.
1102		Steel Forms
1103		Construction Sheds, Garages, Work Shacks
1104		Parts and Supplies
1105		Scaffolding
1200	08	Earth
1201		Manure Fertilizers (Ammonia Nitrate)
1202		Mud and Earthfill Top Soil
1203		Sod
1204		Peat Moss
1300	13	Electrical Equipment (Heavy)
1301		Generators, Motors
1302		Transformers
1400	05	Explosives
1401		Ammunition
1402		Dynamite
1500	09	Empty (No Commodity)
1600	17	Farm Crops (Other than Grain)
1601		Onions
1602		Peas

CODES 72-79	80-86	DESCRIPTION
1603		Potatoes
1604		Sugar Beets
1605		Sunflowers
1606		Watermelons
1607		Rice
1608		Senecaroot
1609		Corn
1700	12	Farm Equipment
1701		Agricultural Implements (Non-Mechanical)
1702		Swathers, Augers Spreaders, Planters, Etc.
1703		Combines and Harvesters
1704		Plows, Discs
1705		Tractors
1706		Parts
1707		Dairy Equipment
1708		Storage Bins, Etc.
1709		Poultry Raising Equipment
1800	15	Fish and Fish Products
1801		Fresh Fish
1802		Canned, Pickled or Preserved Fish
1803		Fish Oil
1804		Shrimp
1805		Whale Meat
1806		Frozen Fish
1900		Foodstuffs (Perishable)
1901		Bread and other Baked Goods
1902		Frozen Foods
1903		Fruits
1904		General Groceries
1905		Vegetables (Produce)
1906		Commercial Ice
2000		Foodstuffs (Non-Perishable)
2001		Baking Ingredients (Flour, Soda)
2002		Candy or Confectionary
2003		Canned Goods or Preserved Fruit Juices
2004		Dried Fruits
2005		Spices
2006		Sugar (Molasses)
2007		Tea and Coffee (Dry Ground)
2008		Honey
2100	19	Fuel
2101	18	Coal
2102	19	Diesel Fuel Oil
2103	18	Distillate
2104		Furnace Fuel Oil
2105	19	Gasoline (Aviation)
2106	18	Kerosene
2107		Hexane

CODES 72-79	80-86	DESCRIPTION
2108		Pressed Sunflower Husks
2200	06	Compressed Gases
2201		Acetylene
2202		Carbon Dioxide
2203		Oxygen (Liquid Air)
2204		Propane (Petro Gas)
2205		Pentane
2206		Nitrogen
2300	26	General Freight (Merchandise)
2301		Unknown Commodities
2302		Small Miscellaneous Goods
2400	20	Glass Products
2401		Glassware, Bottles, Jars
2402		Sheet Glass
2403		Windows and Doors
2500	16	Grain (Cereal)
2501		Barley-Malt
2502		Oats
2503		Rice, Wild Rice
2504		Rye
2505		Wheat
2506		Buckwheat
2600		Grain (Seed)
2601		Barley
2602		Oats
2603		Rye
2604		Wheat
2605		Flax
2606		Grass - Fescue
2607		Rape
2608		Mustard
2609		Alfalfa - Clover
2610		Cranbie (Oil from Rape Seed or Mustard)
2700	01	Hides and Furs
2701		Dressed or Tanned Furs or Hides
2702		Leather Goods
2703		Raw Hides, Pelts or Skins
2800	20	Household Goods and Appliances
2801		Bedding and Towelling
2802		Bathroom or Lavatory Fixtures
2803		Floor Covering
2804		Furniture (Baby Carriage)
2805		Electrical Appliances
2806		Mechanical Appliances
2807		Utensils
2808		Electrical Fixtures
2809		T.V.áTubes, Antenna, Aerial and Radios
2900	22	Livestock

CODES 72-79	80-86	DESCRIPTION
2901		Cattle
2902		Hogs
2903	23	Horses
2904		Sheep
2905		Miscellaneous Insects and Animals
3000	33	Lumber and Wood Products
3001		Dressed Lumber
3002		Plywood
3003		Sawdust or Wood Shavings
3004		Pulpboard (Ceiling Tiles)
3005		Finished Wood Products, Sash and Door, Etc
3100	13	Machinery and Machines
3101		Commercial Machines (Scales)
3102		Industrial Machines (Mining Equipment)
3103		Furnaces and Burners
3104		Drill Rigs - Portable Pumps
3105		Motors
3106		Parts
3200	24	Medical Supplies
3201		Blood Plasma
3202		Drugs and Medicines
3203		Dental and Medical Instruments
3204		X-Ray Equipment
3300	15	Meat and Meat Products
3301		Canned Meat
3302		Fresh Meat
3303		Prepared Meat Products
3304		Frozen Meat
3305	01	Animal By-Product - Glue, Dead Cattle, Rendering
3400	02	Milk and Milk Products
3401	15	Cheese
3402	02	Milk or Cream
3403	15	Butter
3404		Ice Cream
3500	13	Military Equipment
3501		Heavy Equipment
3502		General Supplies
3600	25	Minerals
3601		Ores
3602		Salt - Phosphate
3603		Metal Products - Metallic Ores
3604		Potash
3605		Mercury
3700	26	Miscellaneous Goods
3701		Houses, Cottages, Bunkhouses
3702	34	House Trailers (Camper)
3703	26	Grandstands and Platforms
3704		Signs

CODES 72-79	80-86	DESCRIPTION
3705		Grain (Elevators) Storage Sheds
3706		Photographic Equipment
3707		Building Moving Equipment
3708		Record Service
3709		Beehives
3710		Office Furniture
3800	20	Paint and Varnish Material
3801		Linseed Oil
3802		Paints
3803		Turpentine
3804		Varnishes
3805		Wood Preservatives
3806		Equipment (Brushes, Etc.)
3807		Waxes
3900	27	Paper Products
3901		Advertising Displays
3902		Books
3903		Cardboard Boxes
3904		Newspapers and Newsprint
3905		Paper
3906		Paper Articles
3907		Mail
3908		Ink
3909		School Supplies
4000	28	Petroleum and Petroleum Products
4001		Crude Oil, Tars
4002		Lubricants - Grease
4003		Oil
4100	100	People
4101		Local Residents
4102		Tourists
4200	04	Pipe
4201		Culverts
4202	13	Plumbing Equipment and Septic Tanks
4203	04	Sewer Pipe (Cast Iron, Steel, Asbestos, Comcrete)
4204		Water Pipe (Lead or Copper)
4205	13	Oil Pipe and Equipment
4206	04	Tubing
4207		Fittings
4208		Furnace Pipe
4209		Casings (Drilling Pipe)
4300	29	Plants
4301		Trees, Shrubs
4302		Flowers
4303		Bulbs
4304		Bedding Plants
4400	15	Poultry and Poultry Products
4401		Eggs

CODES 72-79	80-86	DESCRIPTION
4402		Fresh Poultry
4403		Canned or Prepared Poultry
4404		Frozen Poultry
4405	21	Live Poultry (Geese)
4406	01	Poultry By-Products
4407	21	Hatchery Chicks
4500	10	Rubber and Rubber Articles
4501		Tires and Tubes
4502	26	Rubber Articles
4503		Rubber Hose
4600	30	Service Vehicle and Equipment
4601		Hydro Trucks and Electrical Repair
4602		Telephone Trucks and Equipment
4603		Tow Trucks
4604		Fire Trucks, Fire Fighting Apparatus
4605		Railway Equipment
4606		Logging Equipment (Mill Plainer)
4607		Feed Mixer
4608		Septic Tank Cleaner
4609		Milk Pickup
4700	31	Scrap Materials
4701		Garbage
4702		Light Scrap Materials (Rags)
4703		Scrap Metal
4704		Scrap Rubber
4705		Scrap Lumber
4706		Snow, Ice or Water
4707		Ashes
4708		Scrap Vehicles
4800	04	Sheet Metal and Steel Ware
4801		Plain Sheet Metal
4802		Sheet Metal Roofing and Siding
4803		Steel Beams
4804		Steel Doors
4805		Steel Drums
4806		Steel Casings and Plates
4807		Eavestroughing
4900	05	Soaps and Detergents
4901		Commercial
4902		Industrial
4903		Household
5000	32	Sporting Goods
5001		Athletic Equipment
5002		Bowling and Billiard Equipment
5003		Firearms
5004		Toys
5005		Sleds and Skis
5100	33	Timber and Timber Products

CODES 72-79	80-86	DESCRIPTION
5101		Cordwood
5102		Poles (Hydro Poles, Fence Posts)
5103		Pulpwood
5104		Rough Lumber (Firewood)
5105		Christmas Trees
5106		Logs
5200	26	Tobacco
5201		Leaf Tobacco
5202		Processed Tobacco (Cigarettes, Cigars)
5300		Tools, Hardware and Kindred Materials
5301		Abrasives
5302		Adhesives
5303		Asbestos Articles
5304		Electric and Pneumatic Tools
5305		Hand Tools
5306		Household Accessories - Nails, Hinges
5307		Welding Supplies and Equipment
5400	34	Vehicles
5401		Cars
5402		Trucks
5403		Automobie, Truck and Bus Parts
5404		Batteries
5405		Airplanes and Parts
5406	32	Snowmobiles
5407	34	Motorcycles
5408	32	Bicycles
5409	34	Truck Carrier (Piggyback)
5410		Auto Carrier
5500	15	Vegetable Oils
5501		Cooking Oils
5502		Margerine
5600	04	Wire, Cable and Wire Goods
5601		Barbed Wire
5602		Plain, Galvanized, Coppered or Tinned Wire
5603		Wire Work or Fencing(Snow), Screens
5700	13	Musical Instruments
5800		Commercial Equipment
5801		Drink Coolers
5802		Automatic Car Wash Equipment

APPENDIX C:
Manitoba Department of Highways and Transportation Truck Weight and Dimension Survey Locations

YEAR	STN NO.	LOCATION
1972	976	PTH #1 & PTH #12 (E. of PTH #12 WB only)
	765	PTH #1 & PR #351 (W. Jct.)
	904	PTH #3 & PTH #14
	918	PTH #3 & PTH #18 (N. Jct.)
	778	PTH #5 & PTH #23
	804	PTH #6 & PR #513
	912	PTH #10 & PTH #20
	779	PTH #10 N.of Riding Mtn. Nat'l Park
	915	PTH #11 & PTH #44 (S. Jct.)
	730	PTH #21 & PTH #45
	920	PTH #24 & PTH #83
	978	PTH #59 & PR #201
	946	PTH #59 & PR #212
1973	976	PTH #1 & PTH #12 (E. of PTH #12 WB only)
	780	PTH #2 PTH #5
	891	PTH #2 & PR #305
	807	PTH #3 & PTH #10
	781	PTH #5 & PR #471
	782	PTH #6 & PTH #68 (N. Jct.)
	783	PTH #9 & PR #413
	809	PTH #10 & PTH #45
	784	PTH #10 & PR #268 (N. Jct.)
	986	PTH #11 & PR #304 (Perm. Scale)
	785	PTH #32 & PR #201 (N. Jct.)
	902	PTH #52 & PTH #59
1974	91	PTH #1 - HEADINGLEY
	93	PTH #1 - WESTHAWK
	95	PTH #2 & PTH #10 (N. Jct. Perm Scale)
	603	PTH #3 & PR #244
	937	PTH #7 & PR #231 (N. Jct.)
	608	PTH #12 & PR #208
	611	PTH #16 & PR #260
	922	PTH #20 & PTH #20A (S. Jct.)
	833	PTH #23 & PR #422
	92	PTH #75 - EMERSON
	612	PTH #83 & PR #591
	613	PR #200 & Floodway Inlet Road
1975	91	PTH #1 - HEADINGLEY
	93	PTH #1 - WESTHAWK
	901	PTH #2 & PTH #3
	760	PTH #2 & PTH #83
	917	PTH #3 & PTH #34 (E. JCT.)

YEAR	STN NO.	LOCATION
	949	PTH #7 & PTH #101
	914	PTH #8 & PR #225
	864	PTH #11 & PTH #44 (N. JCT.)
	832	PTH #12 & PTH #15
	961	PTH #14 & PTH #30
	941	PTH #16 & PR #270
	816	PTH #17 & PTH #68
	92	PTH #75 - EMERSON
1976	998	PTH #3 & PTH #18 (S. JCT.)
	907	PTH #3 & PTH #83 (N. JCT.)
	862	PTH #6 & PTH #62
	708	PTH #10 - C.F.I. PLANT ROAD
	727	PTH #12 & PTH #59 (S. JCT.)
	621	PTH #12 & PR #308
	873	PTH #16 & PTH #50
	638	PTH #20 & PR #273
	910	PTH #21 & PTH #24
	639	PTH #23 & PR #200
	806	PTH #23 & PR #244
	834	PTH #26 & PR #430
	703	PR #391 - THOMPSON
1977	985	PTH #2 & PTH #21 (E. JCT.)
	905	PTH #2 & PTH #34
	942	PTH #3 & PTH #23
	745	PTH #5 & PTH #20
	713	PTH #5 & PR #351
	706	PTH #6 & PTH #67
	707	PTH #8 & PTH #67
	906	PTH #10 & PTH #23 (S. JCT.)
	919	PTH #10 & PTH #25
	940	PTH #10 & PR #267
	986	PTH #11 & PR #304
	916	PTH #12 & PR #205
	640	PTH #16 & PR #475
1978	91	PTH #1 - HEADINGLEY
	93	PTH #1 - WESTHAWK
	877	PTH #2 & PTH #18
	704	PTH #3 & PTH #31
	984	PTH #3 & PTH #83 (S. JCT.)
	804	PTH #6 & PR #513
	990	PTH #8 & PTH #68
	838	PTH #10 & PR #268 (S. JCT.)
	631	PTH #11 & PR #214
	823	PTH #21 & PTH #23
	730	PTH #21 & PTH #45
	978	PTH #59 & PR #201

YEAR	STN NO.	LOCATION
	92	PTH #75 - EMERSON
1979	901	PTH #2 & PTH #3
	95	PTH #2 & PTH #10 (N. JCT.)
	90	PTH #5 - DAUPHIN
	772	PTH #6 & PR #391
	662	PTH #7 & PR #231 (S. JCT.)
	911	PTH #16 & PTH #45
	941	PTH #16 & PR #270
	920	PTH #24 & PTH #83
	785	PTH #32 & PR #201 (N. JCT.)
	710	PTH #50 & PR #265
	711	PR #200 & PR #201 (W. JCT.)
	667	PR #216 & PR #311
1980	673	PTH #2 & PR #256 (E. JCT.)
	778	PTH #5 & PTH #23
	987	PTH #9 & PR #525
	794	PTH #10 & PTH #10A (S. JCT.)
	812	PTH #10 & PR #391
	832	PTH #12 & PTH #15
	690	PTH #12 & WAMPUM ACCESS
	611	PTH #16 & PR #260
	816	PTH #17 & PTH #68
	682	PTH #21 & PR #251
	656	PTH #21 & PR #259
	691	PTH #83 - ROBLIN
	689	PR #245 & PR #338
1981	93	PTH #1 - WESTHAWK
	929	PTH #1 & PTH #41
	891	PTH #2 & PR #305
	860	PTH #3 & PTH #21 (N. JCT.)
	994	PTH #3 & PTH #34 (W. JCT.)
	698	PTH #3 & PR #248
	699	PTH #5 & PR #353 (W. JCT.)
	781	PTH #5 & PR #471
	802	PTH #23 & PTH #59
	500	PTH #23 & PR #336 (W. JCT.)
	785	PTH #32 & PR #201 (N. JCT.)
	903	PTH #44 & PR #214
	92	PTH #75 - EMERSON
1982	91	PTH #1 - HEADINGLEY
	780	PTH #2 & PTH #5
	760	PTH #2 & PTH #83
	807	PTH #3 & PTH #10
	721	PTH #7 & PR #517
	986	PTH #11 & PR 304

YEAR	STN NO.	LOCATION
	743	PTH #12 & PR #317
	705	PTH #16 & PTH #21
	982	PTH #20 & PR #267
	656	PTH #21 & PR #259
	808	PTH #41 & PTH #42
	868	PTH #52 & PR #210
1983	901	PTH #2 & PTH #3
	95	PTH #2 & PTH #10 (N. JCT.)
	904	PTH #3 & PTH #14
	918	PTH #3 & PTH #18 (N. JCT.)
	810	PTH #5 & PR #23
	837	PTH #5 & PR #366
	90	PTH #5 - DAUPHIN
	782	PTH #6 & PR #235
	836	PTH #10 & PTH #24
	916	PTH #12 & PR #205
	709	PTH #22 & PTH #23
	944	PTH #59 - BIRDS HILL
	952	PTH #83 & PR #345
1984	93	PTH #1 - WESTHAWK
	949	PTH #7 & PTH #101
	838	PTH #10 & PR #391
1985	794	PTH #10 & PTH #10A (S. JCT.)
	986	PTH #11 & PR #304
	92	PTH #75 - EMERSON
1986	91	PTH #1 - HEADINGLEY
	90	PTH #5 - DAUPHIN
	986	PTH #11 & PR #304

APPENDIX D

DEFINITIONS

A-train: A three or four-vehicle combination consisting of a tractor, a semi-trailer, and one or two trailers. The trailers are usually attached to the lead semitrailer or trailer by means of an A-dolly converter (with a single drawbar) that has two points of articulation--one at the pintle hook and one at the dolly. The standard a-train ("doubles" or three vehicle combination) has a total of three articulation points. The special permit A-trains in some provinces ("triples") have five points of articulation.

Axle: A shaft and the wheels on that shaft. See also "single axle", "tandem axle".

Axle Group: Two or more consecutive axles. The term "axle group" may be used to refer to two or more axles connected to the same vehicle, or it may be used to refer to axles connected to different vehicles in a vehicle combination. An axle group may be a tandem axle, two single axles, a triple axle, a tandem plus single, etc.

Axle Spacing: See "Spacing".

Axle Spread: See "Spread".

B-Train: A three vehicle combination consisting of a tractor and two semitrailers. The lead semitrailer has a fifth wheel permanently attached to its rear. The standard B-Train "double" has two points of articulation.

C-Train: A three (sometimes four) vehicle combination consisting of a tractor, a semitrailer, and one (or two) trailers. The trailers may be either full double drawbar trailers (with self-steering front axle(s) or more typically semitrailers converted to full trailers by means of a B-dolly converter.

Dolly: An A-dolly converter is an axle (or tandem axle) connected to a single drawbar and a fifth wheel which can be coupled with a semitrailer, thereby converting the semitrailer to a single drawbar full trailer. A B-dolly converter is an axle (or tandem axle) connected to a double drawbar and a fifth wheel which can be coupled with a semitrailer, thereby converting the semitrailer to a double drawbar full trailer.

Double: A truck combination with two freight-carrying bodies (platforms, tanks, etc.). "Doubles" include truck plus trailer combinations (two vehicles) as well as the standard trains (three vehicles).

Drive Axle: An axle that transmits tractive effort to the road surface.

Dual-tire Axle: An axle with four tires.

Fifth Wheel: A plate with a latching mechanism used to connect a semitrailer to a tractor or a converter dolly. The "wheel" is a (roughly) round plate, lubricated (thereby allowing articulation) with a hole allowing a kingpin to be inserted.

Fifth Wheel Offset: The distance from the centre of the hole in a fifth wheel to the centre of the axle or axle group over which the fifth wheel is positioned. If the fifth wheel is forward of the centre of the axle or axle group, the fifth wheel offset is considered a negative magnitude: if to the rear, it is considered a positive magnitude.

Kingpin: A metal pin located on a plate mounted on the underside of the frame of a semitrailer which couples with the locking mechanism of a fifth wheel to permit towing.

Other Highway: A highway or road other than a primary or secondary highway.

Overhang: The distance from the centre of either the first or last axle in a vehicle or vehicle combination and the extreme front or back of the vehicle; generally referred to as either the "front overhang" or the "rear overhang".

Primary Highway: The major highways, usually under provincial/territorial jurisdiction (although there are some federal and local highways that qualify). For here, the major distinguishing feature of these roads is that these are almost always the "highest class" roads in terms of allowable weight and dimension regulations.

RTAC/CCMTA Study: The major research activity of the Roads and Transportation Association of Canada and the Canadian Council of Motor Transport Administrators over the last few years into weight and dimension regulations (pavements, structures, stability, economics).

Secondary Highway: Those highways, other than primary highways under provincial or local government jurisdictions. For here, the major distinguishing feature of these roads is that they sometimes are subject to more restrictive weight regulations than are primary highways.

Semitrailer: A non-self-propelled vehicle used to transport goods, supported in transit by a combination of its own axle(s) and the axle(s) of the preceding vehicle. The connection between a semitrailer and a lead vehicle (truck, tractor or another semitrailer) is made with a kingpin (on the semitrailer) and a fifth wheel (on the lead vehicle). A semitrailer may be converted to a trailer by the use of a dolly.

Single Axle: An axle which is independently connected to the body of a vehicle and which has no mechanism for equalizing loads with any other axle.

Single-tire Axle: An axle with two tires.

Spacing: The longitudinal distance between the centres of two axles or axle groups. "Inner spacing" refers to the distance between two adjacent axles; "outer spacing" refers to the distance between non-adjacent axles (e.g., axles 1 and 4 where two tandem axles are involved). Note that "spacing" is not used to mean "spread".

Spread: The distance between axles in a tandem or triple axle. In the case of triple axles, "inner spread" refers to the distance from the first to second or second to third axle. "Outer spread" refers to the distance from the first to the third axle.

Steering Axle: An axle connected to the front of a vehicle and steered by a driver in the driver's compartment.

Tandem Axle: Two adjacent axles which are attached to a vehicle at a common point or which have some mechanism for approximately equalizing a load between them.

Trailer: A non-self-propelled vehicle used to transport goods, fully supported by its own axles. The connection between a trailer and a lead vehicle (truck, tractor or semitrailer) is made with a drawbar and pintle hook(s).

Tractor: A self-propelled vehicle with a fifth wheel, used primarily for the purpose of towing a semitrailer (or various combinations of semitrailers and/or trailers). Although the primary purpose of tractors is towing, they may also contain a platform or a van ("drome") which allows some freight to be carried.

Train: The standard train is a three vehicle combination, consisting of a tractor, a semitrailer, and either a second semitrailer or a full trailer. See "A-Train", "B-Train", and "C-Train". In some provinces, under special permit, there are also four vehicle trains which are referred to as "triples".

Truck: A self-propelled vehicle with a box, tank, or platform in which or on which freight is carried, including permanently connected or mounted equipment. Trucks can be used in combination with one or more trailers (and/or semitrailers).

Wheelbase: On a tractor or truck, the distance from the steering axle to the drive axle or the centre of a drive-tandem axle.

APPENDIX E.
NUMERICAL DATA

NON-RESIDENT VEHICLES REGISTERED IN MANITOBA

	83-84	82-83	81-82	80-81	79-80	78-79	77-78	76-77	75--76
B.C.	350	497		207	194	157	137		82
ALTA.	2911	2542		597	518	403	340		272
SASK.	2026	1709		673	656	450	482		399
ONTARIO	2021	1894		761	631	511	454		357
QUEBEC	200	203		0	0	0	0		0
N. BRUNSWICK	34	54		11	10	21	17		21
NOVA SCOTIA	74	85		0	0	0	0		0
P.E.I.	0	0		0	0	0	0		0
NFLD.	16	16		0	0	0	0		0
TOTAL	7632	7000	N/A	2249	2009	1542	1430	N/A	1131

VEHICLES WITH FOUR OR MORE AXLES BASE-PLATED IN MANITOBA

FEB/75	N/A
FEB/76	3492
FEB/77	N/A
FEB/78	4116
FEB/79	N/A
FEB/80	2609
FEB/81	3448
FEB/82	4910
FEB/83	6033
FEB/84	6335
JAN/85	6608

MANITOBA TRUCK WEIGHT AND DIMENSION SURVEY DATA: FLEET MIX
INCLUDES BOTH LADEN AND EMPTY VEHICLES

LARGE TRUCK CONFIGURATION	1972	1973	1974	1975	1976	1977	1978	1979
2 AXLE STRAIGHT TRUCK	2737	3160	2612	2001	1398	1493	1345	1805
3 AXLE STRAIGHT TRUCK	863	1522	1470	1331	1036	902	1221	1487
5 AXLE TRACTOR SEMITRAILER	2517	3622	4344	4973	2213	2370	4161	2731
TRAINS	7	21	22	43	9	13	150	104
OTHER	522	607	618	663	217	219	345	249
TOTAL	6646	8932	9066	9011	4873	4997	7222	6376

LARGE TRUCK CONFIGURATION	1980	1981	1982	1983	1984	1985	1986
2 AXLE STRAIGHT TRUCK	2216	1971	1291	1400	124	126	57
3 AXLE STRAIGHT TRUCK	1015	1160	747	1054	260	114	15
5 AXLE TRACTOR SEMITRAILER	2638	4513	2232	2791	1120	1048	393
TRAINS	87	348	297	360	199	114	89
OTHER	277	325	228	276	97	52	7

TARE WEIGHTS: 2 AXLE STRAIGHT TRUCKS

	13700 kg.		14600 kg.	
YEAR	MEAN	# OF OBS	MEAN	# OF OBS.
72	4026	823		
73	4235	883		
74	4182	603	4970	46
75	4465	325	4732	132
76	4458	139	4288	258
77	4634	166	4733	345
78	4078	120	4515	282
79	4284	254	4757	355
80	4504	245	4494	546
81	5228	171	4765	568
82	4608	107	4589	267
83	5121	19	4725	362
84	5600	3	5682	11
85			4916	19
86			5560	5

TARE WEIGHTS: 3 AXLE STRAIGHT TRUCKS

	20000 kg.		21500 kg.	
YEAR	MEAN	# OF OBS	MEAN	# OF OBS.
72	7423	322		
73	7749	489		
74	7540	453	7688	19
75	7995	181	8013	88
76	7038	129	7785	144
77	7637	161	7775	177
78	7857	299	7851	191
79	7370	289	7745	240
80	7755	127	8432	227
81	8027	109	8323	346
82	8232	114	8460	170
83	11790	10	9065	225
84	11450	2	10500	13
85			8867	12
86				

TARE WEIGHTS: 3-S2 TRACTOR SEMITRAILERS

ALL ROADS: ALL SCALES: ALL MONTHS

YEAR	MEAN	# OF OBS	STD DEV
72	12773	753	1901
73	13505	1089	1994
74	13513	664	2181
75	13834	596	2270
76	13085	711	3030
77	13556	837	2565
78	13376	800	2466
79	13110	602	1303
80	13983	1033	2727
81	13762	1105	1990
82	14378	469	2580
83	14464	563	2522
84	16329	52	4330
85	14777	80	2168
86	15727	44	4748

TARE WEIGHTS: 5-AXLE TRACTOR SEMITRAILERS

	33600 kg.		36500 kg.		37500 kg.	
YEAR	MEAN	# OF OBS	MEAN	# OF OBS	MEAN	# OF OBS.
72	12826	670				
73	13529	1010				
74	13251	468	14490	54	14319	56
75	13545	329	13689	152	14851	115
76	13095	244	13079	467		
77	13641	284	13352	456	14270	97
78	12828	328	13536	350	14387	122
79	12807	155	13159	295	13322	152
80	13876	213	13747	473	14370	347
81	13482	128	13699	278	13795	631
82					14184	364
83					14393	516
84					16568	47
85					14784	79
86					15395	42

MANITOBA TRUCK WEIGHT AND DIMENSION SURVEY RESULTS
TARE WEIGHTS AS A FUNCTION OF NO. OF AXLES: 1972-1986

# OF AXLE (X)	MEAN TARE	REGRESSION LINE $-3650+4350(X)-160(X)^2$
2	4455	4410.0
3	7932	7960.0
4	11202	11190.0
5	13630	14100.0
6	17487	16690.0
7	18315	18960.0
8	20948	20910.0

MAX. PAYLOADS OF MANITOBA TRUCK COMBINATIONS

TRUCK TYPE	WEIGHT LIMIT	ESTIMATED TARE	PAYLOAD
2 AXLE STRAIGHT TRUCK	14600	4410	10190
3 AXLE STRAIGHT TRUCK	21500	7960	13540
5 AXLE TRACTOR SEMITRAILER	37500	14100	23400
6 AXLE A-TRAIN	48800	16690	32110
7 AXLE B-TRAIN	53500	18960	34540
7 AXLE A-TRAIN	55700	18960	36740
8 AXLE A-TRAIN	56500	20910	35590

Tandem Axle Spacings
Three Axle Straight Truck
Limit = 20000 kg.

Spacing (m.)	No. of Obs.
0.00 - 1.3 m.	564
1.31 - 1.4 m.	2665
1.41 - 1.5 m.	14
1.51 - 1.6 m.	10
over 1.6 m.	11

Tandem Axle Spacings
Three Axle Straight Truck
Limit = 21500 kg.

Spacing (m.)	No. of Obs.
0.00 - 1.3 m.	1215
1.31 - 1.4 m.	1532
1.41 - 1.5 m.	8
1.51 - 1.6 m.	7
over 1.6 m.	5

Tandem Axle Spacings
Five Axle Tractor Semitrailer
Limit = 20000 kg.

Spacing (m.)	No. of Obs.
0.00 - 1.3 m.	0
1.31 - 1.4 m.	161
1.41 - 1.5 m.	0
1.51 - 1.6 m.	0
over 1.6 m.	1

Tandem Axle Spacings
Five Axle Tractor Semitrailer
Limit = 33600 kg.

Spacing (m.)	No. of Obs.
0.00 - 1.3 m.	1804
1.31 - 1.4 m.	15350
1.41 - 1.5 m.	178
1.51 - 1.6 m.	96
over 1.6 m.	187

Tandem Axle Spacings
Five Axle Tractor Semitrailer
Limit = 34500 kg.

Spacing (m.)	No. of Obs.
0.00 - 1.3 m.	918
1.31 - 1.4 m.	6
1.41 - 1.5 m.	27
1.51 - 1.6 m.	21
over 1.6 m.	48

Tandem Axle Spacings
Five Axle Tractor Semitrailer
Limit = 36500 kg.

Spacing (m.)	No. of Obs.
0.00 - 1.3 m.	1226
1.31 - 1.4 m.	5344
1.41 - 1.5 m.	30
1.51 - 1.6 m.	79
over 1.6 m.	107

Tandem Axle Spacings
Five Axle Tractor Semitrailer
Limit = 37500 kg.

Spacing (m.)	No. of Obs.
0.00 - 1.3 m.	9941
1.31 - 1.4 m.	7389
1.41 - 1.5 m.	240
1.51 - 1.6 m.	287
over 1.6 m.	470

Tandem Axle Spacings
Seven Axle A-Trains
Limit = 50000 kg.

Spacing (m.)	No. of Obs.
0.00 - 1.3 m.	136
1.31 - 1.4 m.	202
1.41 - 1.5 m.	1
1.51 - 1.6 m.	11
over 1.6 m.	12

Tandem Axle Spacings
Seven Axle A-Trains
Limit = 53500 kg.

Spacing (m.)	No. of Obs.
0.00 - 1.3 m.	612
1.31 - 1.4 m.	9
1.41 - 1.5 m.	41
1.51 - 1.6 m.	39
over 1.6 m.	19

Tandem Axle Spacings
Seven Axle B-Trains
Limit = 47600 kg.

Spacing (m.)	No. of Obs.
0.00 - 1.3 m.	127
1.31 - 1.4 m.	0
1.41 - 1.5 m.	17
1.51 - 1.6 m.	13
over 1.6 m.	11

Tandem Axle Spacings
Seven Axle B-Trains
Limit = 53500 kg.

Spacing (m.)	No. of Obs.
0.00 - 1.3 m.	244
1.31 - 1.4 m.	19
1.41 - 1.5 m.	28
1.51 - 1.6 m.	29
over 1.6 m.	22

Tandem Axle Spacings
Eight Axle A-Trains
Limit = 56500 kg.

Spacing (m.)	No. of Obs.
0.00 - 1.3 m.	163
1.31 - 1.4 m.	0
1.41 - 1.5 m.	7
1.51 - 1.6 m.	8
over 1.6 m.	5

MEAN TANDEM AXLE GROUP WEIGHTS OF
TRACTOR SEMITRAILERS HAULING GRAVEL
(3-S2's on primary highways)

Spacing	Before Nov. 7/82	After Nov. 7/82
3.0	28761	31060
3.1	29961	30436
3.2	30859	30672
3.3	30616	30793
3.4	29754	30900
3.5	29623	30818
3.6	28841	30741
3.7	29041	30673
3.8	29278	29327
3.9	28991	31350
4.0	27566	30873

GROSS VEHICLE WEIGHT DISTRIBUTIONS

Type = "2 AXLE STRAIGHT TRUCKS"

G.V.W. LIMIT

Tonnes	13700	14600
0	1	0
1	0	1
2	28	27
3	363	206
4	746	374
5	1053	618
6	992	651
7	1036	693
8	1108	743
9	978	664
10	733	599
11	488	425
12	213	205
13	53	83
14	16	28
15	3	6
16	5	1
17	0	1
18	0	0
19	1	0
20	0	0
21	0	0
22	0	0
23	0	0
24	0	0
25	0	0
26	0	0
27	0	0
28	0	0
29	0	0
30	0	0
31	0	0
32	0	0
33	0	0
34	0	0
35	0	0
36	0	0
37	0	0
38	0	0
39	0	0
40	0	0
41	0	0
42	0	0
43	0	0
44	0	0
45	0	0
46	0	0
47	0	0
48	0	0
49	0	0
50	0	0
51	0	0
52	0	0
53	0	0
54	0	0
55	0	0
56	0	0
57	0	0
58	0	0
59	0	0
60	0	0
TOTAL	7817	5325
MEAN	7736	8109
STD DEV	2404	2499

GROSS VEHICLE WEIGHT DISTRIBUTIONS

Type = "3 AXLE STRAIGHT TRUCKS"

G.V.W. LIMIT

Tonnes	20000	21500	Tonnes	20000	21500
0	0	0	33	0	0
1	0	0	34	0	0
2	0	0	35	0	0
3	0	0	36	0	0
4	0	1	37	0	0
5	12	5	38	0	0
6	31	12	39	0	0
7	76	54	40	0	0
8	103	56	41	0	0
9	126	84	42	0	0
10	139	96	43	0	0
11	173	139	44	0	0
12	201	142	45	0	0
13	176	142	46	0	0
14	190	180	47	0	0
15	218	203	48	0	0
16	224	171	49	0	0
17	354	208	50	0	0
18	566	300	51	0	0
19	354	364	52	0	0
20	144	280	53	0	0
21	73	165	54	0	0
22	66	88	55	0	0
23	21	42	56	0	0
24	8	20	57	0	0
25	2	4	58	0	0
26	1	5	59	0	1
27	4	4	60	0	0
28	0	1			
29	0	0	TOTAL	3262	2767
30	0	0	MEAN	15783	16638
31	0	0	STD DEV	3959	4182
32	0	0			

GROSS VEHICLE WEIGHT DISTRIBUTIONS

Type = "3-S2 SEMI"

G.V.W. LIMIT

Tonnes	20000	33600	34500	36500	37500
0	0	1	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	0	0	0
7	0	0	0	0	0
8	0	0	0	0	0
9	0	1	0	0	0
10	0	0	0	0	0
11	0	10	1	7	3
12	0	22	1	10	10
13	1	24	3	12	16
14	1	48	1	22	44
15	2	67	3	24	48
16	0	88	11	40	67
17	1	108	17	41	91
18	0	100	13	49	121
19	4	130	15	52	159
20	0	129	18	74	192
21	2	161	18	65	190
22	1	195	14	82	195
23	4	216	14	76	210
24	2	239	18	94	245
25	3	239	15	99	255
26	4	231	15	110	285
27	3	296	19	98	288
28	1	322	21	136	321
29	5	478	19	133	399
30	4	563	26	160	440
31	8	793	35	177	611
32	11	1276	34	217	744
33	17	1663	27	362	1010
34	4	618	40	424	1211
35	1	435	60	418	1252
36	1	231	36	251	548
37	0	67	10	85	124
38	1	31	4	34	30
39	0	5	0	21	24
40	0	5	1	15	10
41	0	7	0	0	11
42	0	2	0	3	3
43	0	1	1	0	4
44	0	4	0	1	0
45	0	0	0	1	0
46	0	0	0	0	1
47	0	0	0	0	0
48	0	0	0	0	0
49	0	0	0	0	1

Tonnes	20000	33600	34500	36500	37500
50	0	0	0	0	0
51	0	0	0	0	0
52	0	0	0	0	0
53	0	0	0	0	0
54	0	0	0	0	0
55	0	0	0	0	0
56	0	0	0	0	0
57	0	0	0	0	0
58	0	0	0	0	0
59	0	0	0	0	0
60	0	0	0	0	0
TOTAL	81	8806	510	3393	9163
MEAN	29008	30022	28933	30509	30626
STD DEV	5616	5212	6448	5941	5465

GROSS VEHICLE WEIGHT DISTRIBUTIONS

Type = "6 AXLE A-TRAIN"

G.V.W. LIMIT

Tonnes	33600	36500	44600	48800
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0	0	0
15	0	0	0	0
16	0	0	0	1
17	0	0	0	1
18	0	0	1	1
19	0	0	0	1
20	1	1	0	1
21	2	0	0	2
22	0	0	1	2
23	2	0	1	1
24	0	0	1	1
25	2	0	0	4
26	0	0	0	3
27	4	0	0	3
28	1	0	1	6
29	1	0	1	10
30	1	1	1	6
31	2	1	0	4
32	1	1	0	14
33	1	1	1	18
34	2	1	0	8
35	1	2	1	7
36	2	1	0	8
37	1	3	0	12
38	3	1	0	9
39	1	0	0	6
40	0	0	0	8
41	1	1	0	5
42	0	0	0	4
43	0	0	0	6
44	0	0	0	3
45	0	0	0	0
46	0	0	0	0
47	0	0	0	0
48	0	0	0	0
49	0	0	0	0
50	0	0	0	0
51	0	0	0	0
52	0	0	0	0
53	0	0	0	0
54	0	0	0	0
55	0	0	0	0
56	0	0	0	0
57	0	0	0	0
58	0	0	0	0
59	0	0	0	0
60	0	0	0	0
TOTAL	29	14	9	155
MEAN	31066	34481	27300	33973
STD DEV	6136	5150	5598	5977

GROSS VEHICLE WEIGHT DISTRIBUTIONS

Type = "7 AXLE A-TRAIN"

G.V.W. LIMIT

Tonnes	33600	36500	47600	50000	55700
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	0	0	0
7	0	0	0	0	0
8	0	0	0	0	0
9	0	0	0	0	0
10	0	0	0	0	0
11	0	0	0	0	0
12	0	0	0	0	0
13	0	0	0	0	0
14	0	0	0	0	0
15	1	0	0	0	0
16	0	0	0	0	1
17	0	0	0	0	0
18	0	2	2	0	1
19	0	0	0	0	0
20	0	0	0	0	0
21	0	0	0	1	0
22	0	0	0	0	1
23	0	0	0	1	0
24	1	0	0	1	1
25	0	0	0	0	0
26	0	0	0	0	0
27	0	0	1	1	1
28	0	0	0	1	0
29	0	0	0	1	2
30	0	1	0	1	2
31	1	0	0	1	1
32	0	0	0	1	3
33	0	0	1	1	1
34	0	1	1	1	1
35	2	0	1	2	1
36	1	1	0	2	3
37	0	0	0	2	4
38	0	0	0	1	2
39	0	0	1	2	1
40	0	0	2	2	4
41	1	0	2	4	9
42	1	0	1	6	9
43	2	0	4	5	19
44	8	0	5	3	16
45	4	0	8	6	19
46	4	1	9	18	16
47	2	0	3	20	26
48	3	3	7	27	28
49	5	1	5	37	36

Tonnes	33600	36500	47600	50000	55700
50	1	2	6	28	41
51	4	0	8	2	33
52	0	0	8	2	27
53	0	0	2	0	20
54	1	0	5	0	27
55	0	0	0	0	4
56	0	0	0	1	0
57	0	0	0	0	0
58	0	0	0	0	0
59	0	0	0	0	0
60	0	0	0	0	0
TOTAL	42	12	82	181	360
MEAN	44570	40014	46738	46314	47796
STD DEV	7346	12003	6728	5677	5843

GROSS VEHICLE WEIGHT DISTRIBUTIONS

Type = "7 AXLE B-TRAIN"

G.V.W. LIMIT

Tonnes	33600	36500	47700	50000	53500
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	0	0	0
7	0	0	0	0	0
8	0	0	0	0	0
9	0	0	0	0	0
10	0	0	0	0	0
11	0	0	0	0	0
12	0	0	0	0	0
13	0	0	0	0	0
14	0	0	0	0	0
15	0	0	0	0	0
16	0	0	0	0	0
17	0	0	0	1	0
18	0	0	0	0	0
19	0	0	0	0	0
20	0	0	0	0	0
21	0	1	0	1	0
22	0	0	0	0	0
23	0	0	0	0	0
24	0	0	0	0	0
25	0	0	0	0	0
26	0	1	0	0	0
27	0	0	0	0	1
28	0	0	0	0	0
29	0	0	0	0	1
30	0	0	0	0	0
31	0	0	0	0	0
32	0	0	0	0	0
33	0	0	0	0	0
34	0	0	0	0	0
35	0	0	0	0	0
36	0	0	0	0	1
37	0	0	0	0	1
38	0	0	0	0	0
39	0	0	0	0	0
40	0	0	0	0	1
41	0	1	0	0	2
42	1	0	0	0	2
43	0	0	2	0	1
44	0	0	2	0	3
45	0	1	2	5	2
46	1	0	0	0	10
47	1	1	4	2	14
48	0	1	13	5	11
49	0	1	16	4	23

Tonnes	33600	36500	47700	50000	53500
50	1	3	11	5	13
51	1	0	3	1	12
52	2	0	2	2	7
53	0	0	0	0	2
54	0	0	0	0	3
55	0	0	0	0	0
56	0	0	0	0	1
57	0	0	1	0	2
58	0	0	0	0	1
59	0	0	0	0	0
60	0	0	0	0	0
TOTAL	7	10	56	26	114
MEAN	49134	43306	49132	46502	48632
STD DEV	3892	10703	2212	8189	4410

GROSS VEHICLE WEIGHT DISTRIBUTIONS

Type = "8 AXLE A-TRAIN"

G.V.W. LIMIT

Tonnes	36500	47600	50000	56500	Tonnes	36500	47600	50000	56500
0	0	0	0	0	34	0	0	1	1
1	0	0	0	0	35	0	0	1	1
2	0	0	0	0	36	0	0	0	1
3	0	0	0	0	37	1	0	0	0
4	0	0	0	0	38	0	0	3	0
5	0	0	0	0	39	0	1	0	0
6	0	0	0	0	40	0	0	1	0
7	0	0	0	0	41	1	0	1	1
8	0	0	0	0	42	0	1	0	0
9	0	0	0	0	43	0	0	2	1
10	0	0	0	0	44	0	1	0	0
11	0	0	0	0	45	0	0	2	2
12	0	0	0	0	46	0	1	2	0
13	0	0	0	0	47	0	3	1	4
14	0	0	0	0	48	0	0	5	4
15	0	0	0	0	49	0	2	3	2
16	0	0	0	0	50	0	0	2	2
17	0	0	0	0	51	0	1	1	5
18	0	0	0	0	52	0	0	0	3
19	0	0	0	0	53	0	0	1	8
20	0	0	0	0	54	0	1	1	4
21	0	0	0	0	55	0	0	0	4
22	0	0	0	0	56	0	1	0	3
23	0	0	0	0	57	0	1	0	6
24	0	0	0	1	58	0	0	2	3
25	0	0	0	0	59	0	0	1	2
26	1	0	0	1	60	0	0	0	0
27	0	0	0	0					
28	0	0	0	0	TOTAL	3	15	33	61
29	0	0	0	0	MEAN	35305	46513	45636	50359
30	0	1	2	0	STD DEV	7451	7836	7697	8007
31	0	0	0	1					
32	0	1	1	0					
33	0	0	0	1					

AXLE WEIGHT DISTRIBUTIONS

Type = "2 AXLE STRAIGHT TRUCK"
Axle = "SINGLE"
Comm = "ALL"

GVW LIMIT

KG.	13700	14600	KG.	13700	14600
0	0	0	6600	198	125
200	1	0	6800	288	169
400	2	0	7000	260	158
600	1	0	7200	268	143
800	1	0	7400	209	144
1000	2	1	7600	127	103
1200	2	5	7800	157	105
1400	18	16	8000	120	105
1600	47	25	8200	93	102
1800	70	50	8400	56	60
2000	97	60	8600	67	71
2200	117	80	8800	37	44
2400	211	93	9000	33	44
2600	158	101	9200	20	32
2800	299	132	9400	13	13
3000	227	162	9600	15	23
3200	261	177	9800	14	19
3400	387	199	10000	4	7
3600	230	188	10200	4	6
3800	310	217	10400	5	4
4000	245	199	10600	1	2
4200	290	188	10800	1	3
4400	223	173	11000	1	0
4600	287	187	11200	1	0
4800	312	210	11400	0	1
5000	186	169	11600	1	0
5200	253	148	11800	0	1
5400	288	168	12000+	3	0
5600	301	201			
5800	298	213	TOTAL	7817	5325
6000	213	169	MEAN	5179	5338
6200	270	150	STD DEV	1836	1910
6400	214	160			

AXLE WEIGHT DISTRIBUTIONS

Type = "2 AXLE STRAIGHT TRUCK"
Axle = "STEERING"
Comm = "ALL"

GVW LIMIT

KG.	13700	14600	KG.	13700	14600
0	0	0	6600	0	0
200	2	1	6800	0	1
400	0	0	7000	0	0
600	0	0	7200	0	0
800	10	2	7400	0	0
1000	51	24	7600	0	0
1200	242	115	7800	0	0
1400	470	232	8000	0	0
1600	559	245	8200	0	0
1800	870	338	8400	0	0
2000	805	399	8600	0	0
2200	649	456	8800	0	0
2400	750	516	9000	0	0
2600	562	415	9200	0	0
2800	680	511	9400	0	0
3000	438	467	9600	0	0
3200	342	349	9800	0	0
3400	481	361	10000	0	0
3600	334	247	10200	0	0
3800	242	218	10400	0	0
4000	113	138	10600	0	0
4200	84	99	10800	0	0
4400	60	73	11000	0	0
4600	25	52	11200	0	0
4800	21	21	11400	0	0
5000	7	19	11600	0	0
5200	11	12	11800	0	0
5400	6	8	12000+	0	0
5600	0	1			
5800	3	3	TOTAL	7817	5325
6000	0	1	MEAN	2557	2771
6200	0	1	STD DEV	793	831
6400	0	0			

AXLE WEIGHT DISTRIBUTIONS

Type = "3 AXLE STRAIGHT TRUCK"
Axle = "STEERING"
Comm = "ALL"

GVW LIMIT

KG.	20000	21500	KG.	20000	21500
0	0	0	6600	7	15
200	0	0	6800	13	19
400	2	2	7000	12	50
600	0	1	7200	11	29
800	0	0	7400	20	23
1000	3	2	7600	13	19
1200	0	1	7800	22	19
1400	3	2	8000	12	15
1600	5	0	8200	7	4
1800	32	4	8400	7	1
2000	44	10	8600	3	1
2200	76	14	8800	1	1
2400	113	53	9000	0	0
2600	94	63	9200	1	0
2800	163	90	9400	0	1
3000	148	115	9600	2	0
3200	175	110	9800	0	0
3400	250	171	10000	0	0
3600	221	193	10200	0	1
3800	352	232	10400	0	0
4000	304	184	10600	0	0
4200	332	221	10800	0	0
4400	234	218	11000	0	0
4600	146	133	11200	0	1
4800	121	158	11400	0	0
5000	86	137	11600	0	0
5200	72	113	11800	0	0
5400	47	113	12000+	0	0
5600	33	82			
5800	33	63	TOTAL	3262	2766
6000	17	35	MEAN	4039	4461
6200	13	26	STD DEV	1154	1239
6400	12	21			

AXLE WEIGHT DISTRIBUTIONS

Type = "3 AXLE STRAIGHT TRUCK"
Axle = "TANDEM"
Comm = "ALL"

GVW LIMIT

KG.	20000	21500	KG.	20000	21500
0	0	0	13200	174	105
400	0	0	13600	246	139
800	0	0	14000	290	202
1200	0	1	14400	384	257
1600	0	0	14800	154	202
2000	0	0	15200	82	134
2400	0	0	15600	48	150
2800	1	1	16000	34	75
3200	6	3	16400	32	42
3600	12	6	16800	11	17
4000	25	12	17200	8	14
4400	34	29	17600	1	10
4800	30	25	18000	4	6
5200	47	35	18400	2	3
5600	59	34	18800	4	2
6000	57	35	19200	1	0
6400	53	51	19600	0	2
6800	64	42	20000	1	0
7200	65	60	20400	1	0
7600	77	47	20800	0	2
8000	80	73	21200	0	0
8400	77	77	21600	0	0
8800	101	67	22000	0	1
9200	97	70	22400	0	1
9600	85	75	22800	0	0
10000	74	64	23200	0	0
10400	85	76	23600	0	0
10800	79	78	24000	0	0
11200	107	93			
11600	115	74	TOTAL	3262	2767
12000	92	88	MEAN	11744	12162
12400	132	88	STD DEV	3204	3302
12800	131	99			

AXLE WEIGHT DISTRIBUTIONS

Type = "3-S2 SEMI"
Axle = "STEERING"
Comm = "ALL"

GVW LIMIT

KG.	20000	33600	34500	36500	37500
0	0	2	0	0	0
200	0	10	0	0	1
400	0	15	0	0	6
600	0	0	0	0	0
800	0	0	0	0	0
1000	0	0	0	0	0
1200	0	0	0	0	0
1400	0	0	0	0	0
1600	0	1	0	0	0
1800	0	0	0	0	0
2000	0	3	0	0	2
2200	0	5	0	1	2
2400	0	13	1	3	6
2600	0	12	0	12	7
2800	1	43	1	12	14
3000	0	89	2	28	33
3200	7	161	7	41	70
3400	9	429	18	123	212
3600	15	692	29	193	429
3800	6	1187	45	369	899
4000	10	1325	79	467	1446
4200	20	1916	78	695	1920
4400	7	1468	80	648	1802
4600	3	742	57	360	1005
4800	3	409	58	202	715
5000	0	144	40	118	324
5200	0	59	9	45	159
5400	0	34	3	30	61
5600	0	18	2	20	17
5800	0	13	0	11	19
6000	0	4	0	3	5
6200	0	2	0	5	0
6400	0	4	0	1	2
6600	0	0	0	1	1
6800	0	1	0	0	0
7000	0	1	0	3	1
7200	0	0	1	0	2
7400	0	0	0	0	0
7600	0	2	0	0	0
7800	0	0	0	1	1
8000	0	0	0	0	0
8200	0	0	0	0	0
8400	0	0	0	0	0
8600	0	0	0	0	0
8800	0	0	0	0	0
9000	0	0	0	1	0
9200	0	1	0	0	1
9400	0	0	0	0	0
9600	0	0	0	0	0
9800	0	1	0	0	0
10000	0	0	0	0	1
10200	0	0	0	0	0
10400	0	0	0	0	0
10600	0	0	0	0	0
10800	0	0	0	0	0

KG.	20000	33600	34500	36500	37500
11000	0	0	0	0	0
11200	0	0	0	0	0
11400	0	0	0	0	0
11600	0	0	0	0	0
11800	0	0	0	0	0
12000+	0	0	0	0	0
TOTAL	81	8806	510	3393	9163
MEAN	3990	4204	4336	4319	4329
STD DEV	458	513	500	505	451

AXLE WEIGHT DISTRIBUTIONS

Type = "3-S2 SEMI"
Axle = "TANDEM"
Comm = "ALL"

GVW LIMIT

KG.	20000	33600	34500	36500	37500
0	0	2	0	0	0
400	0	0	0	0	0
800	0	0	0	0	0
1200	0	0	0	0	0
1600	0	1	0	0	0
2000	0	0	0	1	0
2400	0	0	0	0	0
2800	0	7	0	2	6
3200	0	7	2	4	7
3600	0	21	2	13	15
4000	1	50	0	15	42
4400	0	60	4	32	56
4800	1	76	12	49	84
5200	3	91	10	55	86
5600	1	130	16	44	102
6000	3	126	24	77	147
6400	2	153	19	50	153
6800	1	182	23	81	214
7200	1	208	12	90	215
7600	3	208	12	78	213
8000	1	204	22	100	274
8400	3	253	25	116	261
8800	2	255	26	86	326
9200	1	278	27	130	323
9600	5	329	19	123	298
10000	6	340	38	130	395
10400	6	318	36	117	380
10800	4	395	26	176	474
11200	3	458	24	196	496
11600	4	495	28	190	394
12000	6	596	37	212	533
12400	8	773	28	219	677
12800	7	835	27	258	690
13200	3	882	39	222	782
13600	22	1562	48	363	961
14000	23	2437	51	435	1363
14400	24	2805	65	645	1738
14800	12	1166	72	656	1845
15200	4	655	100	616	1934
15600	0	645	66	607	1472
16000	0	300	39	309	805
16400	1	141	18	110	282
16800	0	60	12	63	114
17200	0	42	4	36	57
17600	0	27	3	29	30
18000	0	8	1	20	34
18400	1	7	0	16	16
18800	0	7	0	2	12
19200	0	6	2	2	8
19600	0	6	0	4	4
20000	0	1	1	4	2
20400	0	2	0	1	4
20800	0	0	0	1	0
21200	0	0	0	0	0
21600	0	0	0	0	0

KG.	20000	33600	34500	36500	37500
22000	0	2	0	0	1
22400	0	0	0	0	0
22800	0	0	0	1	0
23200	0	0	0	0	0
23600	0	0	0	0	1
24000+	0	0	0	0	0
TOTAL	162	17612	1020	6786	18326
MEAN	12509	12909	12299	13095	13149
STD DEV	2746	2635	3328	3014	2829

AXLE WEIGHT DISTRIBUTIONS

Type = "6 AXLE A-TRAIN"
Axle = "SINGLE"
Comm = "ALL"

GVW LIMIT

KG.	33600	36500	44600	48800
0	0	0	0	0
200	0	0	0	0
400	0	0	0	0
600	0	0	0	0
800	0	0	0	0
1000	0	0	0	0
1200	0	0	0	0
1400	0	0	0	0
1600	0	0	0	0
1800	0	0	0	0
2000	2	0	0	4
2200	2	1	1	2
2400	0	0	0	4
2600	3	0	1	6
2800	1	0	0	1
3000	1	1	1	7
3200	2	0	0	3
3400	7	0	2	7
3600	2	0	0	8
3800	1	0	5	8
4000	3	0	2	9
4200	5	2	2	14
4400	6	1	1	18
4600	2	0	0	8
4800	0	1	0	13
5000	2	2	2	18
5200	3	1	2	15
5400	5	0	1	18
5600	0	1	1	14
5800	1	5	0	16
6000	4	2	0	26
6200	2	5	1	32
6400	3	3	1	24
6600	5	2	0	16
6800	5	2	1	18
7000	5	3	2	23
7200	6	2	0	24
7400	3	2	0	18
7600	2	1	0	19
7800	1	1	0	22
8000	0	2	1	13
8200	0	0	0	10
8400	0	0	0	10
8600	3	0	0	7
8800	0	1	0	3
9000	0	0	0	5
9200	0	1	0	1
9400	0	0	0	0
9600	0	0	0	0
9800	0	0	0	0
10000	0	0	0	0
10200	0	0	0	0
10400	0	0	0	0
10600	0	0	0	0
10800	0	0	0	1

KG.	33600	36500	44600	48800
11000	0	0	0	0
11200	0	0	0	0
11400	0	0	0	0
11600	0	0	0	0
11800	0	0	0	0
12000+	0	0	0	0
TOTAL	87	42	27	465
MEAN	5405	6308	4778	6099
STD DEV	1726	1376	1463	1597

AXLE WEIGHT DISTRIBUTIONS

Type = "6 AXLE A-TRAIN"
Axle = "STEERING"
Comm = "ALL"

GVW LIMIT

KG.	33600	36500	44600	48800
0	0	0	0	0
200	1	0	0	0
400	0	0	0	0
600	0	0	0	0
800	0	0	0	0
1000	0	0	0	0
1200	0	0	0	0
1400	0	0	0	0
1600	0	0	0	0
1800	0	0	0	0
2000	0	0	0	0
2200	0	0	0	0
2400	0	0	0	0
2600	0	0	1	0
2800	0	0	0	0
3000	0	1	1	1
3200	0	0	0	1
3400	3	2	1	1
3600	3	1	1	7
3800	7	1	1	15
4000	6	2	3	36
4200	3	2	0	43
4400	3	3	1	29
4600	2	0	0	11
4800	0	2	0	3
5000	1	0	0	4
5200	0	0	0	2
5400	0	0	0	1
5600	0	0	0	0
5800	0	0	0	0
6000	0	0	0	0
6200	0	0	0	0
6400	0	0	0	0
6600	0	0	0	0
6800	0	0	0	0
7000	0	0	0	0
7200	0	0	0	0
7400	0	0	0	0
7600	0	0	0	0
7800	0	0	0	0
8000	0	0	0	0
8200	0	0	0	0
8400	0	0	0	0
8600	0	0	0	0
8800	0	0	0	0
9000	0	0	0	0
9200	0	0	0	1
9400	0	0	0	0
9600	0	0	0	0
9800	0	0	0	0
10000	0	0	0	0
10200	0	0	0	0
10400	0	0	0	0
10600	0	0	0	0
10800	0	0	0	0

KG.	33600	36500	44600	48800
11000	0	0	0	0
11200	0	0	0	0
11400	0	0	0	0
11600	0	0	0	0
11800	0	0	0	0
12000+	0	0	0	0
TOTAL	29	14	9	155
	3955	4119	3689	4284
	789	532	580	528

AXLE WEIGHT DISTRIBUTIONS

Type = "6 AXLE A-TRAIN"
Axle = "TANDEM"
Comm = "ALL"

GVW LIMIT

KG.	33600	36500	44600	48800
0	0	0	0	0
400	0	0	0	0
800	0	0	0	0
1200	0	0	0	0
1600	0	0	0	0
2000	0	0	0	0
2400	0	0	0	0
2800	0	0	0	0
3200	0	0	0	0
3600	0	0	0	0
4000	0	0	0	0
4400	0	0	0	0
4800	0	0	0	0
5200	0	0	1	2
5600	0	0	0	1
6000	0	0	0	1
6400	0	1	0	2
6800	3	0	0	1
7200	0	0	1	2
7600	0	0	0	3
8000	1	1	1	5
8400	1	0	1	3
8800	2	1	1	5
9200	1	0	1	9
9600	2	1	0	10
10000	2	2	0	6
10400	2	0	1	4
10800	3	0	0	15
11200	0	0	0	13
11600	2	0	0	6
12000	3	2	1	11
12400	0	2	0	14
12800	2	0	1	6
13200	2	0	0	5
13600	1	2	0	10
14000	1	2	0	6
14400	0	0	0	3
14800	1	0	0	4
15200	0	0	0	4
15600	0	0	0	3
16000	0	0	0	1
16400	0	0	0	0
16800	0	0	0	0
17200	0	0	0	0
17600	0	0	0	0
18000	0	0	0	0
18400	0	0	0	0
18800	0	0	0	0
19200	0	0	0	0
19600	0	0	0	0
20000	0	0	0	0
20400	0	0	0	0
20800	0	0	0	0
21200	0	0	0	0
21600	0	0	0	0

KG.	33600	36500	44600	48800
22000	0	0	0	0
22400	0	0	0	0
22800	0	0	0	0
23200	0	0	0	0
23600	0	0	0	0
24000+	0	0	0	0
TOTAL	29	14	9	155
	10896	11437	9278	11391
	2217	2455	2408	2353

AXLE WEIGHT DISTRIBUTIONS

Type = "7 AXLE A-TRAIN"
Axle = "SINGLE"
Comm = "ALL"

GVW LIMIT

KG.	33600	36500	47600	50000	55700
0	0	0	0	0	0
200	0	0	0	0	0
400	0	0	0	0	0
600	0	0	0	0	0
800	0	0	0	0	0
1000	0	0	0	0	2
1200	1	0	0	0	1
1400	1	0	0	0	1
1600	0	0	0	0	0
1800	0	2	2	0	2
2000	0	0	0	0	3
2200	0	1	0	2	2
2400	0	1	2	0	2
2600	0	2	0	0	0
2800	0	0	1	1	1
3000	2	2	1	1	1
3200	0	0	1	2	4
3400	0	0	0	1	4
3600	0	0	0	6	3
3800	0	0	0	3	1
4000	1	0	0	2	2
4200	0	0	2	4	4
4400	3	0	0	5	0
4600	1	0	2	6	6
4800	1	0	0	3	7
5000	2	1	2	1	15
5200	1	0	1	2	10
5400	4	0	3	8	21
5600	2	0	2	9	18
5800	5	1	2	11	14
6000	10	0	6	11	24
6200	6	3	12	25	21
6400	5	1	6	23	34
6600	4	2	13	36	20
6800	11	3	12	48	24
7000	6	0	12	29	47
7200	4	1	9	38	36
7400	4	1	13	26	71
7600	3	1	11	17	81
7800	2	0	9	25	49
8000	2	0	12	8	53
8200	2	0	5	2	22
8400	0	1	10	2	23
8600	0	0	4	3	19
8800	0	0	4	0	27
9000	0	0	3	0	30
9200	0	0	1	2	9
9400	0	0	0	0	6
9600	1	0	1	0	0
9800	0	0	0	0	0
10000	0	0	0	0	0
10200	0	0	0	0	0
10400	0	1	0	0	0
10600	0	0	0	0	0
10800	0	0	0	0	0

KG.	33600	36500	47600	50000	55700
*****					
11000	0	0	0	0	0
11200	0	0	0	0	0
11400	0	0	0	0	0
11600	0	0	0	0	0
11800	0	0	0	0	0
12000+	0	0	0	0	0
TOTAL	84	24	164	362	720
	6297	5460	7006	6651	7106
	1351	2411	1387	1130	1421

AXLE WEIGHT DISTRIBUTIONS

Type = "7 AXLE A-TRAIN"
Axle = "STEERING"
Comm = "ALL"

GVW LIMIT

KG.	33600	36500	47600	50000	55700
0	0	0	0	0	0
200	0	0	0	0	0
400	0	0	0	0	0
600	0	0	0	0	0
800	0	0	0	0	0
1000	0	0	0	0	0
1200	0	0	0	0	0
1400	0	0	0	0	0
1600	0	0	0	0	0
1800	0	0	0	0	0
2000	0	0	0	0	0
2200	0	0	1	0	0
2400	0	0	0	0	0
2600	0	0	0	0	0
2800	0	0	0	0	0
3000	1	0	1	0	1
3200	0	0	0	1	0
3400	0	0	2	2	4
3600	3	2	3	7	6
3800	2	0	1	6	15
4000	7	1	0	16	29
4200	9	3	10	34	54
4400	5	1	25	45	79
4600	7	2	14	43	73
4800	3	0	13	15	48
5000	3	1	9	8	23
5200	1	2	2	4	11
5400	1	0	1	0	6
5600	0	0	0	0	1
5800	0	0	0	0	3
6000	0	0	0	0	3
6200	0	0	0	0	0
6400	0	0	0	0	0
6600	0	0	0	0	0
6800	0	0	0	0	1
7000	0	0	0	0	0
7200	0	0	0	0	0
7400	0	0	0	0	3
7600	0	0	0	0	0
7800	0	0	0	0	0
8000	0	0	0	0	0
8200	0	0	0	0	0
8400	0	0	0	0	0
8600	0	0	0	0	0
8800	0	0	0	0	0
9000	0	0	0	0	0
9200	0	0	0	0	0
9400	0	0	0	0	0
9600	0	0	0	0	0
9800	0	0	0	0	0
10000	0	0	0	0	0
10200	0	0	0	0	0
10400	0	0	0	0	0
10600	0	0	0	0	0
10800	0	0	0	0	0

KG.	33600	36500	47600	50000	55700
11000	0	0	0	0	0
11200	0	0	0	0	0
11400	0	0	0	0	0
11600	0	0	0	0	0
11800	0	0	0	0	0
12000+	0	0	0	0	0
TOTAL	42	12	82	181	360
	4392	4481	4511	4458	4566
	477	545	481	355	519

AXLE WEIGHT DISTRIBUTIONS

Type = "7 AXLE A-TRAIN"
Axle = "TANDEM"
Comm = "ALL"

GVW LIMIT

KG.	33600	36500	47600	50000	55700
0	0	0	0	0	0
400	0	0	0	0	0
800	0	0	0	0	0
1200	0	0	0	0	0
1600	0	0	0	0	0
2000	0	0	0	0	0
2400	0	0	0	0	0
2800	1	0	0	0	1
3200	0	0	0	0	1
3600	0	0	0	1	1
4000	0	2	2	1	0
4400	0	0	0	0	0
4800	0	0	0	0	2
5200	1	2	0	0	1
5600	0	0	0	2	1
6000	0	0	3	2	2
6400	0	0	0	3	0
6800	1	0	1	2	3
7200	0	0	1	0	0
7600	4	0	1	3	3
8000	0	0	0	1	3
8400	1	0	1	2	0
8800	1	0	2	3	3
9200	0	0	1	4	4
9600	0	0	0	1	3
10000	0	2	0	2	9
10400	1	0	0	2	4
10800	0	1	4	6	4
11200	4	0	1	3	8
11600	0	0	0	3	6
12000	0	2	4	5	12
12400	4	1	5	9	15
12800	3	2	7	8	19
13200	4	1	11	8	36
13600	6	0	11	15	26
14000	7	1	19	32	56
14400	10	0	14	33	63
14800	11	4	18	50	101
15200	9	2	15	70	94
15600	6	3	16	67	112
16000	4	1	14	20	96
16400	2	0	7	2	26
16800	1	0	3	1	3
17200	0	0	2	1	1
17600	0	0	0	0	1
18000	0	0	0	0	0
18400	0	0	0	0	0
18800	1	0	0	0	0
19200	2	0	0	0	0
19600	0	0	0	0	0
20000	0	0	0	0	0
20400	0	0	0	0	0
20800	0	0	0	0	0
21200	0	0	0	0	0
21600	0	0	0	0	0

KG.	33600	36500	47600	50000	55700
22000	0	0	0	0	0
22400	0	0	0	0	0
22800	0	0	0	0	0
23200	0	0	0	0	0
23600	0	0	0	0	0
24000+	0	0	1	0	0
TOTAL	84	24	164	362	720
	13792	12307	14107	14277	14509
	2865	3870	2548	2241	1995

AXLE WEIGHT DISTRIBUTIONS

Type = "7 AXLE B-TRAIN"
Axle = "STEERING"
Comm = "ALL"

GVW LIMIT

KG.	33600	36500	47600	50000	53500
0	0	0	0	0	0
200	0	0	0	0	0
400	0	0	0	0	0
600	0	0	0	0	0
800	0	0	0	0	0
1000	0	0	0	0	0
1200	0	0	0	0	0
1400	0	0	0	0	0
1600	0	0	0	0	0
1800	0	0	0	0	0
2000	0	0	0	0	0
2200	0	0	0	0	0
2400	0	0	0	0	0
2600	0	0	0	0	0
2800	0	0	0	0	0
3000	0	0	0	0	0
3200	0	0	0	0	0
3400	1	1	0	0	1
3600	0	0	1	1	1
3800	0	0	1	4	2
4000	0	0	3	2	8
4200	1	2	10	5	18
4400	0	5	16	5	39
4600	0	1	16	4	21
4800	2	1	6	2	12
5000	1	0	0	2	6
5200	0	0	2	0	3
5400	1	0	1	0	1
5600	0	0	0	0	0
5800	0	0	0	0	0
6000	1	0	0	0	0
6200	0	0	0	1	0
6400	0	0	0	0	0
6600	0	0	0	0	0
6800	0	0	0	0	1
7000	0	0	0	0	1
7200	0	0	0	0	0
7400	0	0	0	0	0
7600	0	0	0	0	0
7800	0	0	0	0	0
8000	0	0	0	0	0
8200	0	0	0	0	0
8400	0	0	0	0	0
8600	0	0	0	0	0
8800	0	0	0	0	0
9000	0	0	0	0	0
9200	0	0	0	0	0
9400	0	0	0	0	0
9600	0	0	0	0	0
9800	0	0	0	0	0
10000	0	0	0	0	0
10200	0	0	0	0	0
10400	0	0	0	0	0
10600	0	0	0	0	0
10800	0	0	0	0	0

KG.	33600	36500	47600	50000	53500
11000	0	0	0	0	0
11200	0	0	0	0	0
11400	0	0	0	0	0
11600	0	0	0	0	0
11800	0	0	0	0	0
12000+	0	0	0	0	0
TOTAL	7	10	56	26	114
	4844	4389	4523	4464	4542
	870	393	316	544	448

AXLE WEIGHT DISTRIBUTIONS

Type = "7 AXLE B-TRAIN"
Axle = "TANDEM"
Comm = "ALL"

GVW LIMIT

KG.	33600	36500	47700	50000	53500
0	0	0	0	0	0
400	0	0	0	0	0
800	0	0	0	0	0
1200	0	0	0	0	0
1600	0	0	0	0	0
2000	0	0	0	0	0
2400	0	0	0	0	0
2800	0	0	0	0	0
3200	0	0	0	1	0
3600	0	0	0	1	0
4000	0	0	0	0	0
4400	0	1	0	1	0
4800	0	0	0	1	0
5200	0	0	0	0	0
5600	0	0	0	0	0
6000	0	3	0	1	1
6400	0	0	0	0	1
6800	0	0	0	0	1
7200	0	0	0	0	1
7600	0	1	0	0	0
8000	0	0	0	1	1
8400	0	0	0	1	1
8800	0	1	0	0	0
9200	0	0	0	0	2
9600	0	0	0	0	0
10000	0	0	0	0	3
10400	1	0	1	1	0
10800	0	0	0	0	2
11200	0	1	0	1	1
11600	1	1	0	0	3
12000	1	0	1	1	5
12400	3	1	4	2	8
12800	0	1	4	1	8
13200	0	1	2	3	14
13600	1	1	9	6	15
14000	0	1	24	7	44
14400	0	3	24	8	37
14800	2	6	35	6	55
15200	2	3	26	12	50
15600	5	4	18	18	29
16000	2	0	13	4	28
16400	1	1	4	0	12
16800	1	0	0	0	5
17200	0	0	1	0	4
17600	1	0	0	0	4
18000	0	0	2	0	5
18400	0	0	0	1	2
18800	0	0	0	0	0
19200	0	0	0	0	0
19600	0	0	0	0	0
20000	0	0	0	0	0
20400	0	0	0	0	0
20800	0	0	0	0	0
21200	0	0	0	0	0
21600	0	0	0	0	0

KG.	33600	36500	47700	50000	53500
22000	0	0	0	0	0
22400	0	0	0	0	0
22800	0	0	0	0	0
23200	0	0	0	0	0
23600	0	0	0	0	0
24000+	0	0	0	0	0
TOTAL	21	30	168	78	342
	14763	12972	14870	14013	14697
	1923	3480	1009	2940	1719

AXLE WEIGHT DISTRIBUTIONS

Type = "8 AXLE A-TRAIN"
Axle = "SINGLE"
Comm = "ALL"

GVW LIMIT

KG.	36500	47600	50000	56500
0	0	0	0	0
200	0	0	0	0
400	0	0	0	0
600	0	0	0	0
800	0	0	0	0
1000	0	0	0	0
1200	0	0	0	0
1400	0	0	0	0
1600	0	0	0	0
1800	0	0	0	0
2000	0	0	0	0
2200	0	0	0	1
2400	0	0	0	0
2600	0	0	0	0
2800	0	0	0	0
3000	1	0	0	0
3200	0	0	1	0
3400	0	1	0	1
3600	0	1	1	1
3800	0	1	0	1
4000	0	1	0	0
4200	0	1	0	0
4400	0	0	0	1
4600	1	0	2	3
4800	0	0	0	1
5000	0	0	1	0
5200	0	1	1	0
5400	0	0	1	1
5600	0	0	3	1
5800	0	1	0	3
6000	0	3	0	5
6200	0	1	1	3
6400	1	0	2	5
6600	0	0	1	1
6800	0	0	1	1
7000	0	1	2	2
7200	0	0	4	2
7400	0	0	1	1
7600	0	1	3	6
7800	0	0	3	4
8000	0	0	1	2
8200	0	0	1	4
8400	0	0	0	2
8600	0	0	1	3
8800	0	0	0	0
9000	0	0	0	2
9200	0	2	2	2
9400	0	0	0	0
9600	0	0	0	2
9800	0	0	0	0
10000	0	0	0	0
10200	0	0	0	0
10400	0	0	0	0
10600	0	0	0	0
10800	0	0	0	0

KG.	36500	47600	50000	56500
11000	0	0	0	0
11200	0	0	0	0
11400	0	0	0	0
11600	0	0	0	0
11800	0	0	0	0
12000+	0	0	0	0
TOTAL	3	15	33	61
	4778	5847	6769	6911
	1634	1875	1492	1618

AXLE WEIGHT DISTRIBUTIONS

Type = "8 AXLE A-TRAIN"
Axle = "STEERING"
Comm = "ALL"

GVW LIMIT

KG.	36500	47600	50000	56500
0	0	0	0	0
200	0	0	0	0
400	0	0	0	0
600	0	0	0	0
800	0	0	0	0
1000	0	0	0	0
1200	0	0	0	0
1400	0	0	0	0
1600	0	0	0	0
1800	0	0	0	0
2000	0	0	0	0
2200	0	0	0	0
2400	0	0	0	0
2600	0	0	0	0
2800	0	0	0	0
3000	0	0	0	0
3200	0	0	0	0
3400	0	1	2	0
3600	0	0	1	1
3800	0	0	2	4
4000	1	1	9	7
4200	0	1	5	17
4400	2	1	3	19
4600	0	5	5	5
4800	0	4	5	5
5000	0	1	0	3
5200	0	1	0	0
5400	0	0	0	0
5600	0	0	0	0
5800	0	0	0	0
6000	0	0	0	0
6200	0	0	0	0
6400	0	0	0	0
6600	0	0	0	0
6800	0	0	0	0
7000	0	0	0	0
7200	0	0	0	0
7400	0	0	0	0
7600	0	0	0	0
7800	0	0	0	0
8000	0	0	1	0
8200	0	0	0	0
8400	0	0	0	0
8600	0	0	0	0
8800	0	0	0	0
9000	0	0	0	0
9200	0	0	0	0
9400	0	0	0	0
9600	0	0	0	0
9800	0	0	0	0
10000	0	0	0	0
10200	0	0	0	0
10400	0	0	0	0
10600	0	0	0	0
10800	0	0	0	0

KG.	36500	47600	50000	56500
11000	0	0	0	0
11200	0	0	0	0
11400	0	0	0	0
11600	0	0	0	0
11800	0	0	0	0
12000+	0	0	0	0
TOTAL	3	15	33	61
	4385	4573	4412	4382
	189	422	784	295

AXLE WEIGHT DISTRIBUTIONS

Type = "8 AXLE A-TRAIN"
Axle = "TANDEM"
Comm = "ALL"

GVW LIMIT

KG.	36500	47600	50000	56500
0	0	0	0	0
400	0	0	0	0
800	0	0	0	0
1200	0	0	0	0
1600	0	0	0	0
2000	0	0	0	0
2400	0	0	0	0
2800	0	0	0	0
3200	0	0	0	0
3600	0	0	0	0
4000	0	1	0	0
4400	0	0	0	1
4800	0	1	0	2
5200	1	2	0	1
5600	0	0	0	0
6000	0	1	0	1
6400	0	1	3	1
6800	1	0	2	2
7200	1	0	3	2
7600	0	2	2	0
8000	0	0	9	8
8400	0	0	1	5
8800	1	2	4	4
9200	2	0	2	3
9600	0	0	5	4
10000	2	0	9	5
10400	0	4	3	0
10800	1	1	3	3
11200	0	3	4	4
11600	0	2	1	1
12000	0	1	7	9
12400	0	0	11	7
12800	0	3	4	10
13200	0	2	3	8
13600	0	2	1	9
14000	0	2	4	16
14400	0	2	4	9
14800	0	4	5	19
15200	0	2	3	16
15600	0	6	0	16
16000	0	1	2	11
16400	0	0	2	5
16800	0	0	0	1
17200	0	0	0	0
17600	0	0	1	0
18000	0	0	1	0
18400	0	0	0	0
18800	0	0	0	0
19200	0	0	0	0
19600	0	0	0	0
20000	0	0	0	0
20400	0	0	0	0
20800	0	0	0	0
21200	0	0	0	0
21600	0	0	0	0

KG.	36500	47600	50000	56500
22000	0	0	0	0
22400	0	0	0	0
22800	0	0	0	0
23200	0	0	0	0
23600	0	0	0	0
24000+	0	0	0	0
TOTAL	9	45	99	183
	8714	12031	11485	13022
	1843	3463	2788	2883