TAC ATC

Technical Report

Design Vehicle Dimensions for Use in Geometric Design

Transportation Association of Canada
Association des transports du Canada

December 1997

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2323 St. Laurent Blvd., Ottawa, ON K1G 4J8
Tel. (613) 736-1350 Fax (613) 736-1395
www.tac-atc.ca

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Design Vehicle Dimensions for Use in Geometric Design

Author(s)
Gerry LeMoal

Corporate Affiliation(s)
DS-Lea Consultants Ltd.

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Chief Engineers' Council
Transportation Association of Canada
2323 St. Laurent Blvd., Ottawa, Canada K1G 4J8

Performing Agencies Names and Addresses

DS-Lea Consultants Ltd.
93 Lombard Avenue, Suite 111
Winnipeg, Manitoba R3B 3B1

Abstract

Good design practice requires that the geometric layout of an intersection be checked to ensure that it can accommodate the class of vehicle that will be using the road system. The physical characteristics and dimensions of representative vehicles are positive controls for the intersection design.

The design vehicle dimensions referenced in the current version of the Geometric Design Guide for Canadian Roads are inappropriate. Some are outdated, having been unchanged since 1965, and some are overly conservative, being based on maximum legal dimensions rather than typical design dimensions. The objective of this study was to undertake a comprehensive review of the current practices and recommend new design vehicle standards to be used in an update for the Guide.

The report, Design Vehicle Dimensions For Use In Geometric Design, provides general background information relating to the theory of offtracking and describes the current (TAC/AASHTO) vehicle classes/dimensions used for geometric design purposes. The results of literature reviews and information obtained from various contacts are summarized and the merits/demerits of potential data sources for use in this study are discussed. Further details of the data sources selected for this study are given and the results of the data analysis along with final recommendations pertaining to design vehicle classes and their dimensions are presented.

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Auteur(s)	Affiliation(s)
Gerry LeMoal	DS-Lea Consultants Ltd.

Nom et adresse de l'organisme parrain	Nom et adresse de l'organisme exécutant
Conseil des ingénieurs en chef Association des transports du Canada 2323, boul. St-Laurent, Ottawa, Canada K1G 4J8	DS-Lea Consultants Ltd. 93 Lombard Avenue, Suite 111 Winnipeg, Manitoba R3B 3B1

Résumé

Les règles de l'art entourant l'établissement du plan d'une intersection routière exigent une vérification des paramètres de conception de cette dernière afin de s'assurer qu'elle répondra aux besoins des catégories de véhicules qui circuleront sur le réseau routier dont elle fait partie. Les caractéristiques physiques et les dimensions des véhicules de référence considérées dans ce contexte constituent des mesures efficaces de vérification de la pertinence de la conception d'une intersection.

Les dimensions des véhicules de référence répertoriés dans la version actuelle du Guide canadien de conception géométrique des routes ne permettent plus de satisfaire à une telle exigence. Ainsi, certaines descriptions de véhicules que contient cet ouvrage sont dépassées, n'ayant pas été mises à jour depuis 1965, tandis que d'autres sont exagérément prudentes, étant fondé sur les dimensions maximales réglementaires plutôt que sur les dimensions réelles des véhicules. Les résultats de cette étude serviront donc à mettre à jour l'édition de 1986 du Guide (lequel était alors désigné sous le nom de Normes canadiennes de conception géométrique des routes).

Le rapport, Design Vehicle Dimensions For Use In Geometric Design, contient 1) de l'information contextuelle générale se rapportant à la théorie de la dérive à l'essieu ainsi que des descriptions des catégories et dimensions des véhicules de référence servant actuellement (ATC/AASHTO) à la conception géométrique des routes, 2) une synthèse de l'information puisée dans différents documents ou obtenue auprès de diverses sources, 3) un traité des mérites et des lacunes des sources d'information pouvant être utilisées, 4) une description des sources de données choisies, 5) les résultats de l'analyse exécutée et 6) des recommandations définitives concernant les catégories et les dimensions des véhicules de référence.

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PROJECT STEERING COMMITTEE

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PROJECT CONSULTANT

Mr. Gerry LeMoal	Project Manager DS-Lea Consultants Ltd.

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The Consultant would like to express their appreciation for the assistance provided by the members of the Project Steering Committee. As well those individuals who provided advice and input to this study are thanked.

TAC wishes to thank all those who contributed input to the study and hopes that it will help transportation professionals to improve the design of roads.

1.0 INTRODUCTION

The physical characteristics of vehicles and the proportions of the various sizes of vehicles using the roadway facilities define several geometric design elements including roadway intersections, special vehicle parking, site access configurations, and specialized applications such as underground transit, trucking and parking facilities. It is necessary to examine all vehicle types using the facility and select a representative design vehicle, whose turning dimensions (i.e. dimensions affecting tracking or turning behaviour) are then used to establish the parameters for geometric design.

Design vehicle categories are generally established by examining all vehicle types, selecting general class groupings on the basis of use and turning behaviour, and defining representative size vehicles within each classification. The dimensions used to represent design vehicles are not averages or maximum, nor are they legal limiting dimensions. Rather, they are characteristic of those vehicles on the highways that form the bulk of the fleet that are approaching maximum permissible dimensions. In addition to current fleets, design dimensions should also take into account the immediate future trends in vehicle design to the extent they are known.

The identification of typical design vehicles and their dimensions is a fundamental part of the TAC (Transportation Association of Canada) Geometric Design Guide for Canadian Roads[1]. The design vehicles referenced in the current version of the Manual have remained unchanged since 1965. The range of vehicle types and their operating characteristics have changed significantly during the period elapsed. The vehicle size regulations have also gone through substantial revisions during this period, which has generally resulted in larger trucks on the road.

In view of the above, the design vehicle dimensions in the 1986 Geometric Design Guide for Canadian Roads are now considered to be outdated. Therefore, there is a need to verify or modify the design vehicle classes/dimensions to reflect current fleets, and future trends to the extent they are known. The results of this study will be used in the update of the 1986 Geometric Design Guide for Canadian Roads.

1.1 STUDY OBJECTIVES

With the purpose of updating the design vehicle classifications and their dimensions in the Geometric Design Guide for Canadian Roads, Lea Associates were engaged by the Transportation Association of Canada to undertake the following tasks:

- Examine the Canadian vehicle population to confirm or amend existing design group designations and develop a full list of design vehicles.

[1] *"Geometric Design Guide for Canadian Roads", Transportation Association of Canada, 1986 Metric Edition.*

- Conduct a survey of literature, regulations and manufacturers to determine existing control envelopes on dimensions and to predict future trends.

- Conduct an analysis of vehicle dimensions (pertinent to tracking behaviour) on statistically representative samples to establish their distribution curves and accordingly, establish dimension ranges, means, 85th percentile and 95th percentile values. Adjust dimensions as required to meet future demands.

In addition to establishing the critical turning dimensions, literature reviews and contacts with manufacturers during the course of this study were used to update other vehicle design dimensions including maximum vehicle height, vehicle width, and driver eye height.

1.2 SCOPE OF STUDY

Given the general objectives of the study, the wide range of variables affecting turning behaviour of vehicles, and the myriad of vehicle types that make-up the current fleet, this study was conducted under the following assumptions:

- The critical turning movements for the design of road facilities are done at low speeds (15 km/h or less). Past experience and comparative tests have shown that, at low speeds, the turning behaviour of vehicles is mainly determined by their geometric characteristics and the effects of friction and dynamics can be safely ignored.

- Groups of evenly spaced axles mounted on a rigid bogie act in the turn as a single axle placed at the center of the group for the purpose of measuring critical turning dimensions.

- Lift axles (permissible in some jurisdictions) are assumed lifted in the turn, with turning behaviour then being determined by the remaining (fixed) axles.

- The study is intended to determine those dimensions which define the turning envelope of vehicles mainly in forward motion. The same dimensions will permit calculation of the turning envelope of non-articulating vehicles in backing motion. The prediction of the backing behaviour of articulating vehicles, however, is very complex mainly because it is inherently unstable, and additional turning controls come into play.

In establishing the design dimensions for the various vehicle classes, this study focuses on vehicles in regular operation only. The following special vehicles were therefore excluded in the determination of specific design dimensions:

- Long load trucks with independently steerable rear bogies (e.g. large fire ladder trucks) are very rare. While their turning characteristics are different and perhaps of some academic interest, they are expected to perform within the envelope of common large trucks.

- Special trucks, such as Long Combination Vehicles (LCV's) and logging trucks, which are normally expected to operate within a limited jurisdiction, have been dealt with in the past as a separate class within the jurisdiction. For instance, British Columbia has conducted extensive research on its logging trucks and developed the computer program "Pathtracker" which provides tracking data for the variety of logging trucks in that province. Manitoba logging trucks deal with shorter log loads, but special trucks for this purpose are nevertheless under consideration. These special trucks are normally of local interest and configuration details are normally available through the local controlling agency[1]. Discussions with these provinces indicate that the geometric design requirements for such trucks are better addressed on an individual basis with templates produced using computer programs.

- Towed recreational vehicles cover a broad range of dimensions. Establishing representative dimensions for such vehicles would require considerable research effort, given their wide range of dimensions and local variations. A legally configured recreational trailer is expected to behave as any other trailer in the turn.

- Large trucks with tandem or triple steering axles in front (e.g. large concrete trucks and large mobile cranes) are very rare. Turning characteristics for such vehicles can be obtained directly from manufacturers.

Typical dimensions for some of these 'special' vehicles were obtained during this study, through industry contacts and published literature. These are summarized in Appendix A.

1.3 STUDY FRAMEWORK

The objectives of this study were accomplished in three distinct phases. The results of the first three phases were submitted in the form of working papers. This report presents the study results as a "stand-alone" document.

During the first phase[2], preliminary contacts were established with the various transportation agencies to identify relevant work by other North American agencies. A thorough review of the literature on related issues was completed, followed by an examination of various potential data sources for use in this study to develop design vehicle classes and their dimensions. Future trends in vehicle types and their dimensions were assessed during the second phase[3] through literature reviews and contacts with manufacturers. The actual analyses of data collected in the first two

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[1] *"Logging Truck Turning Template and Acceleration Study", Alberta Transportation and Utilities, 1992.*

[2] *Working Paper, "Design Vehicle Dimensions for Use in Geometric Design", Phase 1, Distributed to the Project Steering Committee, May 15/1996..*

[3] *Working Paper, "Design Vehicle Dimensions for Use in Geometric Design", Phase 2: A Preliminary Assessment of Future Trends, Distributed to the Project Steering Committee, July 15/1996.*

phases were undertaken during the third phase[1], at the end of which, a preliminary list of design vehicles and their dimensions was developed for discussion purposes.

1.4 REPORT OVERVIEW

Following this introduction, Chapter 2 provides general background information relating to the theory of offtracking and describes the current (TAC/AASHTO) vehicle classes/dimensions used for geometric design purposes. Results of the literature reviews and information obtained from various contacts are summarized in Chapter 3. In Chapter 4, the merits/demerits of potential data sources for use in this study are discussed. Further details of the data sources selected for this study and the results of the data analysis are presented in Chapter 5. The final recommendations pertaining to design vehicle classes and their dimensions are presented in Chapter 6.

For convenience of presentation, this report describes the total road vehicle population in terms of three broad categories, namely, private vehicles, commercial vehicles, and buses. Private vehicles include passenger cars, light trucks, pickups, and vans. Commercial vehicles essentially include single unit trucks and truck combinations. The bus population includes standard single-unit buses, intercity buses, and articulated buses used for urban transportation. This grouping is used merely to facilitate discussions in the following sections and is <u>not</u> indicative of the design vehicle classes.

1.5 KEY DEFINITIONS

Definitions for some of the key terms used in this report are outlined below:

- **Overall length** of a vehicle or trailer combination is the distance between the front bumper of the power vehicle and the rear bumper on the rear unit of the vehicle. The overall length of a vehicle equals the sum of its effective wheelbases, front overhang, and rear overhang.

- **Total Wheelbase (TWB)** is the center-to-center distance between the front axle and the rearmost axle of the vehicle. The nomenclature used in the TAC and AASHTO design vehicle classes generally refer to the total wheelbase. For example, WB-15 refers to a tractor semitrailer with a total wheelbase of 15 m (approximately).

- **Effective Wheelbase (EWB)** is the distance between the centroid of the front axle group and the centroid of the rearmost axle group. The effective wheelbase of a vehicle determines its turning envelope. It should be noted that the total and effective wheelbases are the same for two-axle vehicles.

- **Front Overhang (FOH)** is the distance from the front bumper of a vehicle to the centre of its front axle group.

[1] Working Paper, " Design Vehicle Dimensions for Use in Geometric Design", Phase 3: Analysis of Current Vehicle Fleets, Distributed to the Project Steering Committee, Sep 30/1996.

- **Rear Overhang (ROH)** is the distance from the rear bumper of a vehicle to the centre of its rearmost axle group.

- **Cramp Angle** is the limit of the turning ability of the front wheels of a vehicle's front axle. The cramp angle of a vehicle is limited by the construction of mechanical parts around the front-axle and its kingpin-pivot mechanisms.

- **Minimum Turning Radius (TR)** is the radius of the minimum turning path of the outside of the outer front wheel. This corresponds to the minimum design turning radius definition used in the current TAC and AASHTO Design Guides.

2.0 BACKGROUND

As background information to this study, this chapter describes the phenomenon of offtracking and identifies the various dimensions that affect the turning behaviour of single-unit and multiple-unit vehicle configurations. Following this, the current design vehicle classifications (TAC/AASHTO) and their dimensions are summarized.

2.1 GEOMETRIC TURNING CONTROL PARAMETERS

To understand the phenomenon of offtracking, it is essential to appreciate the significance of the various parameters affecting the turning behaviour of a vehicle. The amount of offtracking varies directly with the wheelbase length of a unit and inversely with the radius of the turn through which the vehicle travels. The magnitude of offtracking is also affected by the number and location of articulation points, by the length of the arc negotiated during the turn, and by the speed and turning ability of the vehicle.

Several mathematical models exist for estimation of offtracking as a function of its wheelbase lengths, and the radius of the curve. Probably the best known of the formularized approaches to offtracking measurements is that of The Society of Automotive Engineers (SAE)[1]. Using this approach, parameters affecting offtracking are illustrated here for single and multiple unit vehicles.

2.1.1 Single-Unit Vehicles

Figure 2.1 shows a single unit vehicle of width w, wheelbase b, front overhang f, and rear overhang g. When this vehicle is in straight forward motion the front wheels track a distance of w apart. As it enters a circular curve, this distance decreases due to the skew of the front axle relative to the direction of motion. For the purpose of this discussion, the vehicle is assumed to be fully deflected in a constant circular path (i.e., a steady-state condition) around a point and all wheels are tangential to concentric paths around the point.

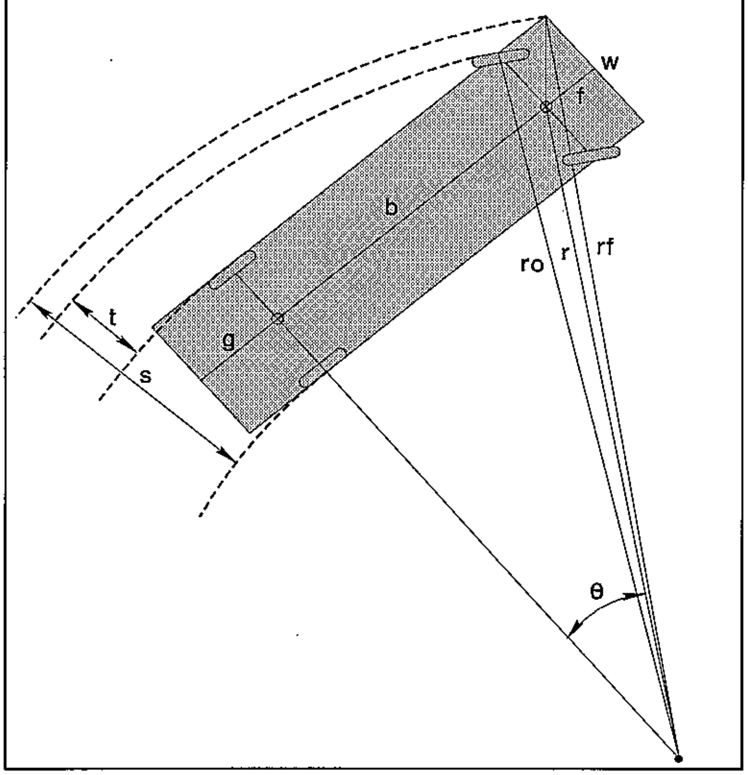
Say, r_o = radius of the outside front wheel (curb-to-curb radius)
r = radius of the centre of the front axle

The centre of the steering axle is used as reference since it is assumed to track in a circular path throughout the turn. The angle of deflection of the vehicle is θ, otherwise known as the cramp angle, and from the Cosine Law:

$$r_o = \sqrt{r^2 + \left(\frac{w}{2}\right)^2 - rw\cos(180-\theta)} \quad \text{(1)}$$

[1] *"Offtracking Characteristics of Trucks and Truck Combinations", Research Committee Report No. 3, Western Highway Institute, 1970.*

Figure 2.1
Off-Tracking and Swept Path of a SU Vehicle



and

$$r = b / \sin\theta \quad \ldots\ldots \quad (2)$$

If the maximum cramp angle θ_{max} is known, the maximum curb-to curb radius of a given vehicle can be determined from equation (1) after solving for r_o in equation (2).

The radius of sweep of the front overhang r_f can be determined, again from the Cosine Law:

$$r_f = \sqrt{r^2 + f^2 + \left(\frac{w}{2}\right)^2 - 2r\sqrt{f^2 + \left(\frac{w}{2}\right)^2}\cos(180-\theta) + \left(\tan^{-1}\left(\frac{f}{w/2}\right)\right)} \ldots \quad (3)$$

The off-tracking distance, t is the departure of the rearmost wheel track from its normal (straight motion) location behind the front wheel.

$$t = r_o - \left(r\cos\theta + \frac{w}{2}\right) \ldots\ldots \quad (4)$$

The total swept path, s, the vehicle describes on the ground is given by

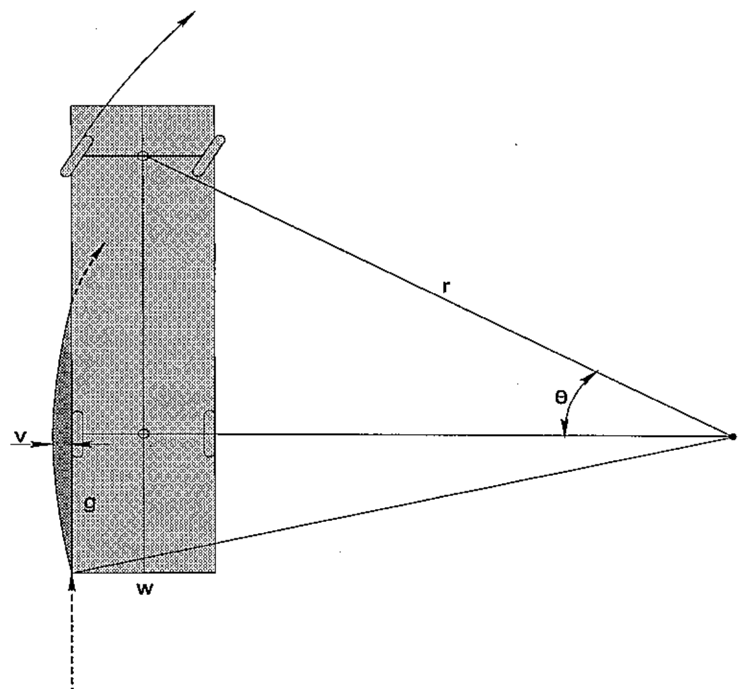
$$s = r_f - r \cos\theta + \left(\frac{w}{2}\right) \quad (5)$$

The rear overhang will normally swing outside of the swept path of the forward part of the vehicle when the turn starts with full cramp angle, as shown in Figure 2.2. The outswing v, is:

$$v = \sqrt{g^2 + \left(r\cos\theta + \frac{w}{2}\right)^2} - (r\cos\theta + \frac{w}{2}) \quad (6)$$

Under normal circumstances, when the overhang is some fraction of the wheelbase and the vehicle eases into the turn on a gradual spiral, the outswing is negligible.

Figure 2.2
Outswing of Rear Overhang



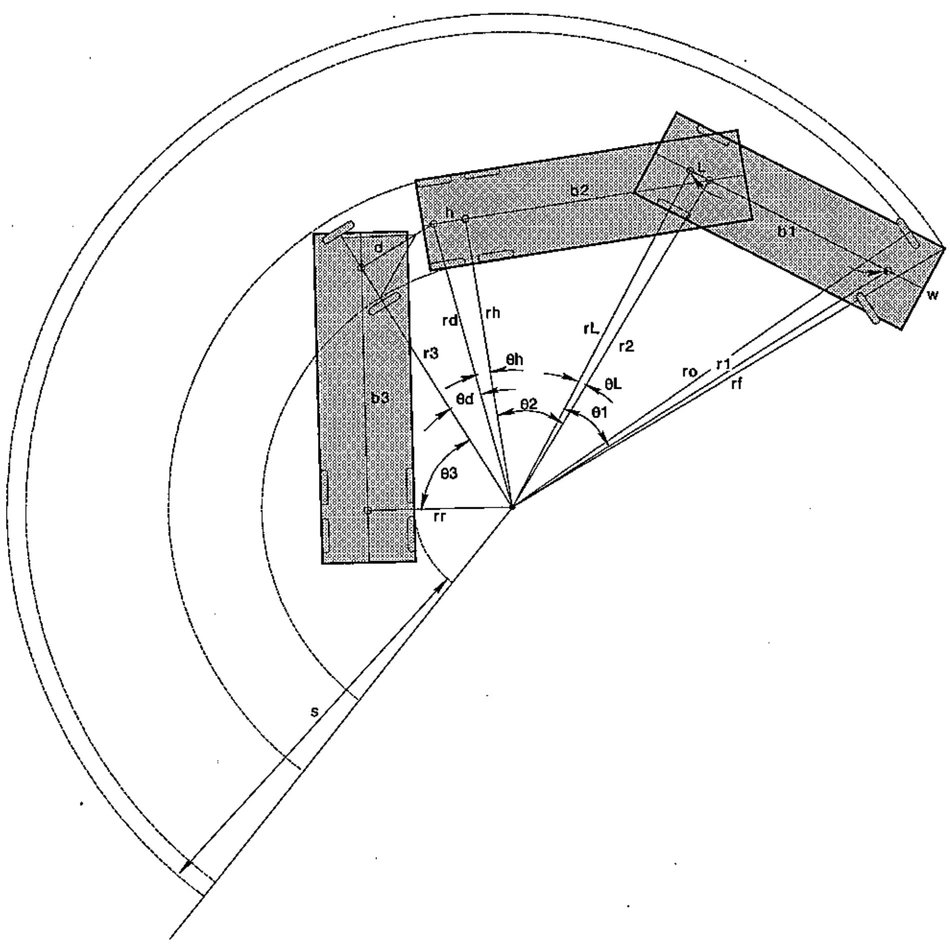
2.1.2 Multiple Unit Vehicles

The steady-state geometry of the turn of a multiple unit vehicle can be described as a series of single units each of whose minimum turning radius is established by the unit immediately in front of it. Given all wheelbases and other articulating dimensions (fifth wheel offset, hitch length, drawbar length) it is possible to calculate the swept path width of the train.

Figure 2.3 represents a three-unit A-train, where:

b_1, b_2, b_3	= wheelbases
L	= fifth wheel offset from the effective drive axle
h	= hitch length from the effective rear axle
d	= A-dolly drawbar length

Figure 2.3
Multiple-Unit Vehicle in a Steady-State Turn



Given the radius of turn of the lead unit (tractor), it is possible to calculate the articulation angle of the tractor unit.

$$\theta_1 = \sin^{-1}\frac{b_1}{r_1} \quad (7)$$

$$r_L = \sqrt{r_1^2 - b_1^2} \quad (8)$$

$$r_2 = \sqrt{r_L^2 + L^2} \quad (9)$$

$$r_h = \sqrt{r_2^2 + b_2^2} \quad (10)$$

$$r_d = \sqrt{r_h^2 + h^2} \quad (11)$$

$$r_3 = \sqrt{r_d^2 - d^2} \quad (12)$$

$$r_r = \sqrt{r_3^2 - b_3^2} \quad (13)$$

Successive substitutions of equations (12) to (8) into equation (13) yield:

$$r_r = \sqrt{r_1^2 - b_1^2 + L^2 - b_2^2 + h^2 - d^2 - b_3^2} \quad (14)$$

The radius of sweep of the front overhang, r_f, can be calculated using equation (3) with $r = r_1$.

The swept path width, s, is:

$$s = r_f - r_r + \frac{w}{2} \quad (15)$$

The above equations (7) to (15) can be applied to all configurations of multiple unit vehicles, by setting the non-applicable dimensions to zero.

From equation (14), the minimum radius of turn for a tractor, given a desired minimum radius of turn for the inner rear-most axle is:

$$r_1 = \sqrt{r_r^2 + b_1^2 - L^2 + b_2^2 - h^2 + d^2 + b_3^2} \quad (16)$$

Equation (16) can be used to establish the minimum radius of tractor turn required for a steady state turn with a multiple unit vehicle, to maintain forward motion on the wheels of the inside rear axle group in order to minimize side shear forces on pavement and tires, and to avoid 'jack-knifing'.

2.1.3 Sensitivity Analysis

In order to establish the desired design dimensions for this study, an analysis of the sensitivity of the width of the swept path to each of the turning control parameters was completed. The detailed analysis for an A-train is included in Appendix B, but the results are directly applicable to any of the single or multiple unit vehicle configurations. The parameters were varied individually over a distance of one metre within the expected range of operation and the effect on the swept path width was plotted. Results are summarized below in Table 2.1.

TABLE 2.1
EFFECT OF ONE METRE VARIATION IN CONTROL PARAMETER ON SWEPT PATH WIDTH

PARAMETER	RANGE OF DIMENSIONS TESTED (METRES)	CHANGE IN SWEPT PATH WIDTH (METRES)
f	0.2 to 1.2	+ 0.388
b_1	5.2 to 6.2	+ 0.721
L	-0.5 to 0.5	-0.150
b_2	6.4 to 7.4	0.829
h	0.7 to 1.7	- 0.143
d	2.1 to 3.1	+ 0.318
b_3	6.4 to 7.4	+ 0.829

2.2 TAC DESIGN VEHICLE SPECIFICATIONS

The current (1986) version of the TAC Manual uses six vehicle classes (Table 2.2) to illustrate geometric design guidelines. The classification includes two tractor-semitrailer truck categories, and one double combination truck category. The Manual also provides representative turning dimensions and minimum turning radii requirements for each of the six vehicle classes (Table 2.3).

TABLE 2.2
CURRENT TAC DESIGN VEHICLE CLASSES

VEHICLE CODE	VEHICLE TYPE
P	Passenger cars, light delivery vans and pickup trucks
SU-9	Single Unit Truck or Bus
B-12R	Highway buses (tandem rear axle) and fire trucks
WB-15	Intermediate semi-trailer combinations
WB-17	Large semitrailer combinations
WB-18	Semitrailer/full trailer combinations

TABLE 2.3
CURRENT TAC DESIGN VEHICLE DIMENSIONS

DIMENSION	P	SU-9	B-12R	WB-15	WB-17	WB-18
Length (m)	5.8	9.1	12.2	16.7	19.5	19.9
WB1 (m)	3.4	6.1	7.3	5.5	5.5	3.0
WB2 (m)	-	-	-	9.1	11.5	6.1
WB3 (m)	-	-	-	-	-	2.9
WB4 (m)	-	-	-	-	-	6.4
Front overhang (m)	0.9	1.2	1.8	0.9	1.0	0.6
Rear overhang (m)	1.5	1.8	3.1	0.6	1.0	0.9
Min. turning radius (m)	7.3	12.8	15.2	13.7	14.6	14.0
Width (m)	2.1	2.6	2.6	2.6	2.6	2.6
Height (m)	1.3	4.1	4.1	4.1	4.1	4.1

While the design vehicle classes in the Manual have been outdated for some time now, TAC has produced and has been updating the vehicle classes and dimensions for use in its "Turning Vehicle Templates" publication[1]. The 1993 edition of this turning vehicle template package was produced in response to changes in the range of vehicle types and dimensions, particularly in response to the Memorandum of Understanding (TAC MoU, 1988)[2] which resulted in the prominent use of several specialized vehicle types in the various provinces. In addition to the design vehicle classes used in the Manual, that publication provides representative dimensions and turning templates for several other vehicle classes as outlined in Table 2.4. It also uses a standard TAC-TST (TAC Tractor Semitrailer) vehicle class, as applicable within the MoU regulations, instead of the two tractor-semitrailer variations used in the Manual.

The Car/RT class represents a passenger car (P-vehicle) towing a large two-axle recreational trailer. The BUS class represents the standard 12.2 m (40 ft) long single unit diesel and trolley transit

[1] *"Turning Vehicle Templates", Transportation Association of Canada, Third Edition, June 1993.*

[2] *"Heavy Truck Weight and Dimension Regulations for Interprovincial Operations in Canada, Resulting from The Federal-Provincial-Territorial Memorandum of Understanding on Interprovincial Weights and Dimensions", June 1995.*

buses, equipped with a single rear axle. While its dimensions differ very little from those of the B-12R design vehicle, it has a considerably smaller minimum turning radius and therefore an improved turning ability. The A-BUS class represents the articulated bus population commonly used for urban transportation. The specifications for Car/RT, BUS, and A-BUS classes are generally consistent with the corresponding design vehicles used in the AASHTO (American Association of State Highway and Transportation Officials) Policy[1].

TABLE 2.4
VEHICLE CLASSES/DIMENSIONS FROM TURNING TEMPLATE PACKAGE

DIMENSION	CAR/RT	BUS	A-BUS	A-TRAIN	B-TRAIN
Length (m)	14.9	12.1	18.4	23.0	25.0
WB1 (m)	3.4	7.3	5.1	4.7	5.3
WB2 (m)	7.1	-	7.9	7.0	8.4
WB3 (m)	-	-	-	3.0	8.3
WB4 (m)	-	-	-	7.0	-
Front overhang (m)	0.9	2.1	2.5	0.7	0.7
Rear overhang (m)	3.5	2.7	2.9	0.6	2.3
Min. turning radius (m)	7.3	12.2	12.2	11.5	12.2
Width (m)	2.4	2.6	2.6	2.6	2.6

Notes:
- *WBN is the center-to-center wheelbase distance between axle groups N and N+1.*
- *For CAR/RT, WB2 of 7.1 m includes the 1.5 m rear overhang of the passenger car.*
- *For the A-BUS class, WB2 of 7.9 m includes a distance of 2.1 m ("S") from the rear effective axle to the hitch point, and an additional 5.8 m ("T") from the hitch point to the lead effective axle of the following unit.*

An A-train is a tractor-semitrailer with a full trailer, or a tractor-semitrailer with an A-dolly and a second semitrailer. This class is represented by the maximum dimensions possible under the MoU within an overall length of 23 m, which was the maximum length at the time of the publication. A B-train is a tractor-semitrailer-semitrailer combination where the first semitrailer tows the second semitrailer directly. This is represented by one of a large number of possible combinations of trailer length that could make up a B-train within the applicable rules.

2.4 AASHTO DESIGN VEHICLE SPECIFICATIONS

The design vehicle classifications and dimensions in the AASHTO Policy have gone through three revisions since its first version in 1957. The current (1994) version of the Policy provides a very comprehensive list of design vehicles based on the 15 categories shown in Table 2.5.
The AASHTO passenger car dimensions are the same as TAC Class "P" definitions. The dimensions, which are based on statistical analyses of fleet data, have been retained through the various versions of the Policy since 1965. As shown in Table 2.5, in addition to conventional

[1] *"A Policy on Geometric Design of Highways and Streets", AASHTO, 1994.*

passenger cars, AASHTO uses four other classes to define private vehicles used for recreational use. These classes were added to the AASHTO definitions in 1990, perhaps due to the increasing use of personal vehicles for recreational use. Their dimensions are based on typical dimensions rather than statistical distributions.

TABLE 2.5
CURRENT AASHTO DESIGN VEHICLE CLASSES

CLASS	CATEGORY	VEHICLE TYPE
Passenger Car Variations	P P/T P/B MH MH/B	Passenger Car Car and Camper Trailer Car and boat trailer Motor home Motor home and boat trailer
Single Unit Trucks	SU	Single unit truck
Semitrailer configurations	WB-12 WB-15 WB-19 WB-20	Intermediate semitrailer Large semitrailer Interstate semitrailer Interstate semitrailer
Double Combinations	WB-18	Semitrailer/full trailer
Long Combinations	WB-29 WB-35	Triple semitrailer Turnpike Double
Buses	BUS A-BUS	Single unit bus Articulated bus

The AASHTO classification for commercial vehicles is quite extensive compared to the TAC classifications. The SU, WB-15 and WB-18 classes are the same as the corresponding TAC definitions. The additional tractor-semitrailer variations used by AASHTO are a reflection of specific regulations in the United States, particularly the impacts of its Surface Transportation Assistance Act (STAA, 1982). The WB-19 and WB-20 tractor-semitrailer classes are the equivalents of the Canadian 21 m and 23 m long tractor-semitrailers. Triple trailer and turnpike double classes, although not permitted to operate on many highways, were added to the classification system in the 1990 version of the AASHTO Policy to recognize their increasing use by the trucking industry. The design dimensions for commercial vehicles were generally based on trucking regulations and data from load surveys.

With respect to buses, the AASHTO classification includes an articulated bus category in its classification scheme to account for their use in specific urban areas in the United States. Their dimensions are generally similar to the A-BUS classification used in TAC's Turning Vehicle Templates publication.

The TAC and AASHTO design vehicle classes/dimensions are generally similar, with the exception of passenger car variations and LCV's. In general, the existing six vehicle designations in the TAC Manual appear to be adequate. Additional sub-classes, however, may be appropriate within some of these designations to reflect the changes in vehicle regulations and trends in recent years.

3.0 INITIAL CONTACTS AND LITERATURE REVIEW

At the onset of this study, existing information pertinent to the following five items was compiled and reviewed:

(1) Relevant work on *design vehicle classifications and their dimensions*;
(2) Prevailing *vehicle classification schemes*;
(3) *Data sources* on vehicle population characteristics for use in this study;
(4) *Future trends* in vehicle fleet composition and their dimensions.
(5) *Other related work.*

This was accomplished by conducting a literature search through TAC, TRB (Transportation Research Board), and ARRB (Australian Road Research Board) library facilities, and by establishing contacts with key officials at several federal/provincial agencies in Canada and the United States. The key agencies contacted in Canada (other than TAC) include:

- Provincial Transportation Departments
- Transport Canada
- Canadian Council of Motor Transport Administrators (CCMTA)
- Canadian Trucking Association (CTA)
- Canadian Transportation Research Institute (CTRI)
- Provincial/Regional Trucking Associations (CTA)
- Canadian Automobile Association (CAA)
- Canadian Automobile Dealers Association (CADA)
- National Research Council (NRC)

In the United States, the following agencies were contacted:

- Transportation Research Board (TRB)
- American Association of State Highway Transportation Officials (AASHTO)
- Federal Highway Administration (FHWA)
- National Co-operative Highway Research Program (NCHRP)
- Society of Automotive Engineers (SAE)
- National Cooperative Highway Research Program (NCHRP)
- Texas Transportation Institute (TTI)

The literature review and the contacts with various agencies/organizations revealed several interesting sources of information relevant to this study. The following sections in this chapter summarize the general results of the literature review and discussions with the various contacts. The results are summarized in terms of the five subject items identified above. The actual literature review continued throughout the study, and publications are identified in the text where relevant. Details of the data sources identified, along with an assessment of their merits/demerits from the point of view of application to this study, are provided separately in Chapter 4.

3.1 DESIGN VEHICLES

In terms of recent and/or ongoing work specifically with respect to establishing design vehicle classes and their dimensions, the most relevant publication identified during the course of this study is a result of work done by Billing and Young (1992)[1] of the Ontario Ministry of Transportation. While the focus of this work was limited to vehicle population characteristics in Ontario, its objectives were very similar to those of the current undertaking. Highlights of the findings from this work are summarized below. The following comments also reflect discussions with the authors during the course of this study.

The paper by Billing and Young provides a review of the design vehicle classes/definitions used in the Ontario Geometric Design Manual[2] (generally similar to the TAC design classes/dimensions), especially, in light of the 1988 MoU which resulted in newer (generally larger) truck types on the road. It draws on data from two weigh-in-motion (WIM) scales in Ontario to assess the range of vehicle types and their dimensions. The conclusions/findings from that analysis are summarized below:

- With respect to passenger cars, about 98% of the sample vehicles observed were within the design wheelbase dimension of 3.4 m, a dimension that is based on data from U.S. car production records in the 1960's. There has been some reduction in the wheelbase of cars over the last 20 years or so, for energy efficiency reasons, due to down-sizing of domestic cars and a greater proportion of sales of smaller foreign cars. However, this has been compensated by the generally longer wheelbase lengths of pickup trucks, which have now increased to over 50% of vehicle registrations. Therefore, the study concluded that the current design vehicle dimensions for passenger cars remain satisfactory.

- Regulatory limits constrain bus dimensions tightly, and the typical dimensions of almost any 12.2 m (40 ft) bus are close to the design vehicle (B-12R) dimensions. There is little practical possibility of change in the dimensions of these vehicles within length and current design constraints[3]. Based on the data from the WIM scales, the current bus design vehicle was considered to be adequate.

- While articulated buses are larger than standard single-unit buses, they were considered to be generally constrained to the same turning envelope (due to the articulation).

[1] *"A Discussion of Design Vehicles & Warrants for Geometric Design of Intersections", John R. Billing and M. Young, Ontario Ministry of Transportation, Presented at the TAC Annual Conference in Quebec, 1992.*

[2] *"Geometric Design Standards for Ontario Highways", Ontario Ministry of Transportation, Surveys and Design Office, 1994.*

[3] *Note: Current MoU (1993) regulations allow intercity buses up to a maximum length of 14m (45 ft). If overall length is greater than 12.5 m, a minimum of 3 axles is required.*

- The largest possible tractor-semitrailer, allowed by the TAC MoU (TAC TST, 23 m long), was considered to be the most critical vehicle for intersection design purposes. This vehicle takes significantly more space to turn than the current design vehicle (WB-17). It was cautioned that it might be prudent, before confirming this as a design vehicle, to assess the impact on critical roadway elements from selection of alternative design vehicles up to this maximum.

- The internal and external dimensions of the A/B/C-train vehicles defined by the MoU are quite tightly constrained, so design vehicles based on these limits were considered reasonable. However, since all these double trailer combinations turn within the space required by a tractor-semitrailer, they are unlikely to be critical design vehicles as virtually any location that will be accessed by doubles is also likely to be accessed by tractor-semitrailers.

While the conclusions from the analysis of WIM data are interesting, it should be noted that the data only represents a snapshot of the traffic at one location for a period of about seven weeks in 1990. It is likely that the results may not apply across Canada (or even Ontario) due to differences in regulations and vehicle classes in other provinces.

3.2 VEHICLE CLASSIFICATION SCHEMES

Many highway agencies have several vehicle classification systems, depending on their data collection procedures and their needs. Traffic monitoring systems installed by the various provinces and states for the Strategic Highway Research Program (SHRP) classify traffic using the FHWA Scheme "F". There have been recent discussions in the U.S. to develop an improved, standard vehicle classification method to facilitate highway engineering and design activities. A study to this effect, proposed by the South Dakota Department of Transportation, is awaiting approval for NCHRP funding[1]. However, at this point in time, the FHWA Scheme "F" classification remains a standard for vehicle classification in North America.

With the introduction of the MoU and the resulting vehicle configurations on the National Highway Road System, a committee of all provincial and territorial highway ministers and Transport Canada came up with a classification scheme called the Canada Scheme "A". This scheme is essentially an expanded version of the original FHWA Scheme "F", and reflects the need to be able to describe Canadian traffic in ways that would be useful for Canadian policy and planning purposes.

The use of WIM data to establish vehicle population characteristics has been demonstrated in several recent studies[2]. With an understanding of the correlation between the vehicle classes in the

[1] *"Problem Statement, "Development of a Standard Vehicle Classification Method", National Co-operative Highway Research Program", 1995.*

[2] *"Utilization of Weigh-in-Motion data for Transportation Planning and Decision Making", J.R. Billing and J. J. Hajek, Ontario Ministry of Transportation, 1991 and "Vehicle classification from WIM data: The Progressive Sieve Algorithm", E.S.K. Fekpe and A.M. Clayton, 1993.*

two schemes, using appropriate algorithms[1], WIM data could be used to estimate vehicle classification based on the Canada Scheme "A". With this interest, the two classification schemes and their correlation are summarized in Table 3.1.

The TAC MoU vehicle classification system is another important scheme to consider in the context of the current undertaking. Essentially a subset of the Canada Scheme "A", the MoU trucks are classified into the following eight categories:

- Tractor-Semitrailer
- A-Train Double
- B-Train Double
- C-Train Double
- Straight Truck
- Truck-Pony Trailer
- Truck-Full Trailer
- Intercity Bus

In summary, the Canada Scheme "A" classification encompasses all vehicle types that one may consider for design vehicle classification purposes. It therefore represents a good starting point towards establishing design vehicle classes.

[1] "An Algorithm for the Uniform Vehicle Classification System for Canada Scheme A", J.R. Billing, Ontario Ministry of Transportation, Prepared for Presentation at the 1994 IRF Conference, TAC, Calgary, Alberta.

TABLE 3.1
FHWA "F" AND CANADA "A" VEHICLE CLASSIFICATION SCHEMES

FHWA Classification Scheme "F"		Canada Scheme "A"	
Class	***Vehicle Description***	***Vehicle Description***	***Class***
1	Motorcycle, also with trailer	Motorcycle, also with trailer	1
2	Car, also with trailer	Car, pickup or light van Car, pickup or light van, with trailer	2 3
3	Other 2-axle, 4-tire vehicles, also with trailer	2-axle light truck, tractor or short RV 2-axle light truck, tractor or short RV, with trailer	4 5
4	Buses	Bus or large RV	6
5	2-axle truck with 6 tires	2-axle single unit truck	7
6	3-axle truck or tractor	3-axle single unit truck or tractor	8
7	4 or more axle truck	4+ axle single unit truck	9
8	Truck/tractor with one trailer, up to 4 axles	2-axle truck with 1 or 2-axle trailer or semitrailer 3-axle truck with 1-axle trailer or semitrailer	10 11
9	Truck/tractor with one trailer, 5 axles	3-axle tractor with 2-axle semitrailer (3S2) Other 5-axle single trailer combinations	12 13
10	Truck/tractor with one trailer, 6+ axles	3-axle tractor with 3-axle semitrailer (3S3) Other 6+ axle single trailer combinations	14 15
11	Truck/tractor with multiple trailers, up to 5 axles	5-axle double	16
12	Truck/tractor with multiple trailers, 6 axles	6-axle double 6-axle B-train double	17 19
13	Truck/tractor with multiple trailers, 7+ axles	7 or 8-axle double or triple 7-axle B-train double 8-axle B-train double 9+ axle multi-unit vehicles	18 20 21 22

3.3 DATA SOURCES

Establishing design vehicle classes and their dimensions requires the following two pieces of data:

- *Frequency distribution of various vehicle types that make up the current Canadian vehicle population*, required to confirm or amend existing group designations in the TAC Manual.

- *Frequency and cumulative distributions of critical turning dimensions for each of these vehicle types*, required to establish the range of dimensions, and accordingly specify a representative set of dimensions for the design vehicles.

With this purpose, several data sources relating to vehicle type frequencies and characteristics were identified as part of a literature review, and through contacts with manufacturers and provincial transportation agencies. A recent reference guide[1] published by the Canadian Trucking Research Institute proved useful in identifying data sources for commercial vehicles.

[1] *"Reference Guide to Sources of Information on Trucking", Canadian Trucking Research Institute, 1995*

This guide provides a bibliography of literature sources describing the nature, size, characteristics, performance and start of the trucking industry within Canada. Citations in this guide include several roadside trucking surveys, market research vehicle registration databases, and federal/provincial studies relating to trucking. With respect to data sources for private vehicles and buses, contacts with manufacturers and industry associations proved to be most useful.

The data sources explored in this study may be generally classified into the following categories:

- Provincial Registration Data
- Private Sector/Manufacturers Research Data
- Roadside Commercial Vehicle Surveys
- Weigh-in-Motion Data
- Provincial/National Regulations

These data sources are described in detail in Chapter 4, in terms of their applicability, and scope to this study.

3.4 FUTURE TRENDS

Future trends in vehicle type distributions and variations in their dimensions were assessed through literature reviews and contacts with manufacturers. The results are summarized in the following sections for each of the three vehicle groups; i.e. private vehicles, commercial vehicles, and buses. In each section, historical trends during the last few years are presented as they provide insight into possible future trends.

3.4.1 Private Vehicles

Historically, distributions of passenger car models and their dimensions have been dictated by two factors: consumer preferences and fuel availability. In general, there has been an increase in the proportion of vans and other "family-oriented" vehicles in recent years due to increased preferences for driver comfort and an increase in use of personal vehicles for recreational purposes. Fuel availability and fuel economy standards have historically contributed to downsizing of passenger cars.

Several important changes occurred in physical dimensions of vehicles during the 1960's and early 1970's[1]. There were clear trends toward smaller passenger cars in terms of their overall lengths and wheelbase dimensions due to concerns about fuel availability, which led to the introduction of several new lines of small cars. The rear overhang lengths decreased noticeably due to a trend towards short rear-deck styling. To some extent, however, the front overhang lengths increased due to trends towards longer hoods. With respect to driver eye height, the styling trend during this

[1] *"Trends of Vehicle Dimensions and Performance Characteristics from 1960 Through 1970", E.E. Segar and R.S. Brink, General Motors Proving Ground, Milford, Michigan, Highway Research Record 420, 1972.*

period resulted in height reductions above the ground level[1]. Reductions were primarily achieved due to styling innovations for the specialty types of 2-door hardtops.

The U.S. DOT launched a detailed study[2] in 1980 to forecast characteristics of the mix of personal vehicles that can be expected to change as a result of industry compliance with fuel consumption standards. As part of that study, detailed vehicle characteristics were assembled for the various model years during the 1970's. Based on these trends, in conjunction with the targets set by fuel consumption regulations, a significant reduction in vehicle size was projected between then and 1995.

Later, in 1990, the U.S. DOT conducted a retrospective evaluation[3] to verify the forecasts predicted in 1980, and to identify major changes that are expected to take place with respect to vehicle characteristics and their implications on geometric design. This study found that the original forecasts which predicted continued downsizing of passenger cars did not materialize. The main reason for departure from earlier thinking was that fuel economy was no longer the pressing issue in the late 1980's (and early 1990's) as it was in the 1970's. The public demand for small cars was not significant, and manufacturers' downsizing was not as dramatic as expected. Technological advances in the industry had also resulted in improved fuel economy independent of vehicle size.

As a result of the 1990 U.S. DOT study, revised projections to the 21st century were developed. The study concluded that passenger vehicle characteristics are not expected to change over the next 15 years as no shortage of gasoline is foreseen in the near future. Improved technologies related to fuel-efficiency suggests an end to the downsizing, and possibly a return to larger cars. In fact, the 1990 data analyzed in that study indicated a clear trend towards an increased proportion of vans, pickups, and other light trucks in the general "passenger car" vehicle population.

The increase in the use of light trucks for private vehicle use is also evident from a recent study undertaken by the Texas Transportation Institute[4] which estimates that in relation to total passenger vehicle sales, the market share of light trucks has increased from approximately 20% in 1980 to almost 40% in 1994. A recent study by the University of Michigan Transportation Research Institute (UMTRI)[5] projects that the ratio of light truck to total passenger vehicle sales will increase further up to year 2003.

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[1] *"Highway Vertical Alignment, Vertical Curve Considerations", Bryar and Mojsiak, Design and Construction Branch, Ontario Ministry of Transportation and Communications, 1978.*

[2] *"Projected Vehicle Characteristics Through 1995", William D. Glauz, Douglas W. Harwood, and Andrew St. John, Transportation Research Record 772, 1980.*

[3] *"Engineering 21st Century Highways - Future Driver and Vehicle Characteristics and Their Influence on Highway Design for Safety", Douglas W.Harwood and William D. Glauz, Midwest Research Institute, 1990.*

[4] *"Evaluation of Roadside Features to Accommodate Vans, Mini-Vans, Pick-up Trucks, and 4-Wheel Drive Vehicles", Texas Transportation Institute, August 1995.*

[5] *"Delphi VII - Forecast and Analysis of the North American Automotive Industry", Published by the Office for the Study of Automotive Transportation, UMTRI, February 1994.*

Due to the intensely competitive nature of the automobile industry and the unpredictable nature of factors that influence vehicle design, it is extremely difficult to project or predict even short term trends in private vehicle fleets. However, from the point of view of establishing design vehicle classes and dimensions, the following future trends seem very likely:

- The downsizing trend with respect to passenger cars in the past 2-3 decades appears to have stabilized. This indicates that *the regular passenger car dimensions are not likely to change in the near future*, as no shortage of gasoline is foreseen in the near future, a factor which predominantly contributed to vehicle downsizing in the past. On the safety side, several research studies[1] have also proven that smaller/lighter vehicles offer intrinsically less occupant protection, which advocate retaining current passenger car dimensions as a minimum standard.

- There appears to be *an increase in the proportion of vans, pickups, and light trucks* in the category of personal vehicles. The larger sizes of these vehicle types may increase the overall "typical" dimensions for personal vehicles. However, with respect to driver eye heights, these vehicles may enhance safety on crest vertical curves.

- Future trends in vehicle types/models that would be manufactured appear to have been stabilized. However, vehicle fleet characteristics evolve with time as older vehicles are replaced with newer vehicles. *The effects of the aging of vehicles on fleet characteristics are discussed in Chapter 6.*

Merely based on historical trends, and a preliminary assessment of future trends, fleet characteristics for private vehicles generally appear to have stabilized. Therefore, current fleet data should form a good basis to establish design vehicle dimensions for future use.

3.4.2 Commercial Vehicles

Unlike private vehicles, fleet distributions of commercial vehicles are mostly a function of regulations which define the maximum allowable dimensions and the types of vehicles permitted to operate on various routes. While the regulatory changes with respect to single-unit trucks have been relatively minimal, both weights and dimensional regulations have been substantially relaxed for combination trucks in the past two decades. This trend still exists due to continuing pressures from the trucking industry to operate larger and heavier trucks on the road system.

With respect to truck sizes, the proportion of tractor-trailer trucks and the average size of trucks in the commercial vehicle population have increased significantly during this period. Several trucking surveys from Western Canada[2] indicate a decrease in use of single unit trucks, while the use of 5+

[1] *Series of Research Materials Produced by Dr. Leonard Evans, The Safety Research Department of The General Motors Research and Development Center, Leonard Evans, Van Nostrand Reinhold, NY.*

[2] *"Characteristics of Large Truck-trailer Combinations Operating on Manitoba's Primary Highways : 1974 - 1984", A. Clayton and M. Lai, Canadian Journal of Civil Engineering, Volume 13, 198; and "Effects of Weight and Dimension Regulations: Evidence from Canada", A. Clayton and F.P. Nix, Transportation Research Record 1061; and "Truck Industry Technological*

axle combinations is growing. The cube (cargo volume) advantage of double combination trucks is increasing their proportion in the large truck fleet. These trends are evident from several nationwide roadside trucking surveys.

In 1991, a Transborder Trucking Survey[1] was conducted by the Federal Transport Minister's Task Force on Trucking. The study was conducted with the objective of determining the nature and extent of the Canadian share of transborder trucking, and the types of fleet used and the hauling patterns adopted by transborder truckers. Based on this study, tractor-semitrailer combinations accounted for about 85% of the commercial vehicles used in transborder operations. Doubles accounted for 7%, with straight trucks accounting for merely 6% of total truck traffic.

During the same period as the Transborder Survey, the Canadian Council of Motor Transport Administrators (CCMTA) conducted a national roadside survey[2] of commercial vehicles to assess the impact of structural and operational changes within the Canadian trucking industry due to the implementation of the 1987 Motor Vehicle Transport Act. With interprovincial trucking operations as the main focus, single unit trucks were excluded from the survey. Of the combination trucks surveyed, about 30% were trucks with 6 axles or more. On a national basis, 44% of the trucks observed were fully loaded (i.e. cubing out or weighting out). Of those, about 75% cubed out while the other 25% weighted out. On a national basis, the standard 5-axle tractor-semitrailer when fully loaded, cubed out approximately 85% of the time. This indicates that an increased cube and not increased weight is the main consideration for improving productivity of this commonly used truck type.

Intraprovincial operations show similar trends with respect to truck sizes and cube demands as evident, for example, from the results of the 1993 Ontario Commercial Vehicle Survey[3]. About 75% of the trucks were combination units. With respect to capacity constraints, about 55% of the trucks were constrained by cubic space while only about 25% were constrained by weight limits.

In 1988, TAC endorsed a Memorandum of Understanding between various provinces, as an attempt to harmonize interprovincial trucking operations[4]. This represented a major shift in vehicle trends as the MoU generally resulted in heavier/larger vehicles on the designated interprovincial road network. TAC conducted a retrospective evaluation study[5] of the MoU in 1994. The study summarized the following key observations for the 1987-92 period:

Response to the Western Canada Highway Strengthening Program", A. Clayton, G. Sparks and R. Mak, RTAC Annual Conference Proceedings, 1983.

[1] *"Transborder Trucking Survey", Statistics Canada, 1991.*

[2] *"CCMTA Roadside Survey", Canadian Council of Motor Transport Administrators, 1991.*

[3] *"Southwestern Ontario Roadside Survey", Ontario Ministry of Transportation, 1993.*

[4] *"Heavy Truck Weight and Dimension Regulations for Interprovincial Operations in Canada", Interjurisdictional Committee on Vehicle Weights and Dimensions, Published in 1988 and updated in 1993 and 1995.*

[5] *"Impacts of Canada's Heavy Vehicle Weights and Dimensions Research and Interprovincial Agreement", Transportation Association of Canada, 1994.*

- Increase in the proportion of tractor semitrailer combinations.
- A general shift from the 14.65 m (48 ft) semitrailer to the 16.2 m (53 ft) semitrailer.
- A marked shift away from C-train and A-train doubles to B-train doubles.
- A significant demand for cubic space compared to weight limits.

Further to the original agreement in the 1988 MoU, the maximum vehicle length was increased in 1993 from 23 m to 25 m (for double combinations). This had significant implications in the Atlantic provinces as the maximum length allowed prior to the MoU was only 21 m. Longer vehicles due to the MoU required some modifications at certain rest stops, pulloffs and weigh scale sites for vehicle maneouverability.

The TAC evaluation study also provided projections relating to truck fleet composition and their dimensions over a 10 year period in light of the MoU agreement between the provinces. For the 1992-2002 period, the study forecasted a decline in the uptake rate of MoU vehicles compared to the initial 5 years, as many fleet upgrades had already been carried out by 1992. The proportion of semitrailers over 14.65 m was predicted to increase substantially by the end of the century.

In spite of various attempts such as the TAC MoU to harmonize trucking regulations among the provinces, there are considerable differences yet in regulations among the various jurisdictions. Some examples follow:

- Provincial regulatory differences in semitrailer lengths and overall combination lengths between eastern and western Canada (based on the Ontario/Manitoba border) present some key barriers to east-west trucking across Canada.

- Compared to the total road network over which trucking operations occur, the designated road length to which the TAC MoU applies is limited. Therefore, a barrier exists yet for those commodities or shippers located on lower class roads.

- Only four of the Canadian provinces allow LCV operations (in the form of Rocky Mountains, Turnpikes, or Triple trailers) on a permit basis, mostly on multi-lane highways only. More recently, there has been an increase in the use of LCV's in Western Canada. Alberta and Saskatchewan currently permit LCV's, particularly Rocky Mountain Doubles, on several two-lane highway routes. Trucking costs may therefore be higher on certain corridors in the non-LCV jurisdictions than would be the case if they allowed LCV's.

In addition to the above, the impact of NAFTA (North American Free Trade Agreement) on trucking regulations and future trends in trucking is an important consideration. However, there have only been a few studies to date in this regard. FHWA recently conducted a comprehensive truck size and weight study[1] to examine trucking operations across the western US/Canada border

[1] *"FHWA Comprehensive Truck Size and Weight Study, Western US-Canada Crossborder Case Study", Contract DTFH61-93-C-00055, A. Clayton and P. Blow, 1995.*

and how it is influenced by truck size and weight regulations. The study highlighted some key regulatory differences between the U.S. and the western Canadian provinces that governed the transborder trucking operations. With respect to dimensions, two points are worth noting:

- Western border States (except Minnesota) permit 4.25 m high vehicles. This is about 100 mm more than that allowed in the western provinces. Alberta has recently proposed the 4.25 m height limit for the Canamex Corridor, an international corridor that extends from Alberta generally along I-15 to California and Mexico.

- TAC regulations require the wheelbase of a tractor to be within the range of 3.0 m to 6.2 m. However, U.S. regulations allow wheelbases between 2.7 m and 6.7 m. Some provinces prohibit use of these non-RTAC tractors, while some allow their use under special permits.

These, and other regulatory differences between Canada and the U.S., may force some changes in trucking regulations to ensure Canadian competitiveness in transborder trucking. With respect to future trends, historical developments point to regulatory barriers affecting interprovincial and transborder trucking as key factors capable of setting future truck size trends. Accordingly, the following trends appear likely:

- The current MoU allows tractor-semitrailers up to 23 m long (i.e. 53 ft trailers), commonly known as the TAC TST, to operate on a designated interprovincial network. *Further attempts to harmonize weight and size regulations among the Canadian provinces are not unlikely*, through negotiations such as the MoU agreement, and/or extensions of the road network where such negotiations may occur.

- The TAC TST currently represents the most critical truck type from an offtracking point of view. Offtracking estimates using computer programs indicate that all other MoU vehicles operate within the envelope of this critical design vehicle. The longer 25 m double combinations offtrack less due to the additional articulation point. Further increases in tractor-semitrailer lengths are unlikely as the cube constraints would rather favour the use of double combinations. Therefore, *the TAC tractor-semitrailer is likely to represent the most critical truck type, from a regulatory point of view, at least in the short term future (i.e. over the next 5 to 10 years).*

- At this stage, it is very difficult to speculate regulatory changes that may occur in response to NAFTA. Most of the studies to date in this area have been on the logistics side of trucking, such as reducing delays at the border check points, driver education on mutual regulations, etc. With respect to regulatory impacts, *one could speculate an increased use of LCV's to conform with the more liberal use of LCV's in the United States*. However, discussions with the western provincial agencies, where LCV's are currently operated on selected routes, indicate that the inclusion of LCV's as design vehicles is not justifiable at this point in time considering their limited usage in relation to total truck fleet.

Based on the historical developments since establishing the current design vehicle classes in the TAC Manual, and future trends that appear likely, it is clear that the current vehicle classes and their dimensions for commercial vehicles are due for an update. The design classes should reflect the broader range of commercial vehicles, and generally longer vehicles with inferior offtracking characteristics, that appear to have emerged in recent years.

3.4.3 Buses

The three most common bus types in use today include the standard 12.2 m (40 ft) long single unit buses (the current TAC design vehicle), articulated buses, and low-floor buses. The 1993 statistics on the number of active revenue bus units in Canada are summarized in Table 3.2.

TABLE 3.2
BUS TYPE FREQUENCIES IN CANADA (1993)

	Number of Active Revenue Buses[1]							
	Frequencies				Percent Distribution			
Year	Standard	Articulated	Low-Floor	Total	Standard	Articulated	Low-Floor	Total
1983	10,396	-	-	10,396	100%	0%	0%	100%
1984	10,538	-	-	10,538	100%	0%	0%	100%
1985	10,114	-	-	10,114	100%	0%	0%	100%
1986	10,264	20	-	10,284	100%	0%	0%	100%
1987	10,288	146	-	10,434	99%	1%	0%	100%
1988	10,206	286	-	10,492	97%	3%	0%	100%
1989	9,631	330	-	9,961	97%	3%	0%	100%
1990	10,296	330	-	10,626	97%	3%	0%	100%
1991	10,474	518	-	10,992	95%	5%	0%	100%
1992	10,141	366	140	10,647	95%	4%	1%	100%
1993	10,337	373	152	10,862	95%	4%	1%	100%

Articulated buses, commonly referred to as "artics", are high capacity buses, capable of carrying approximately 50% more passengers than standard buses. Because of their greater lengths, typically 18.2 m long, artics consist of two rigid sections connected by a bending middle. The hinge connection allows them to turn the same corners as a conventional bus. Generally speaking, an 18.2 m articulated bus will turn within the same inner and outer radii as a conventional 12.2 m single unit bus. The AASHTO design vehicle for an articulated bus specifies a minimum turning radius of 11.6 m, compared to 12.8 m for a single unit bus.

The low floor bus technology enables passenger access from (or near) the curb level for easier access. An additional wheelchair ramp feature is often employed with the low floor bus design. The design essentially allows for complete public transit access for all people of varying degrees

[1] *"Summary of Canadian Transit Statistics", Canadian Urban Transit Association, 1993.*

of mobility. Specifications from some major North American bus manufacturers in Canada indicate the dimensions of low-floor buses and standard unit buses as similar, from a geometric design point of view. In most cases, low floor buses operate within the turning envelopes of standard single unit buses.

As seen from the historical transit statistics, despite other bus options, conventional 12.2 m single unit buses remain the most dominant vehicle type employed by transit operators. The use of articulated buses has been very limited in spite of their lower operating cost per passenger, perhaps because of relatively low demand for transit. The operation of articulated buses in Canada started in 1986. Currently, there are about 325 articulated buses in active use in Canada (mostly in Ontario), accounting for about 5% of the total bus population.

Based on the historical transit statistics and key discussions with major Canadian urban transit operators, including the Toronto Transit Commission, Edmonton Transit, Calgary Transit, Ottawa-Carleton Transpo, and the GO Transit, the following trends appear likely:

- *The number of articulated buses in Canadian fleets is expected to remain constant in the near future.* As highlighted earlier, the current use of articulated buses is mostly concentrated in Ontario. The Ontario Geometric Design Manual recognizes this with a specific design vehicle class to represent an articulated bus. It is specified as a 18.4 m long bus with a 13.0 m wheelbase, at a minimum turning radius of 12.0 m.

- *The proportion of low-floor buses in Canadian bus fleets is expected to increase in the future.* Urban transit operators in Ontario and the prairie provinces indicated short-term plans to acquire a fleet of low-floor buses. Operators indicated that provincial government legislations insist on low-floor technology buses for new purchases in order to qualify for grants. This is to ensure that the elderly, adults with children, and physically challenged individuals obtain easier access to public transit, as opposed to the use of more expensive systems such as paratransit services or private taxi operations.

3.5 OTHER RELATED INFORMATION

In addition to establishing the critical turning dimensions, the literature review and contacts were used to gather other information pertinent to this study, such as driver eye heights for geometric design purposes, vehicle heights for vertical clearance requirements, and vehicle widths.

The Canadian National Committee on Uniform Traffic Control recently completed a study[1] to investigate discrepancies between the TAC Geometric Design Guide for Canadian Roads and the Canadian Manual on Uniform Traffic Control Devices (MUTCD). The study was sponsored jointly by TAC and the Canadian wing of the Institute of Transportation Engineers (ITE). The purpose of that study was to assess the appropriateness of the driver eye height criteria used in the Manual for sight distance computations, in light of the "ever changing real world of passenger car dimensions".

As part of that study, vehicle registration statistics and manufacturers specifications for passenger cars were analyzed to estimate the distribution of driver eye heights for current year models. Eye heights were calculated as being 254 mm (10 inches) lower than the height of the vehicle. The study estimates that more than 99% of the total vehicle population has a driver eye height of at least 1.05 m, which is the current driver eye height recommended for use in the Manual. Accordingly, the study recommends that the current driver eye height criterion in the Manual be retained.

With respect to vehicle heights, the MoU limits the maximum vehicle height to 4.15 m. Trucks up to about 4.25 m (14 ft) are currently allowed in some western states and provinces. Alberta, specifically, has shown some interest in this regard. These overheight vehicles, however, are not likely to influence current regulations as this would imply significant infrastructure costs. Similarly, vehicle widths are not expected to increase beyond the current maximum of 2.6 m in the foreseeable future. Overdimensional (wide) loads are quite common in some of the western provinces. However, these vehicles should be continued to be treated as 'special vehicles'.

[1] *Working Paper Prepared by the Task Force on Intersection and Passing Sight Distance, National Committee on Uniform Traffic Control, October 1994*

4.0 OVERVIEW OF DATA SOURCES

The following data sources were examined to establish vehicle type distributions and their dimensions:

- Provincial Registration Data
- Private Sector/Manufacturers Data
- Roadside Commercial Vehicle Surveys
- Weigh-in-Motion Data
- Provincial/National Regulations

The data availability and their applications to this study are described in the following sections.

4.1 PROVINCIAL REGISTRATION DATA

All vehicles currently in operation on Canadian roads are registered by individual provincial agencies. Registration records will therefore provide a "snapshot" of the current Canadian fleet in terms of model, make and year. Individual provinces were contacted to get the registration data on their fleets. However, for several reasons, it was concluded that the registration records from individual provinces are not an efficient data source for this study. Some key reasons include:

- Registration records are not readily available from all provinces, only from British Columbia, Manitoba, Quebec, and New Brunswick. Other provinces indicated that the data could not be provided within the study schedule (or budget).

- The range of vehicle types recorded by individual provinces (as per the data made available) were not consistent.

- Registration records summarize the number of private vehicles registered within a particular province. However, they don't give any information relating to the vehicle dimensions. This could be done only by cross-referencing each and every vehicle registered to manufacturers specifications. This is a very tedious task considering that the data coding used by various provinces to describe the various passenger car makes and models are considerably different. Cross-referencing to manufacturers data would literally have to be done on an individual province by province basis.

Upon consideration of the cost and time factors involved, it was therefore considered that registration data from individual provinces (given the inconsistencies in their data formats and scope) were not amenable for use in this study.

4.2 PRIVATE SECTOR/MANUFACTURERS DATA

Market research data from private companies and/or manufacturers represent another possible data source for vehicle sales and/or registration data. Manufacturers data provide information such as sales and production data (for the Canadian market) by model, make and year for private vehicles. Their specifications summarize the dimensions for various vehicle types. These two data sources, in combination, can be used to establish fleet classes and dimensions for private vehicles.

Major automobile manufacturers such as Ford and General Motors were contacted to obtain the two data items. However, during the research process, it became clear that manufacturers data can be more easily acquired through market research groups. Several market research groups also provide detailed registration data (at cost) for personal vehicles. This presented an alternative method of compiling registration data for this study, compared to acquiring the data through individual provinces.

Discussions with staff at the Canadian Automobile Association (CAA) and the Canadian Automobile Dealers Association indicated two market research groups, DesRosiers Automotive Consulting and The Polk Company, as vital sources of information for sales/production and registration data. Both companies provide annual registration data for the Canadian private vehicle population in terms of model, make, body style, and year[1], in a computerized database called the CVIOC (Canadian Vehicles In Operation Census) database. The two companies essentially work in collaboration with one another, with DesRosiers Automotive Consulting located in Canada (Toronto) and The Polk Company located in the United States.

DesRosiers Automotive Consulting was consulted to discuss the data requirements for the current undertaking. Following several discussions, and a comparative analysis between acquiring registration data from DesRosiers and obtaining the same from individual provinces, it was concluded that the former is more prudent for this study. The 1994 database was purchased for use in this study.

The CVIOC database provides a snapshot of all vehicles with a consistent nomenclature for the names of models, makes, and body styles, which makes cross-referencing to dimensional data relatively easy. The following data sources were reviewed for dimensional data: the annual CAA's Autopinion magazines, the annual AAMA's "Vehicle Dimensions" publications, and the automobile consumer guides. The consumer guides, covering vehicle makes and models for the past two decades, were acquired for use in this study. They provide vehicle dimensions including wheelbase lengths, overall lengths, widths, and heights by model/make/year. The data was complemented with specifications from individual manufacturers, where necessary. The AAMA

[1] *Note: The annual registration records database from the DesRosiers Automotive Consulting company was used in a recent study (described in section 2.7) by the National Committee on Traffic Control to estimate distributions of vehicle types in terms of their heights.*

publications were used to get the remaining data including overhang dimensions and minimum turning radii.

With respect to data for buses, vehicle specifications by model/make were obtained from major manufacturers including Orion, Nova Bus Corporation, Prevost, and New Flyer. Combined with bus fleet data from individual transit operators, these specifications could be used to establish distributions of various bus dimensions.

4.3 COMMERCIAL VEHICLE SURVEYS

Existing data sources from provincial/federal roadside surveys were examined for use in compiling estimates of commercial vehicle type frequencies and their typical dimensions. The following surveys were reviewed:

- The 1988 and 1993 Ontario Commercial Vehicle Surveys
- The 1991 Transborder Trucking Survey
- The 1991 CCMTA Roadside Survey
- The 1995 CCMTA Roadside Survey

Of the above surveys, the 1995 CCMTA survey is the only one that collected data on vehicle dimensions. Other surveys, including the 1991 CCMTA survey, focused on vehicle weight data only. In the 1995 CCMTA survey, detailed axle spacing measurements and vehicle classifications were recorded through visual observations. The survey, conducted roughly during the same time period at several sites across the 12 Canadian jurisdictions, covered all combination trucks (e.g. semitrailers and multiple combination trucks). The survey content and locations were designed to allow inferences at a provincial/national level. Therefore, the CCMTA database was concluded to be the best potential data source to compile distributions of vehicle types/dimensions for combination trucks. Unfortunately, the database was not available in time to meet the study schedule. Therefore, alternative means were examined.

4.4 WEIGH-IN-MOTION DATA

As described in section 3.2, participation in SHRP (Strategic Highway Research Program) and C-SHRP LTPP (Canadian Long Term Pavement Performance) monitoring programs has resulted in implementation of WIM scales in various Canadian provinces. Some provinces also operate additional WIM sites for their own planning purposes. WIM scales provide a large amount of detailed data for individual vehicles including lengths, axle spacings, and axle loads. The individual vehicle records could be examined for patterns in axle spacings and loads and consequently classified in terms of vehicle configuration. Axle spacing data can then be used to estimate distributions of wheelbase dimensions within each configuration.

The various Canadian transportation agencies were contacted to inquire about the availability of recent WIM data. The data were available in the format required for this study from the provinces of Manitoba, Ontario, Prince Edward Island, Saskatchewan, Alberta and Nova Scotia. Relevant WIM databases were obtained for a minimum recent 1-week duration at 23 sites across these provinces. Table 4.1 summarizes the site locations, and the durations covered by the data.

TABLE 4.1
WIM SITE LOCATIONS AND DURATIONS

Province	Name of WIM Site	Route	Period
Manitoba	Roland	Highway 428	Week starting Mar. 1996
	Brokenhead	Highway 1	Week starting Jul. 1996
	Oak Lake	Highway 1	Week starting Nov. 1995
	Glenlea	Highway 75	Week starting Sept. 1995
Ontario	London	Highway 402, EB	Week starting Jun. 18, 1995
	Bracebridge	Highway 11	Week starting May 28, 1995
	Sarnia	Highway 402, WB	Week starting Sept. 10, 1995
Prince Edward Island	Bedford	Highway 2	Weeks starting Oct. 15, 1994
	Hunter River	Highway 2	Weeks starting Sept. 7, 1994
	Middleton	Highway 1A	Weeks starting May 26, 1994
	Tryon	Highway 1	Week starting Oct. 31, 1994
	Richmond	Highway 2	Weeks starting Sept. 20, 1994
Saskatchewan	Fleming	Highway 1	Week starting Jan. 8, 1996
	Grasswood	Highway 11	Week starting Apr. 15, 1996
	Lloydminister	Highway 16	Week starting May 1996
	Maple Creek	Highway 1	Week starting Jul. 15, 1996
Nova Scotia	Avonport	Highway 101	Week starting Apr. 8, 1996
	Brookfield	Highway 102	Week starting Jan. 8, 1996
	Hebbs Cross	Highway 103	Week starting May 6, 1996
	Marshy Hope	Highway 104	Week starting Oct. 9, 1995
	Canso causeway	Highway 104	Week starting July 15, 1996
	North Sydney	Highway 125	Week starting Feb.5, 1996
Alberta	Leduc Bypass	Highway 2	Week starting Jul. 22, 1996

4.5 VEHICLE SIZE REGULATIONS

Provincial vehicle size regulations in the various provinces, and the current MoU regulations dictate the maximum vehicle dimensions for various truck configurations in Canada. While it not intended to design the roadway facilities for the maximum dimensions, regulations are useful in establishing the maximum dimensions within which the majority of the truck fleet operates. However, they cannot be used to directly define design vehicle dimensions such as vehicle lengths and wheelbases since this would be overly conservative. Regulations are also useful in verifying and calibrating the validity of data from mechanical classifiers such as WIM scales.

A "brochure-style" publication prepared recently by Nix[1] provides an excellent comparison between truck size regulations among the various Canadian jurisdictions and the regulations defined by the TAC MoU. The maximum legal vehicle dimensions including length, wheelbase, width, and height are compared with the MoU regulations. A summary from this publication is presented below in terms of each of these dimensions:

- The maximum **overall length** as per the MoU is 12.5 m for single unit trucks; 23 m for truck-trailers and tractor-semitrailers; and 25 m for double combinations. In Prince Edward Island, British Columbia, and Northwest Territories, provincial regulations allow tractor-semitrailers up to 25 m long.

- The MoU does not regulate the **wheelbase** dimension for single-unit trucks. The minimum is regulated at 6.5 m for pony trailers and full trailers, 3.0 m for the tractor, and 6.5 m for 1-2 axle semitrailers. With respect to maximum wheelbase dimensions, semitrailers are regulated at 12.5 m, while the tractor wheelbase is limited to 6.2 m. Provincially, maximum wheelbase is not regulated in Ontario and the Yukon/Northwest Territories.

- The MoU limits maximum **width** to 2.6 m. Widths up to 3.2 m are allowed in Northwest Territories, and wide load movements (with permits) are allowed in other provinces.

- The MoU limit for maximum **height** is 4.15 m. Prince Edward Island allows vehicle heights up to 4.5 m, while Yukon and the Northwest Territories permit vehicles up to 4.2 m high.

4.6 INVENTORIES FROM TRANSIT OPERATORS

Vehicle inventory data were obtained from the following major Canadian transit operators:

- Calgary Transit (Alberta)
- Edmonton Transit (Alberta)
- Winnipeg Transit (Manitoba)
- Hamilton Transit (Ontario)
- Mississauga Transit (Ontario)
- Toronto Transit Commission (Ontario)
- Ottawa-Carleton Transpo (Ontario)
- GO Transit (Ontario)
- Montreal Transit (Quebec)
- Saint John Transit (Newfoundland)
- Halifax Transit (Nova Scotia)
- Fredericton Transit (New Brunswick)

[1] *"Canadian Truck Weight and Dimension Regulations", Fred Nix, 1995.*

In total, this amounted to fleet data for about 7,000 buses currently in operation in Canada for public/urban transportation. This database, in conjunction with data from bus manufacturers, was considered a good data source to analyze bus classes and dimensions for this study.

4.7 PRIMARY DATA SOURCES

4.7.1 Private Vehicles

The following data sources were used in combination to compile distributions of vehicle dimensions for private vehicles:

- CVIOC database
- Vehicle specifications from manufacturers/private sector groups

The CVIOC database contains a summary of the private vehicle population (i.e. passenger cars, light trucks, pickups, and vans) that was registered in Canada in 1994, in terms of model name, body type, and model year. Vehicle specifications, including length, wheelbase, overhangs, width, height, and minimum turning radii, were added to each vehicle in the database using manufacturers data. The resulting database was then analyzed to obtain frequency and cumulative distributions of key vehicle dimensions, representative of the 1994 personal vehicle population in Canada.

4.7.2 Commercial Vehicles

In the absence of the CCMTA database, data from provincial WIM sites represented the best data source to review various commercial vehicle types and their dimensions. The WIM data were classified using a modified Canada Scheme "A" Classification system (26 classes), using appropriate algorithms related to axle spacings and axle weights. Accordingly, distributions of wheelbase and overall lengths were estimated. Other data such as overhangs, fifth wheel offsets and cramp angles were determined through contacts with truck manufacturers.

4.7.3 Buses

Fleet data from the transit operators were analyzed and cross-tabulated with the vehicle specifications obtained from bus manufacturers. Accordingly, distributions of various turning dimensions were developed.

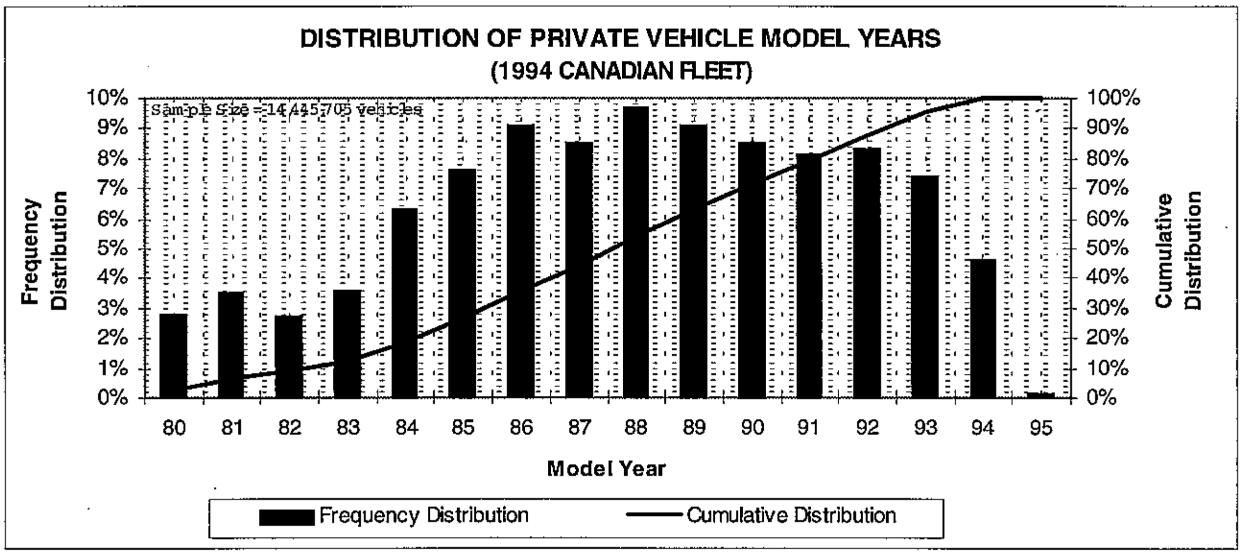
5.0 DATA ANALYSIS

This chapter presents the results from the analysis of various data sources used in this study. The 95th percentile values are desirable for design vehicle dimensions as they generally represent the point of diminishing returns. The 85th percentile values are reported to provide an indication of the slope of the cumulative distribution curves.

5.1 PRIVATE VEHICLES

Based on the CVIOC database analysis, the total Canadian private vehicle population (i.e. passenger cars, light trucks, pickups, vans) was about 16 million in 1994. Of this, about 10% of the vehicles were pre-1980 models, which were excluded from this analysis because their vehicle specifications are not readily available. Furthermore, these vehicles are likely to "expire" soon, and are therefore not critical from the point of view of establishing design vehicle classes/dimensions. The distribution of vehicle model years for the remaining population is summarized in Figure 5.1.

FIGURE 5.1



To the registration data in the CVIOC database, vehicle specifications including overall lengths, wheelbase lengths, front/rear overhangs, minimum turning radii (curb-to-curb), vehicle heights, and vehicle widths were added, using the data sources described in section 4.2. The mean, 85th percentile, and 95th percentile values for the various dimensions are summarized in Table 5.1. Distributions for individual dimensions are discussed further below, in light of the current TAC design vehicle dimensions (which is same as AASHTO) for passenger cars.

TABLE 5.1
DISTRIBUTION OF PRIVATE VEHICLE DIMENSIONS
(1994 VEHICLE POPULATION)

	Mean	85th percentile	95th percentile
Overall Length (m)	4.66	5.05	5.40
Wheelbase (m)	2.70	2.95	3.15
Front overhang (m)	0.98	1.09	1.11
Rear overhang (m)	1.04	1.14	1.28
Min. Turning Radius (m)	5.63	6.14	6.33
Height (m)	1.47	1.34	1.32
Width (m)	1.77	1.95	2.00

The distribution of overall vehicle lengths is summarized in Figure 5.2. The current TAC design vehicle for passenger cars is 5.8 m long. As seen from the figure, close to 100% of the vehicles were less than 5.8 m long. The frequency and cumulative distributions of wheelbase dimensions are shown in Figure 5.3. The wheelbase dimension for the TAC design vehicle is 3.4 m. About 98% of the vehicle population had wheelbase lengths less than 3.4 m.

Statistical distributions for front and rear overhangs for the vehicle population are presented in Figures 5.4 and 5.5 respectively. The TAC design vehicle for passenger cars consists of a 0.9 m front overhang, and a 1.5 m rear overhang. The front overhang lengths for the sample population are generally lower with the mean at 0.98 m and the 95^{th} percentile value at 1.11 m, while the rear overhang is generally higher with the mean at 1.04 m and the 95^{th} percentile at 1.28 m.

The distributions for the curb-to-curb turning radii (for the outside front tire) are summarized in Figure 5.6. The minimum design turning radius for the TAC design vehicle is 7.3 m. All vehicles in the sample population turn within a radius of less than 7.0 m. About 95% of the vehicle population turn within a radius of less than 6.3 m.

Based on the analysis of the 1994 Canadian vehicle population, the current TAC design vehicle dimensions appear to be rather conservative.

FIGURE 5.2

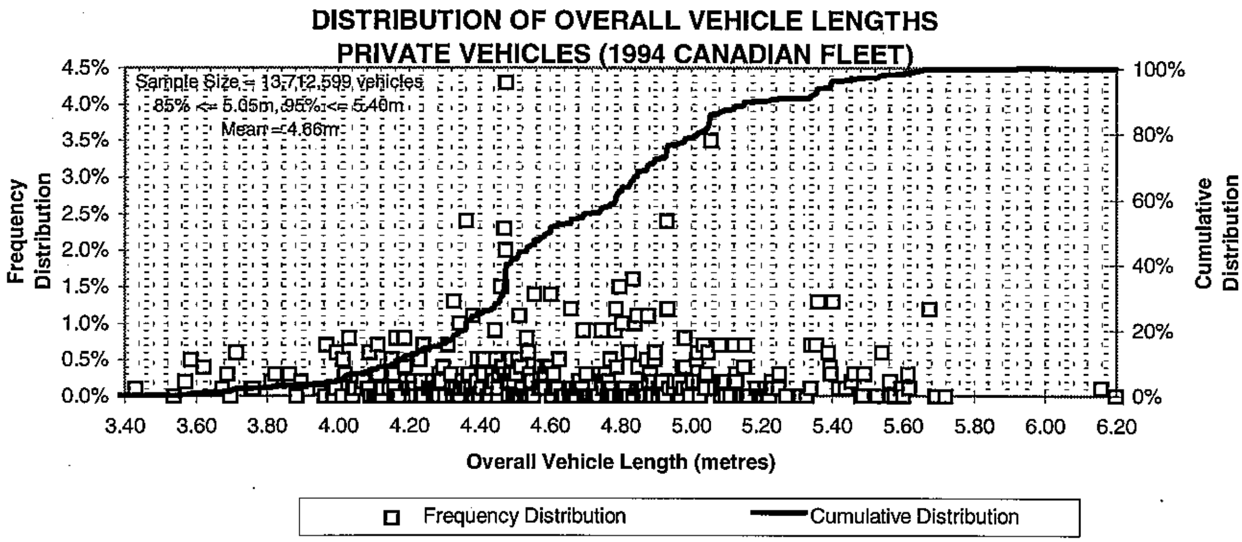


FIGURE 5.3

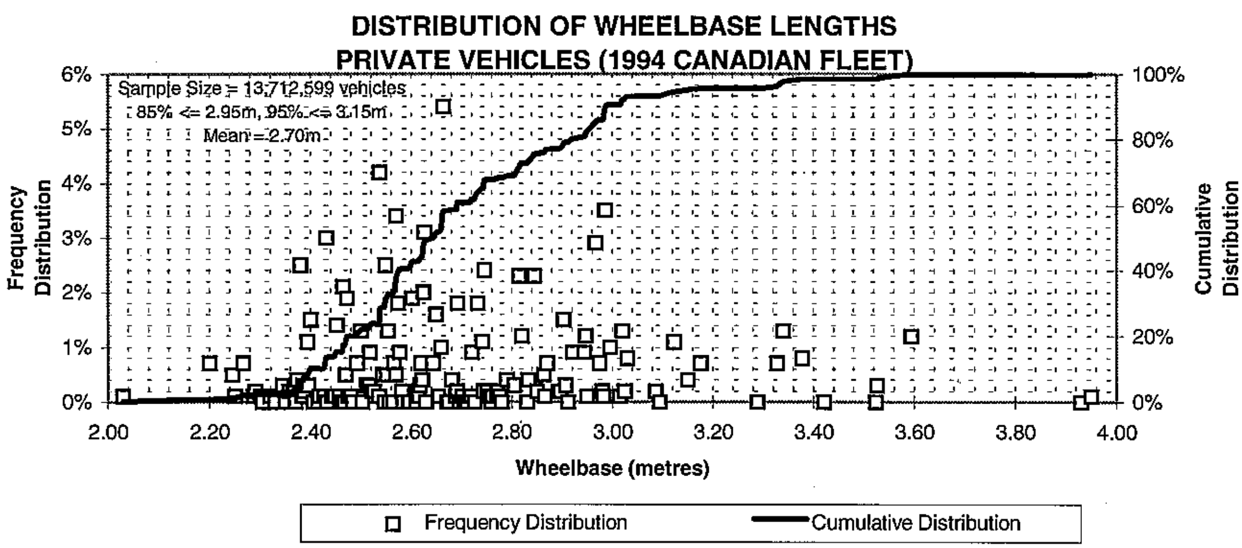


FIGURE 5.4

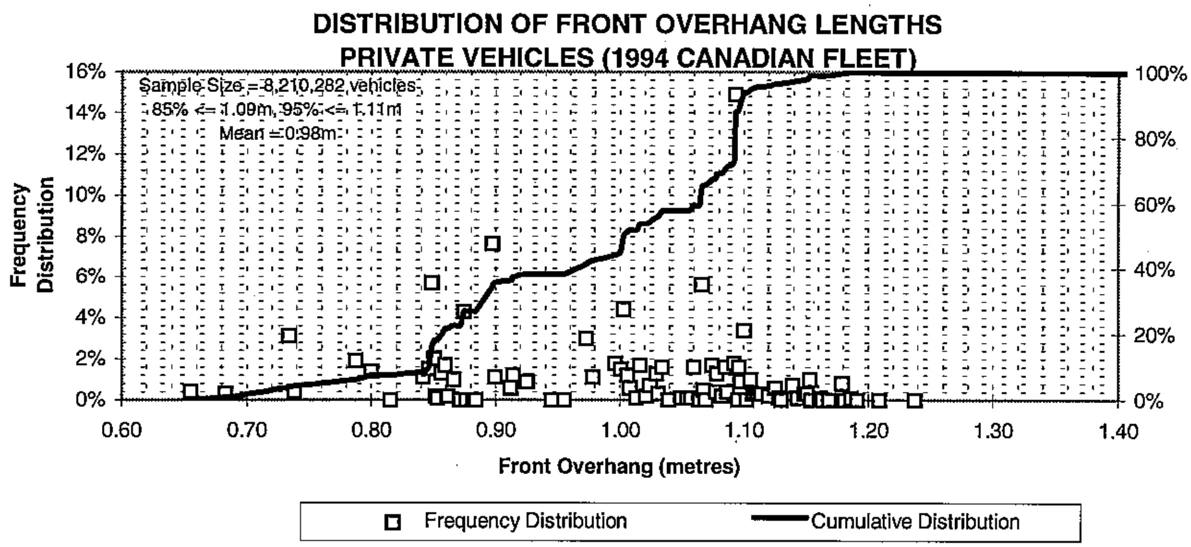


FIGURE 5.5

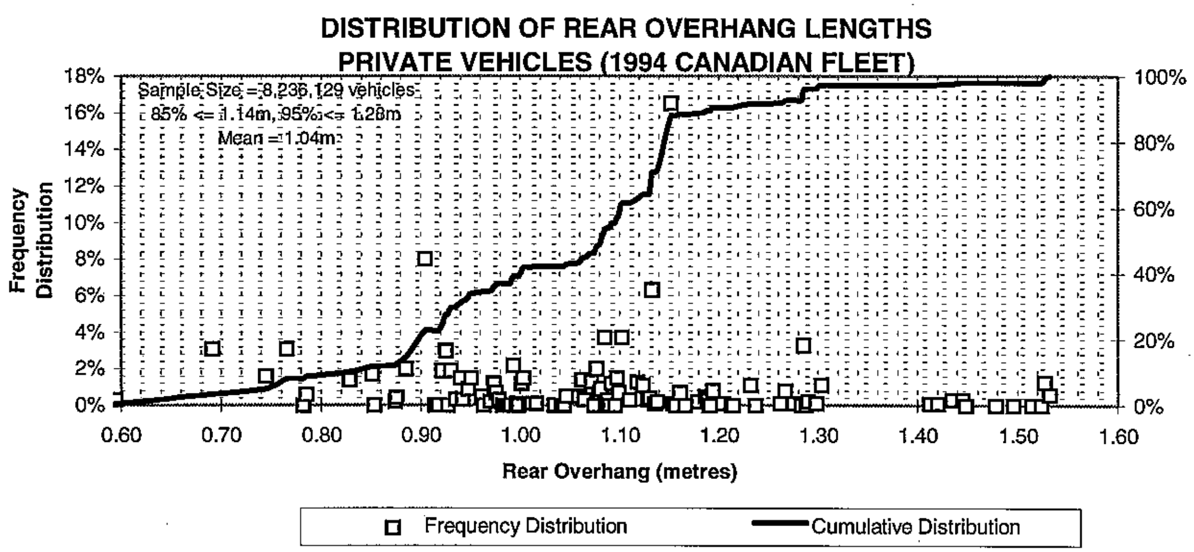
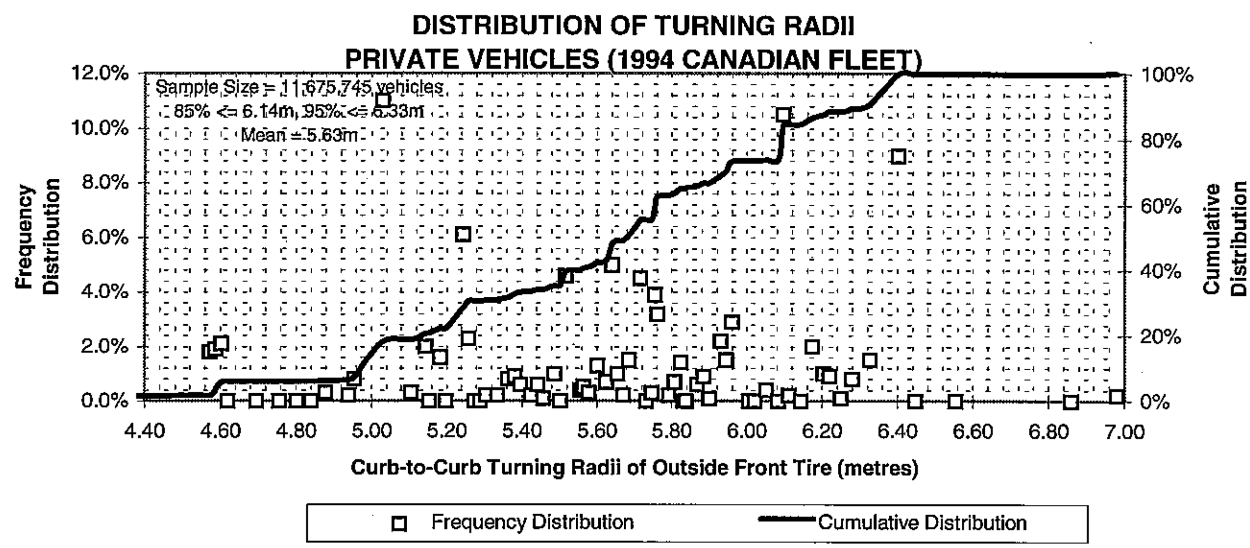


FIGURE 5.6



In addition to the turning dimensions, the database was also used to estimate distributions of driver eye heights (estimated as vehicle height minus 10 inches). The mean driver eye height was 1.21 m. Driver eye heights for the entire population are estimated to be within a range of 0.9 m to 1.6 m. About 95% of the population have driver eye heights greater than 1.06 m. Accordingly, the driver eye height standard (MUTCD) of 1.05 m is considered appropriate.

5.2 COMMERCIAL VEHICLES

The WIM data sample included a total of 72,164 commercial vehicles (i.e. trucks). The vehicle types were initially classified according to the Canada Scheme "A", which includes 16 commercial vehicle classifications (described in section 3.2). The sample data were then further grouped into the following vehicle classes:

- Single-unit trucks (SU)
- Tractor- Semitrailers (TST)
- Tractor-Semitrailer-Trailers (A/C-Train doubles)
- Tractor-Semitrailer-Semitrailers (B-Train doubles)
- Truck-Pony Trailer (TPT)
- Truck-Full Trailer (TFT)

These classes are similar to the current MoU vehicle classification scheme. With the 'special vehicle' types (such as long combination vehicles) excluded from this analysis, the above classes cover all truck types in regular operation. Table 5.2 shows a breakdown of the total WIM data population in terms of the above vehicle types. Truck-pony trailers and truck-full trailers were excluded from further analysis due to their relatively small proportions in the total truck population[1]. Therefore, the objective of this analysis is to assess the need to provide specific design vehicle classes for the remaining four vehicle types (with further sub-classification if necessary), and accordingly establish their representative dimensions.

In the WIM database, there is no way to differentiate between A-trains and C-trains. All dimensions determined for this group are interpreted to apply to A-trains. Since C-trains are relatively rare, and their dimensional regulations are generally similar to those of A-trains, the error introduced was considered tolerable. Furthermore, due to its modified articulation, a C-train would turn within a narrower swept path than an A-train with identical interaxle spacing. Therefore, C-trains were excluded from further analysis.

TABLE 5.2
VEHICLE TYPE DISTRIBUTION FOR THE WIM DATA SAMPLE

Vehicle Type	Sample Size	Percentage
Single-unit trucks (SU)	105,331	68.31%
Tractor- Semitrailers (TST)	43,380	28.13%
Tractor-Semitrailer-Trailers (A/C-Train doubles)	1,097	0.71%
Tractor-Semitrailer-Semitrailers (B-Train doubles)	3,836	2.49%
Truck-Pony Trailer (TPT)	70	0.05%
Truck-Full Trailer (TFT)	480	0.31%
TOTAL SAMPLE	**154,194**	**100%**

The WIM data were analyzed to estimate frequency and cumulative distributions of overall lengths and wheelbase dimensions for each of the four vehicle types. The results are discussed in the following sections. Note that unlike private vehicles and buses, the sum of the 95th percentile dimensions for commercial vehicles (from WIM data) will not necessarily add up to the 95th percentile overall length since the various dimensions are based on independent distributions. Therefore, this section merely reports the results from the analysis of commercial vehicle data. Discussions on design dimensions and comparisons with TAC/AASHTO specifications are provided in Chapter 6.

5.2.1 Single-Unit Trucks

The total single-unit truck population was broken down into three categories:

[1] *Typical dimensions (as obtained from WIM data analysis) for truck-pony trailers and truck-full trailers are summarized (as 'special vehicles') in Appendix A.*

- Light single-unit trucks (gross weight of 2.5 to 4.2 tonnes)
- Medium single-unit trucks (gross weight > 4.2 tonnes)
- Heavy single-unit trucks (4^+ axle single-unit trucks)

The total single-unit vehicle population (105,331 trucks) consisted of 75% light trucks, 22% medium trucks, and about 3% heavy trucks. Distributions of overall lengths and wheelbase dimensions for the three single-unit truck types in the WIM database are summarized in Table 5.3, and presented graphically in figures 5.7 to 5.12.

TABLE 5.3
SUMMARY OF SINGLE-UNIT VEHICLE DIMENSIONS (WIM DATA)

SU Type	Dimension	Mean	85th percentile	95th percentile
Light SU	Length(m)	5.0	5.6	6.4
	WB(m)	3.3	3.5	3.6
Medium SU	Length(m)	7.5	9.3	10.0
	WB (m)	5.7	6.3	6.5
Heavy SU	Length(m)	10.7	11.1	11.5
	WB (m)	6.8	9.0	9.5

FIGURE 5.7

DISTRIBUTION OF OVERALL LENGTHS FOR LIGHT SINGLE-UNIT TRUCKS (WIM DATA)

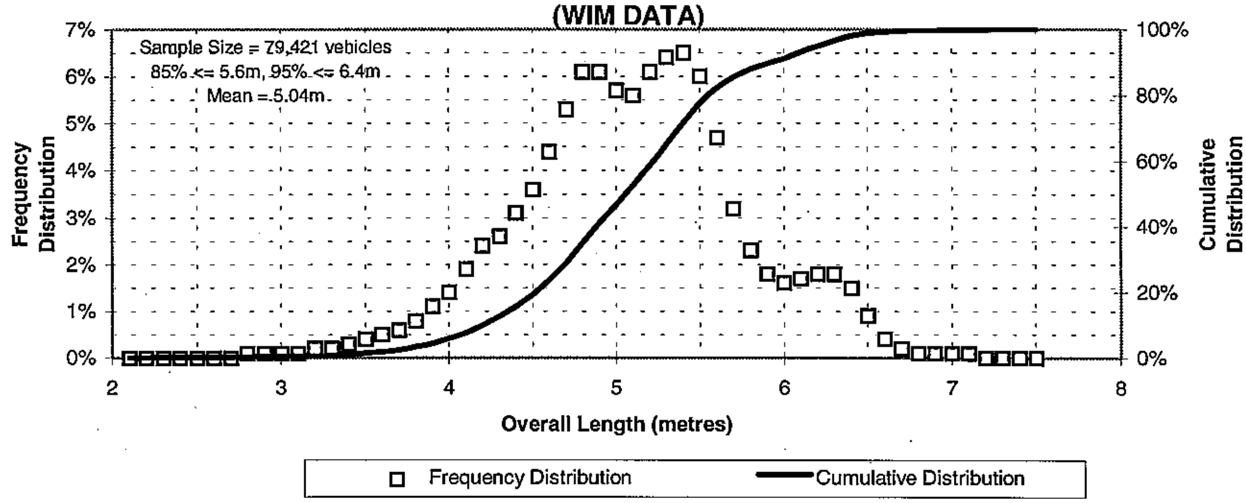


FIGURE 5.8

DISTRIBUTION OF WHEELBASE LENGTHS FOR LIGHT SINGLE-UNIT TRUCKS (WIM DATA)

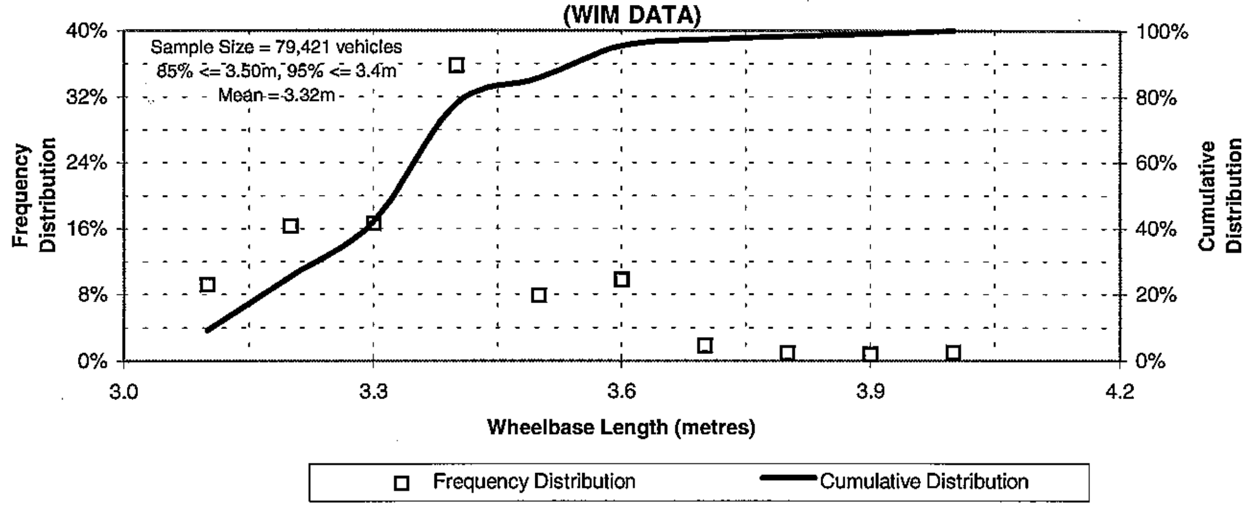


FIGURE 5.9

DISTRIBUTION OF OVERALL LENGTHS FOR MEDIUM SINGLE-UNIT TRUCKS (WIM DATA)

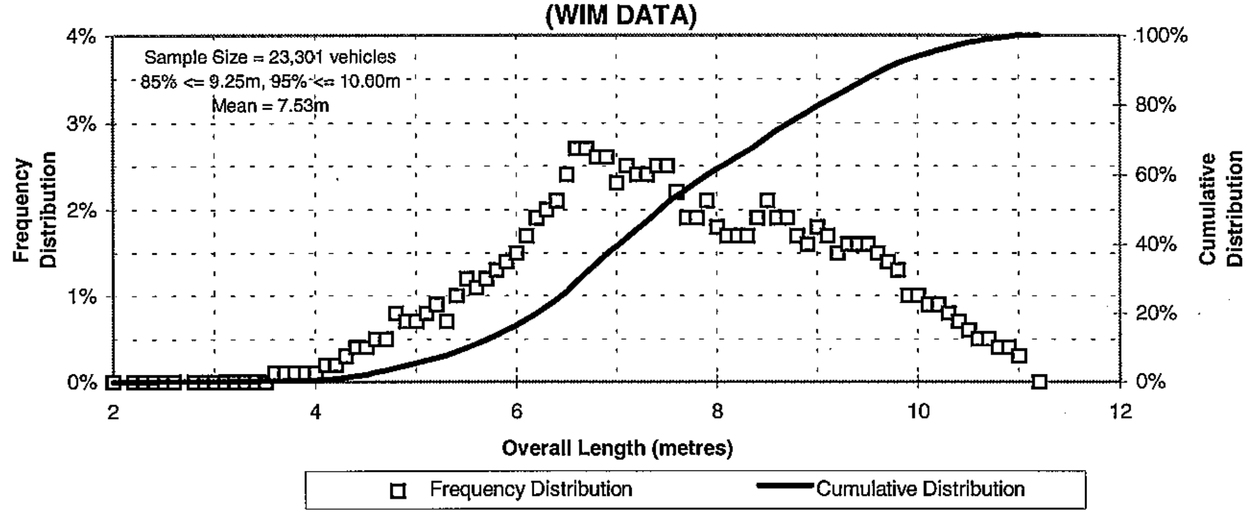


FIGURE 5.10

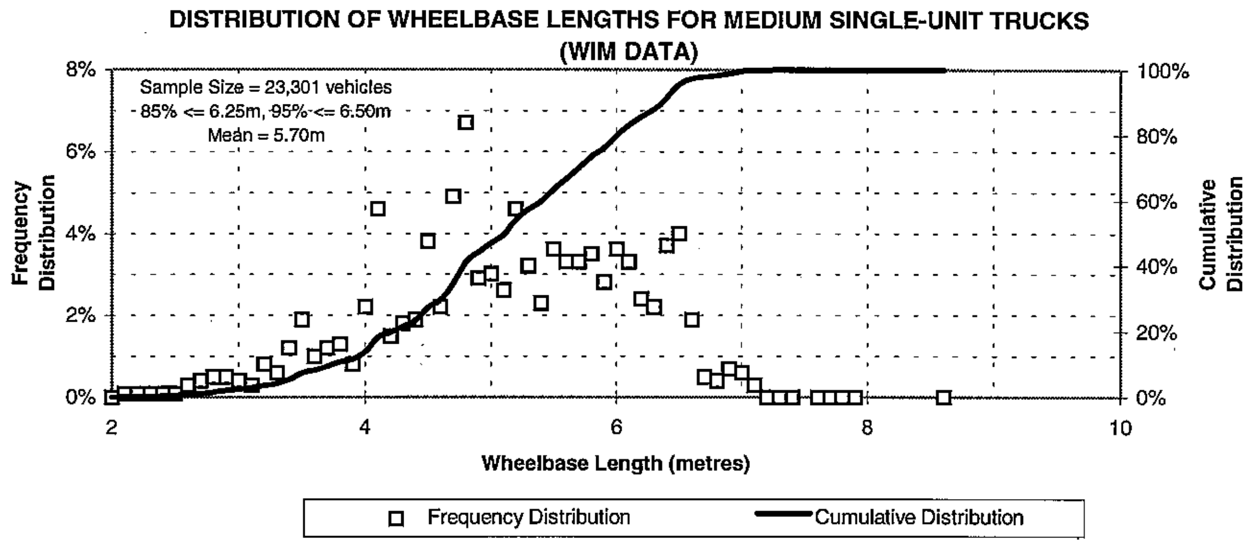


FIGURE 5.11

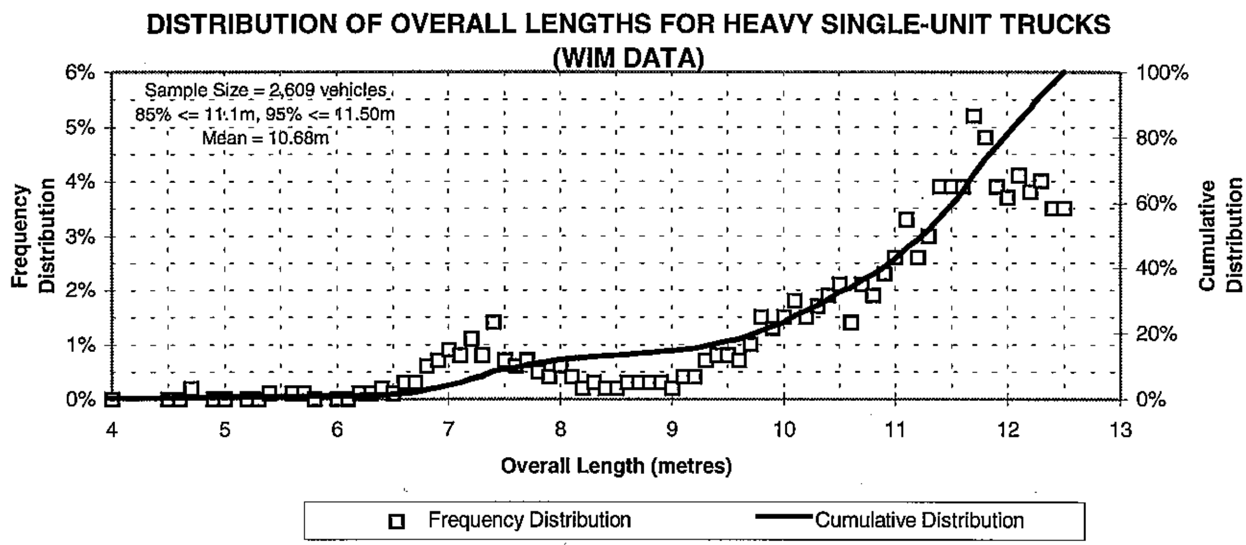
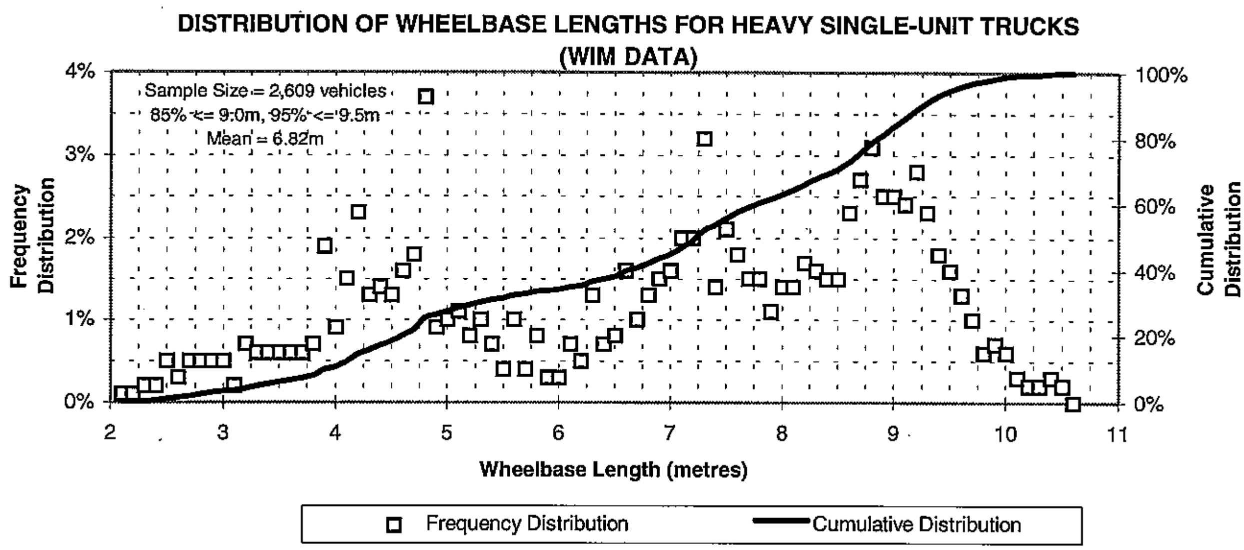


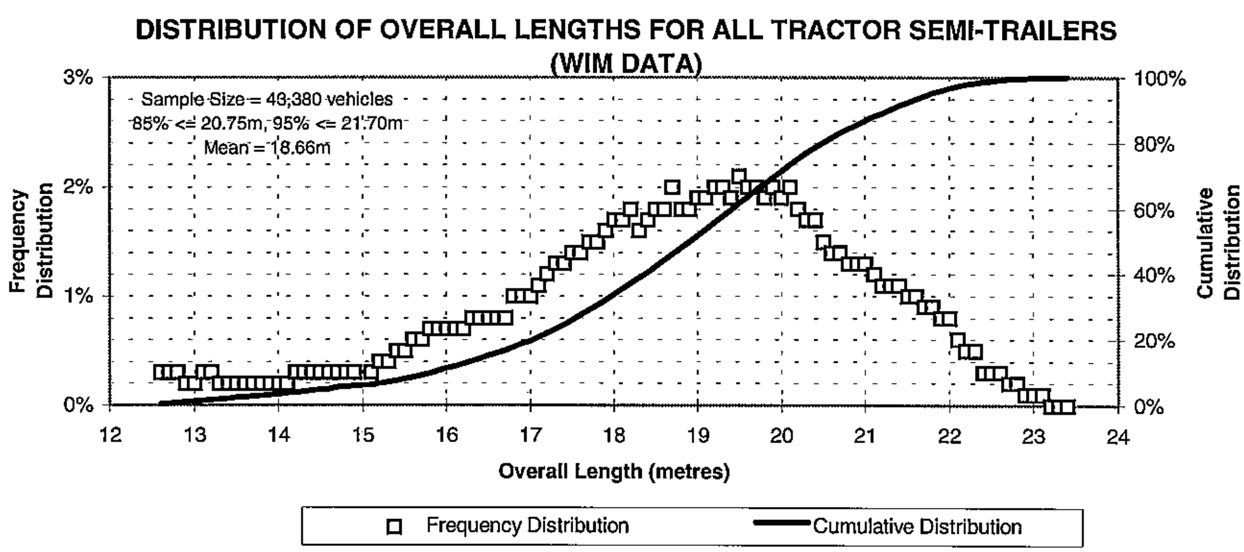
FIGURE 5.12



5.2.2 Tractor Semi-trailers

The conventional tractor-semitrailer accounted for about 90% of the combination truck population. In total, 43,380 vehicles were recorded. The maximum allowable overall length for tractor-semitrailers is 23 m as per the MoU network. Provincially, Prince Edward Island and Alberta allow lengths up to 25 m. Distributions of overall lengths for tractor-semitrailers recorded are summarized in Figure 5.13.

FIGURE 5.13



As seen from Figure 5.13, the overall length is widely distributed with a mean of about 18.7 m, and a 95th percentile value of 21.7 m. Until 1993, the MoU permitted tractor-semitrailers up to 21 m only. Since then, this has been revised to 23 m. Therefore, the total tractor-semitrailer data were separated into two types; trucks with overall lengths less than 21 m (WB-19), and those 21 m to 23 m long (WB-20). WB-19 trucks accounted for about 87% of the total tractor-semitrailer population while the WB-20 trucks accounted for the remaining. Frequency/cumulative distributions of overall lengths, and the tractor/trailer (WB1/WB2) wheelbase dimensions, are summarized for the WB-19 and WB-20 truck types in Figures 5.14 to 5.19.

FIGURE 5.14

DISTRIBUTION OF OVERALL LENGTHS FOR WB-19 TRACTOR-SEMITRAILERS (WIM DATA)

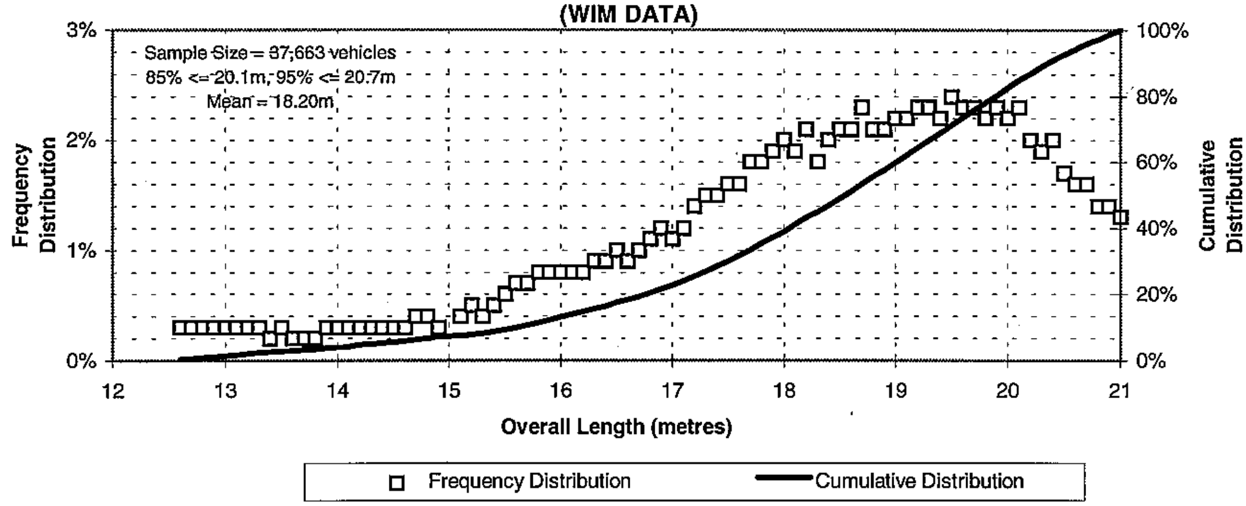


FIGURE 5.15

DISTRIBUTION OF WB1 LENGTHS FOR WB-19 TRACTOR-SEMITRAILERS (WIM DATA)

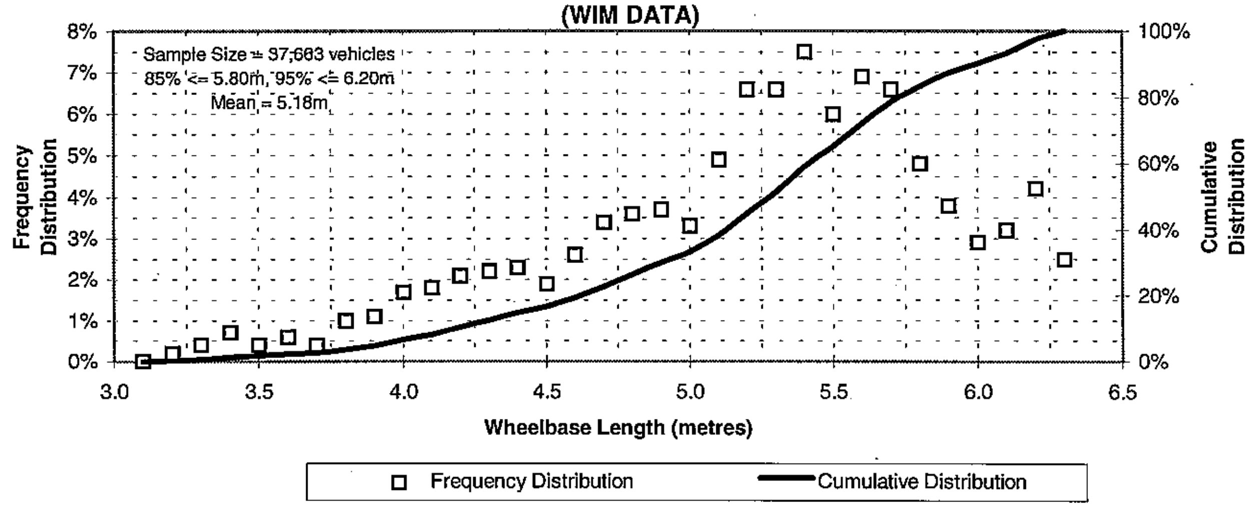


FIGURE 5.16

DISTRIBUTION OF WB2 LENGTHS FOR WB-19 TRACTOR-SEMITRAILERS (WIM DATA)

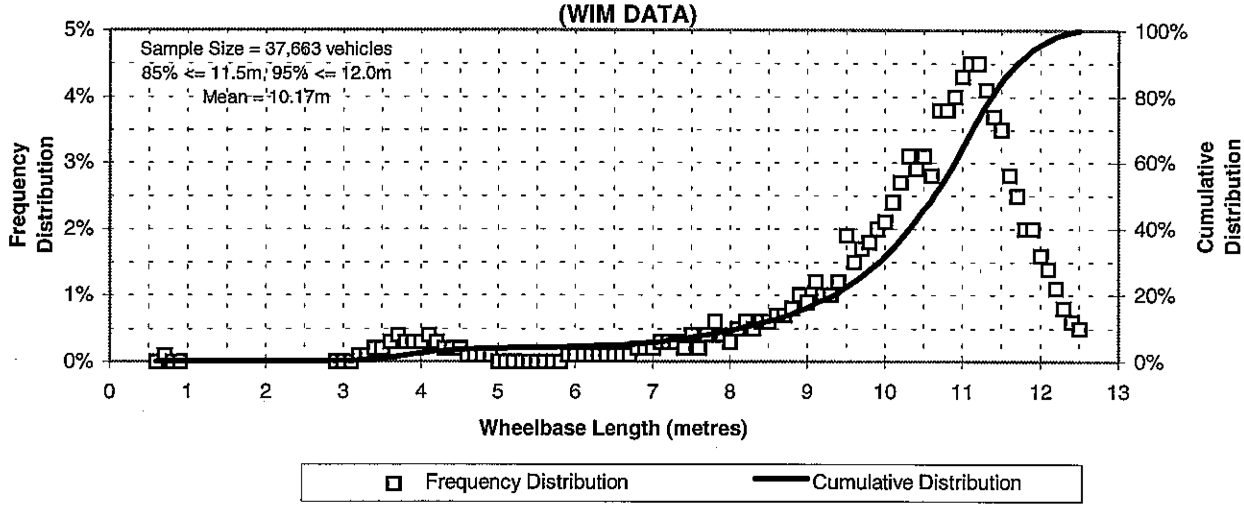


FIGURE 5.17

DISTRIBUTION OF OVERALL LENGTHS FOR WB-20 TRACTOR-SEMITRAILERS (WIM DATA)

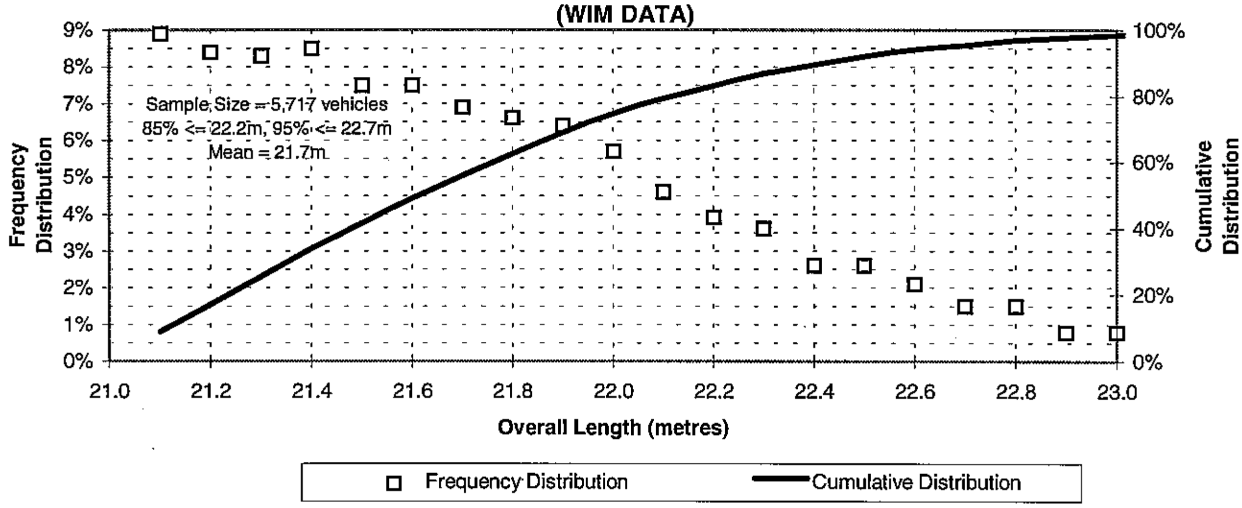


FIGURE 5.18

DISTRIBUTION OF WB1 LENGTHS FOR WB-20 TRACTOR-SEMITRAILERS (WIM DATA)

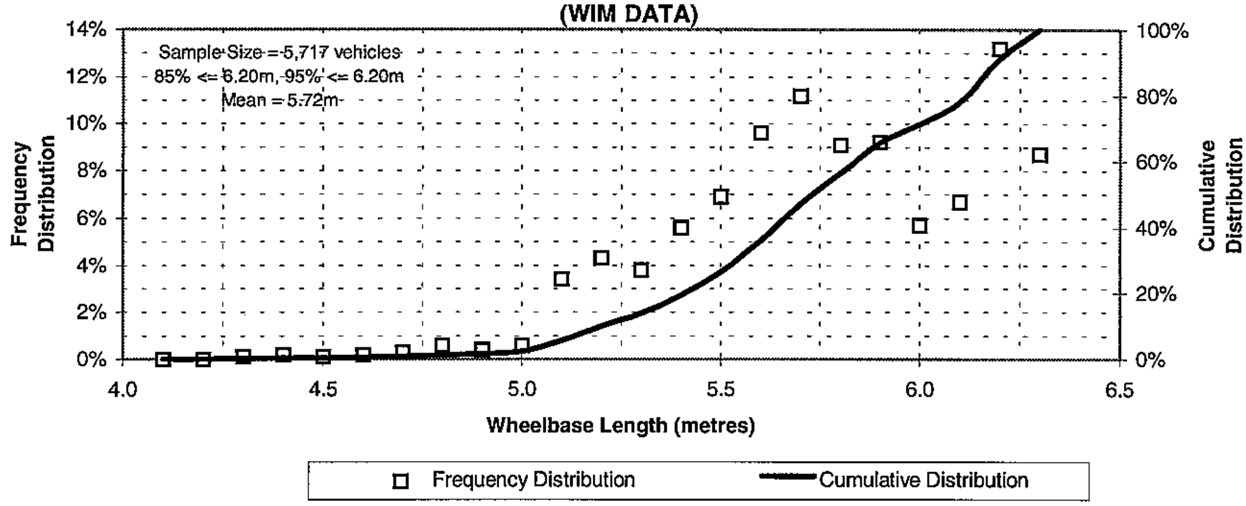
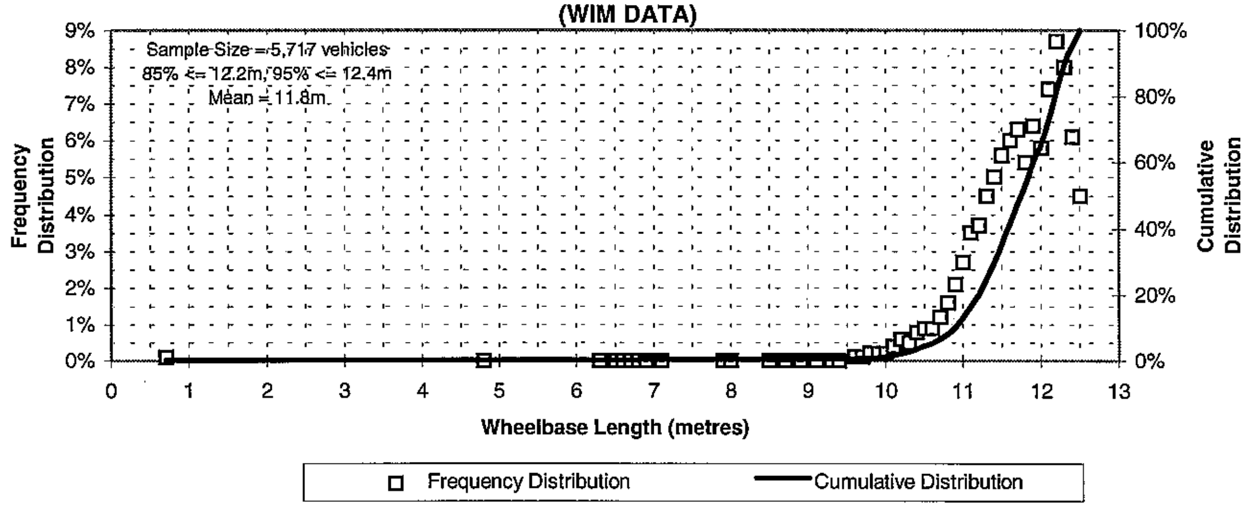


FIGURE 5.19

DISTRIBUTION OF WB2 LENGTHS FOR WB-20 TRACTOR-SEMITRAILERS (WIM DATA)



Current TAC provisions include two tractor-semitrailer classes, namely the WB-15 and WB-17 classes, which have now been replaced by vehicles with longer wheelbases due to changes in regulations. The WB-19 and WB-20 classes, also defined in the AASHTO classification, represent the revised vehicle types. Table 5.4 summarizes the key results for the these two vehicle classes.

TABLE 5.4
SUMMARY OF TRACTOR-SEMITRAILER DIMENSIONS (WIM DATA)

Dimension	Data	WB-19	WB-20
Length(m)	Mean	18.2	21.7
	85th percentile	20.1	22.2
	95th percentile	*20.7*	*22.7*
WB1 (m)	Mean	5.2	5.7
	85th percentile	5.8	6.2
	95th percentile	*6.2*	*6.2*
WB2 (m)	Mean	10.2	11.8
	85th percentile	11.5	12.2
	95th percentile	*12.0*	*12.4*

5.2.3 Tractor Semitrailer-Trailers (A-Train Doubles)

Tractor semitrailer-trailers, or A-train doubles, accounted for about 2.2% of the total combination truck sample. Distributions of overall lengths and wheelbase dimensions (tractor, WB1; semitrailer, WB2; trailer, WB3; hitch and drawbar, WB4) are summarized in Figures 5.20 to 5.24. The key statistics are summarized in Table 5.5.

The maximum allowable overall length for A-trains is 25.0 m. TAC provisions use the WB-18 vehicle class (same as AASHTO) for tractor semitrailer-trailers, with an overall length of 19.9 metres. The 95th percentile overall length of 24.7 m from the WIM data sample represents the revised regulations in the recent years, which increased the maximum allowable length to 25.0 m.

TABLE 5.5
SUMMARY OF A-TRAIN DIMENSIONS (WIM DATA)

Dimension	Data	Value
Length(m)	Mean	22.0
	85th percentile	22.5
	95th percentile	*24.5*
WB1 (m)	Mean	5.1
	85th percentile	5.9
	95th percentile	*6.1*
WB2 (m)	Mean	6.9
	85th percentile	7.5
	95th percentile	*9.1*
WB3 (m)	Mean	5.0
	85th percentile	6.7
	95th percentile	*6.9*
WB4 (m)	Mean	3.3
	85th percentile	3.8
	95th percentile	*4.4*

FIGURE 5.20

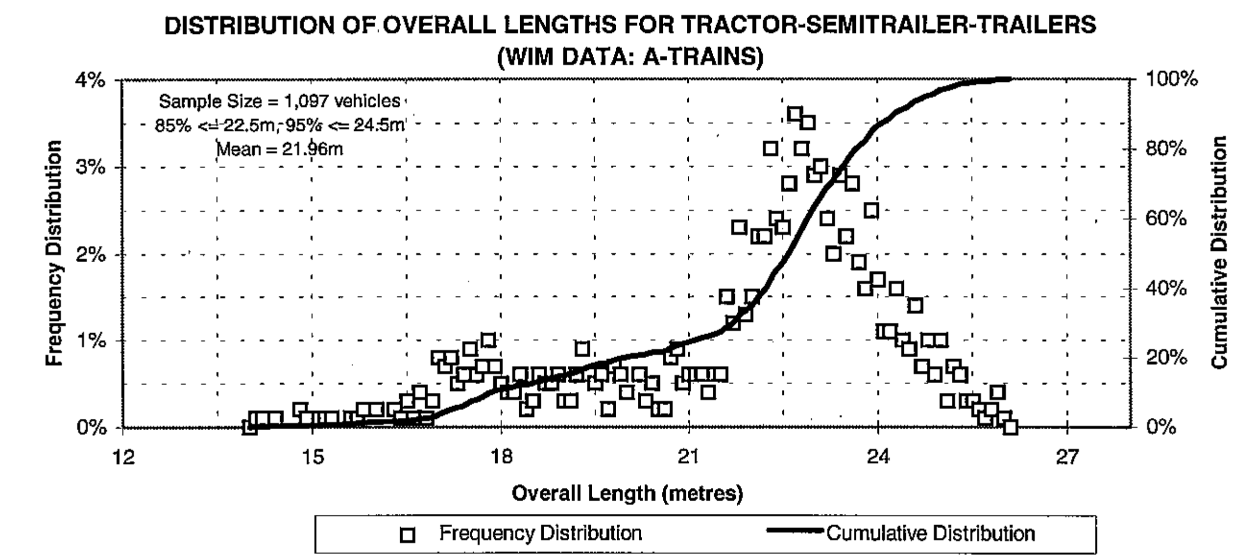


FIGURE 5.21

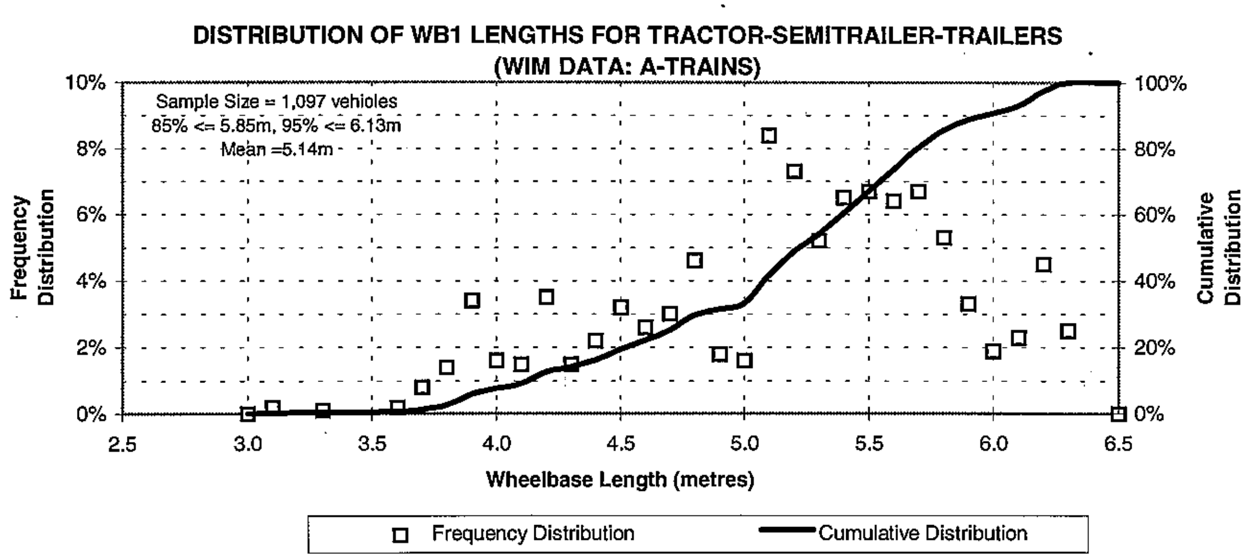


FIGURE 5.22

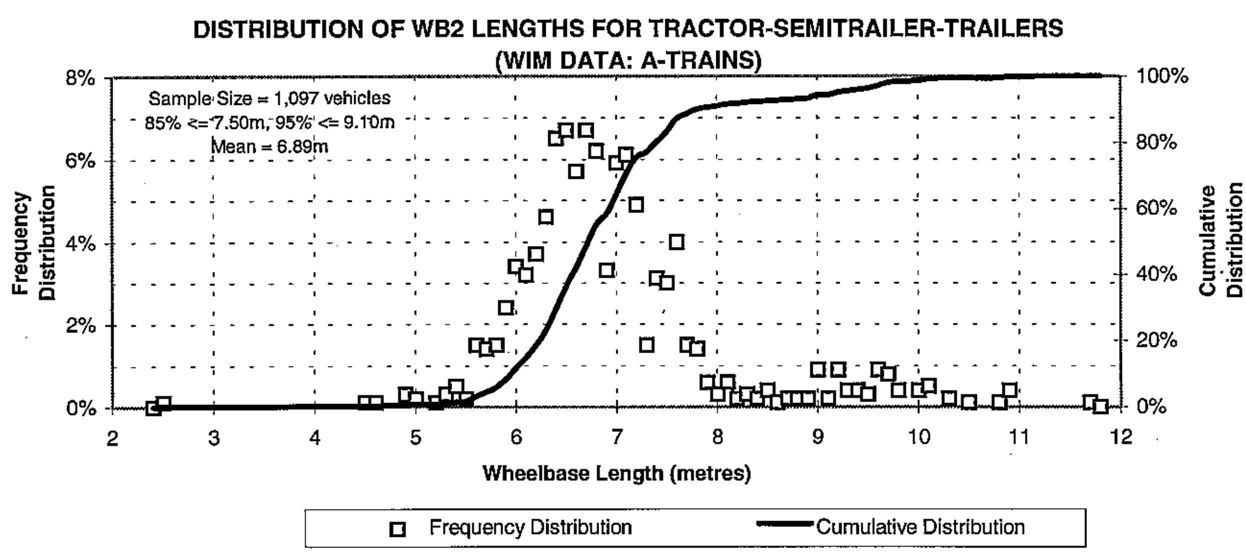


FIGURE 5.23

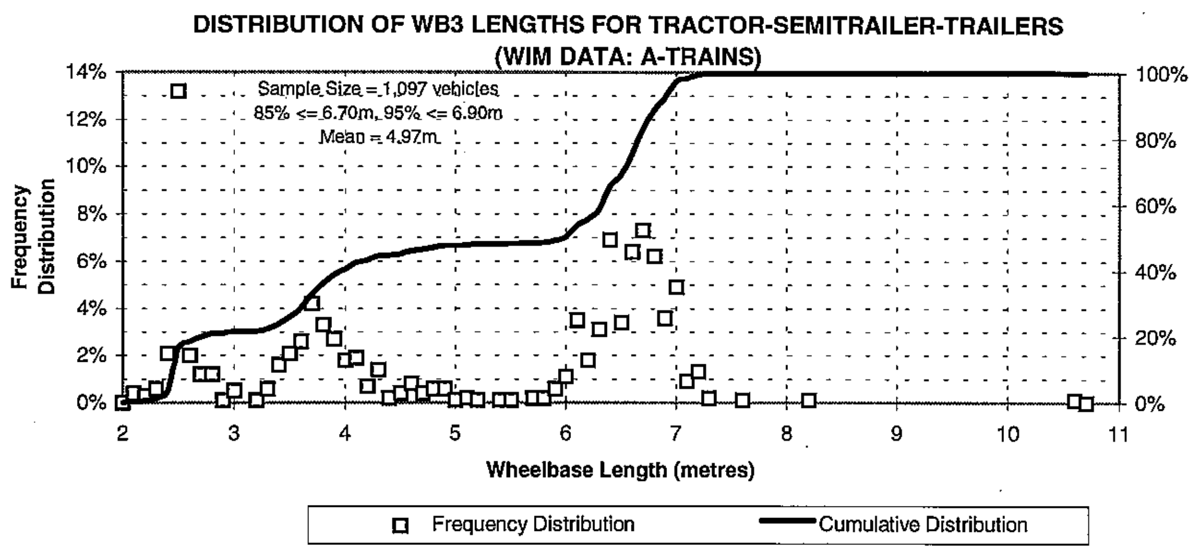
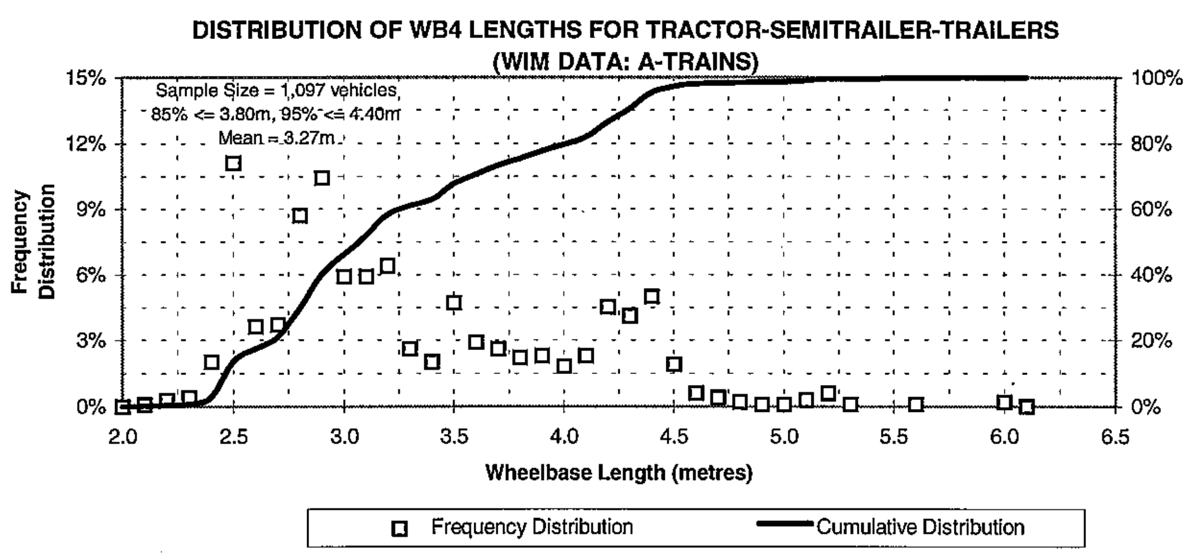


FIGURE 5.24



5.2.4 Tractor Semitrailer-Semitrailers (B-Train Doubles)

Tractor semitrailer-semitrailers, or B-train doubles, accounted for about 8% of the total combination truck population. Distributions of overall lengths and wheelbase dimensions (tractor, WB1; 1st semitrailer, WB2; 2nd semitrailer, WB3) are summarized in Figures 5.25 to 5.28. Key statistics are summarized in Table 5.6. The maximum allowable overall length for B-train doubles is 25.0 m. Neither TAC nor AASHTO currently have design vehicles for tractor semitrailer-semitrailers. The TAC Turning Vehicle Templates package includes the "B-Train" class to represent this vehicle type.

TABLE 5.6
SUMMARY OF B-TRAIN DIMENSIONS (WIM DATA)

Dimension	Data	Value
Length(m)	Mean	23.9
	85^{th} percentile	25.0
	95^{th} percentile	*25.5*
	TAC "B-Train"	**25.0**
WB1 (m)	Mean	5.3
	85^{th} percentile	5.9
	95^{th} percentile	*6.1*
	TAC "B-Train"	**5.3**
WB2 (m)	Mean	8.1
	85^{th} percentile	8.7
	95^{th} percentile	*9.0*
	TAC "B-Train"	**8.4**
WB3 (m)	Mean	7.1
	85^{th} percentile	7.5
	95^{th} percentile	*7.8*
	TAC "B-Train"	**8.3**

FIGURE 5.25

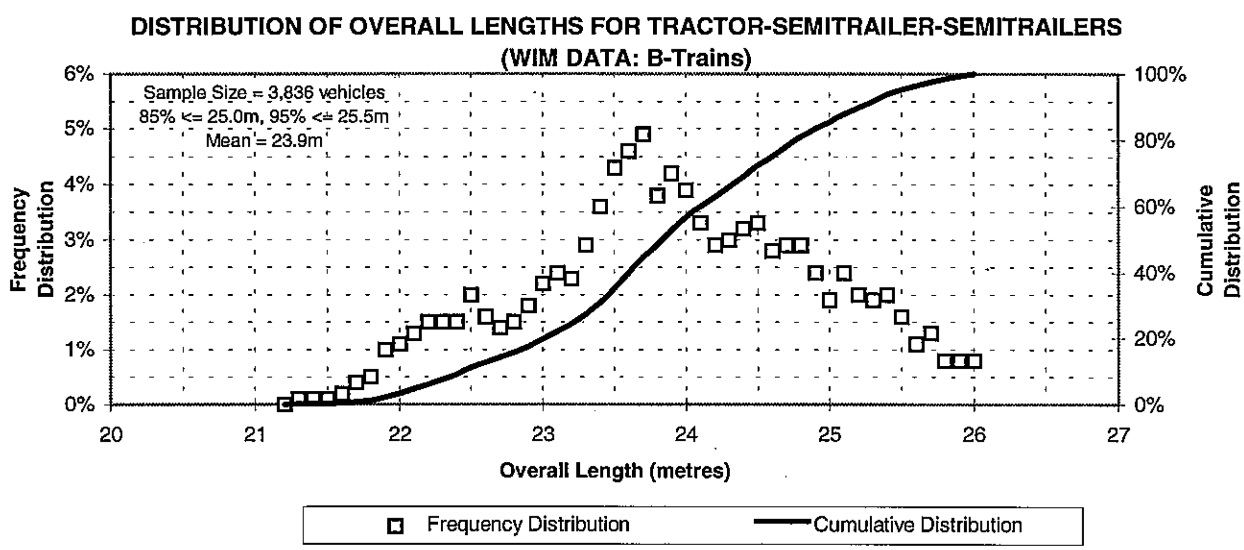


FIGURE 5.26

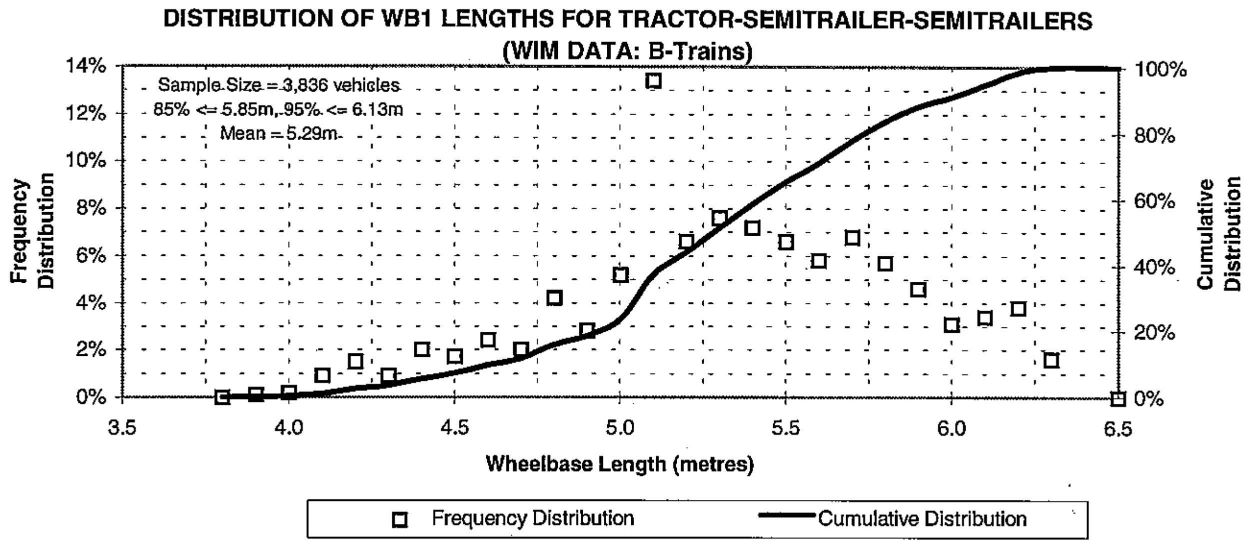


FIGURE 5.27

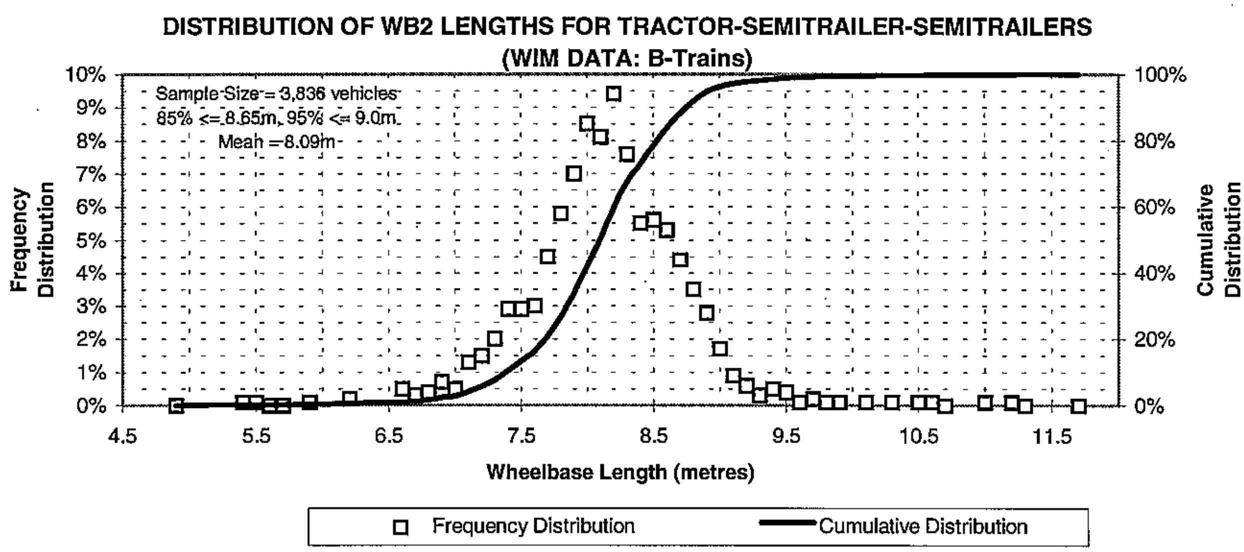
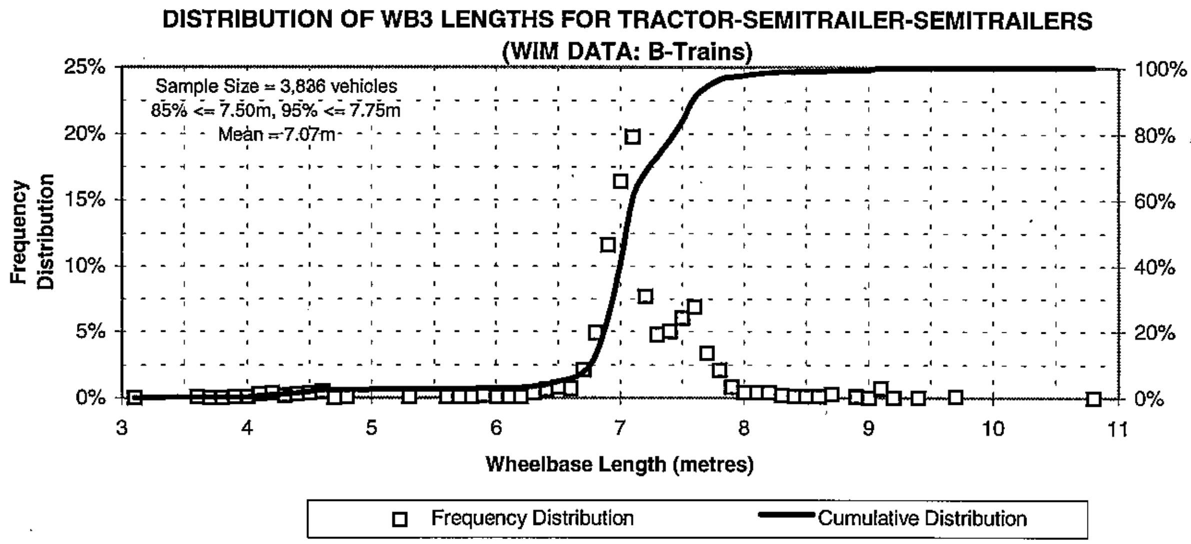


FIGURE 5.28



5.3 BUSES

Vehicle inventory data from the transit operators provided fleet characteristics for 7,000 buses, currently used in Canada for urban transportation. The three most common bus types in use include the standard 12.2 m long single unit buses (the current TAC design vehicle), articulated buses, and low-floor buses. Paratransit buses, CNG (Canadian Natural Gas) buses and other types account for a small proportion of the bus population (Figure 5.29). At this point in time, single-unit buses and articulated buses are the only two classes appropriate for consideration as design vehicles.

Figure 5.30 shows the mean dimensions for the single-unit and articulated buses operated by the agencies surveyed. AASHTO uses specific vehicle classes for the two categories. Currently, the TAC Manual doesn't have specific design vehicle classes for single-unit urban transportation buses or articulated buses. It has one common class for single unit trucks and single-unit buses. However, the TAC Turning Vehicle Templates package includes the "BUS" and "A-BUS" categories to represent single-unit and articulated bus (urban) fleets.

The 95th percentile dimensions from operator data are compared with the TAC (Turning Vehicle Templates) and AASHTO dimensions in Figures 5.31 (standard buses) and 5.32 (articulated buses). As seen from these figures, the 95th percentile data from the operators are very similar to the TAC and AASHTO dimensions. The turning radii for the TAC vehicles appear to be slightly conservative.

FIGURE 5.29

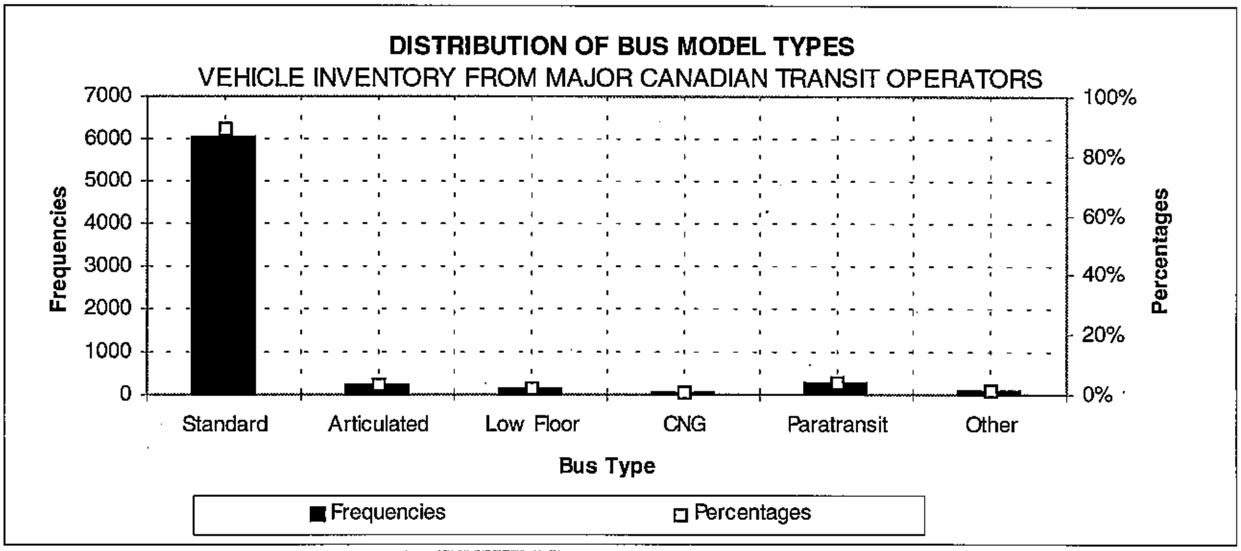


FIGURE 5.30

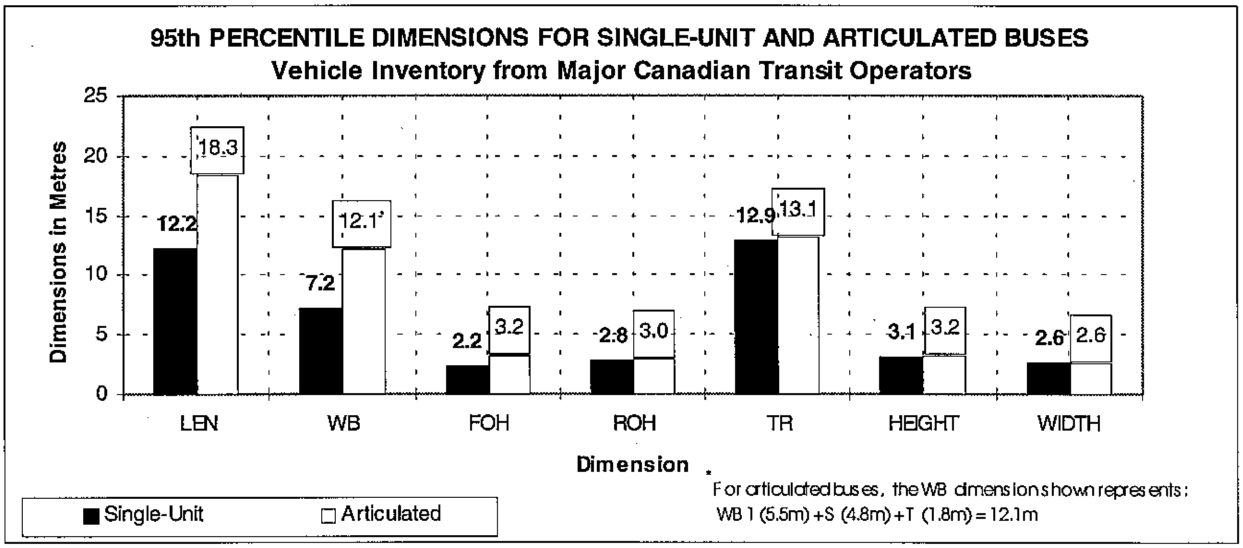


FIGURE 5.31

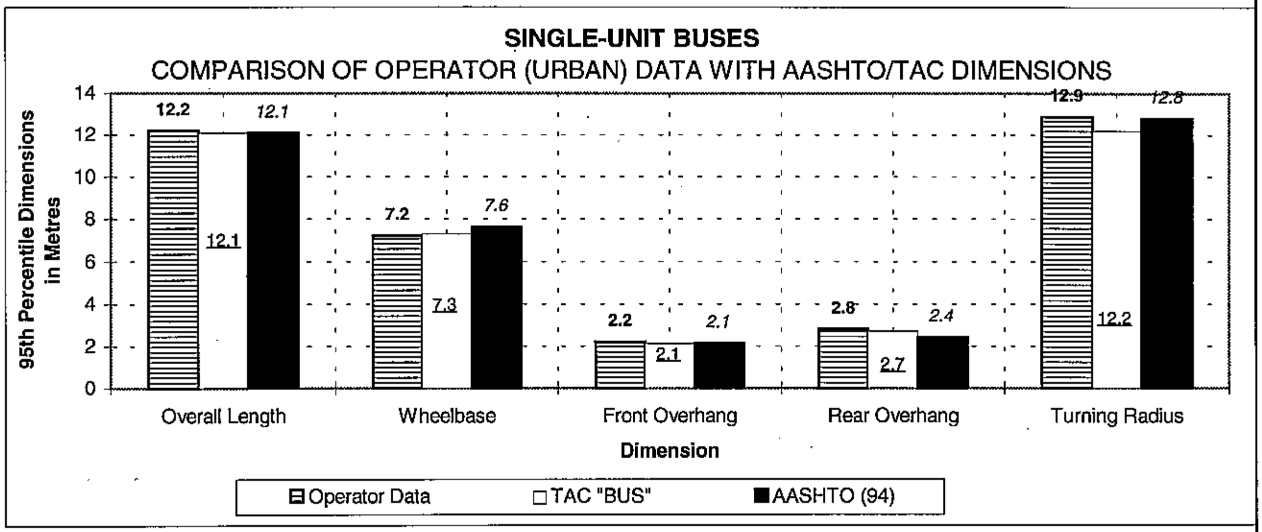
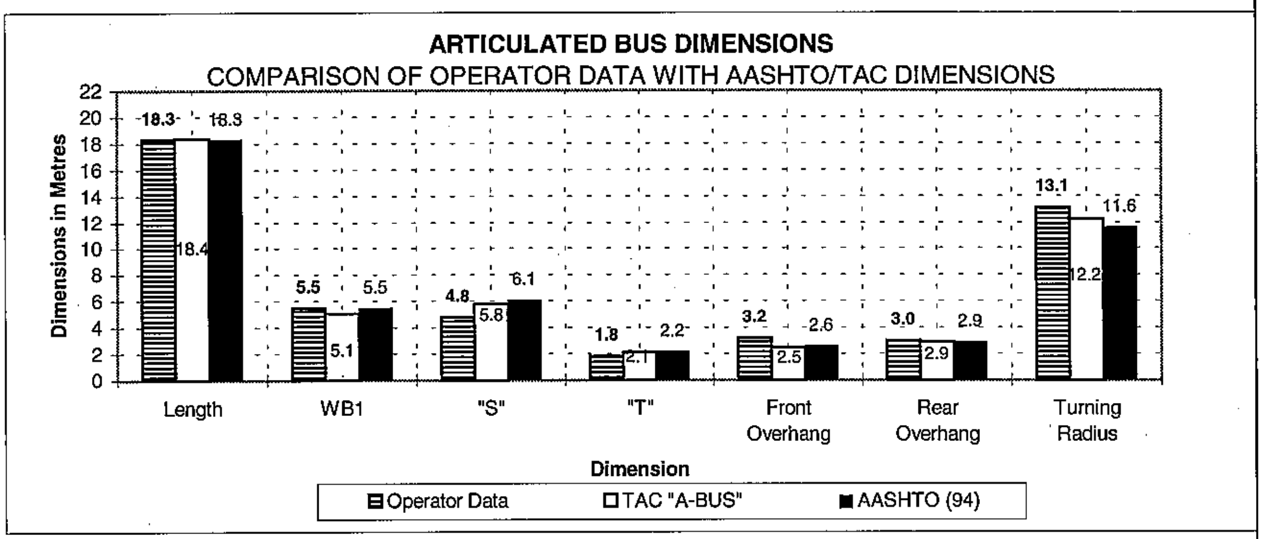


FIGURE 5.32



The TAC Manual also contains a specific class for intercity/highway buses (B-12R), with a minimum design turning radius of 15.2 m. The TAC MoU allows intercity buses up to 14 m long, with the effective rear overhang (from the rear effective axle) restricted to a maximum of 4.0 m. Typical dimensions for these "45 ft buses", obtained from bus manufacturers, indicate an overall length of 13.7 m with an 8.0 m wheelbase.

6.0 RECOMMENDATIONS

6.1 PRIVATE VEHICLES

Passenger cars represent the most common vehicle type used for private/personal use. Passenger cars with recreational trailers are considered as 'special vehicles' and are therefore not dealt with as specific design vehicle class designations. The design dimensions for passenger cars should be determined from the results of the statistical analysis from this study, taking into account any changes foreseen in the future.

Based on the assessment of future trends in section 3.4.1, no apparent changes appear likely in the near future. The CVIOC database was analyzed to estimate the means (weighted by population) of the various vehicle dimensions by model year. The results are shown in Figure 6.1. As seen from the figure, there is little variation between the various model years with respect to their major dimensions. This historical trend again suggests current passenger car fleet characteristics as an appropriate representation for design vehicle specifications.

FIGURE 6.1

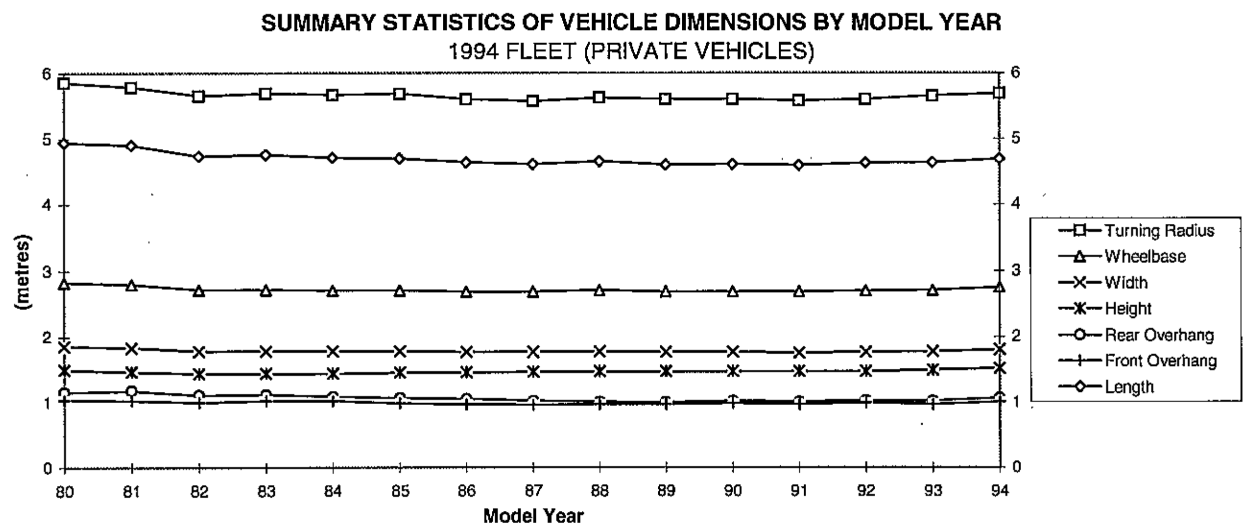
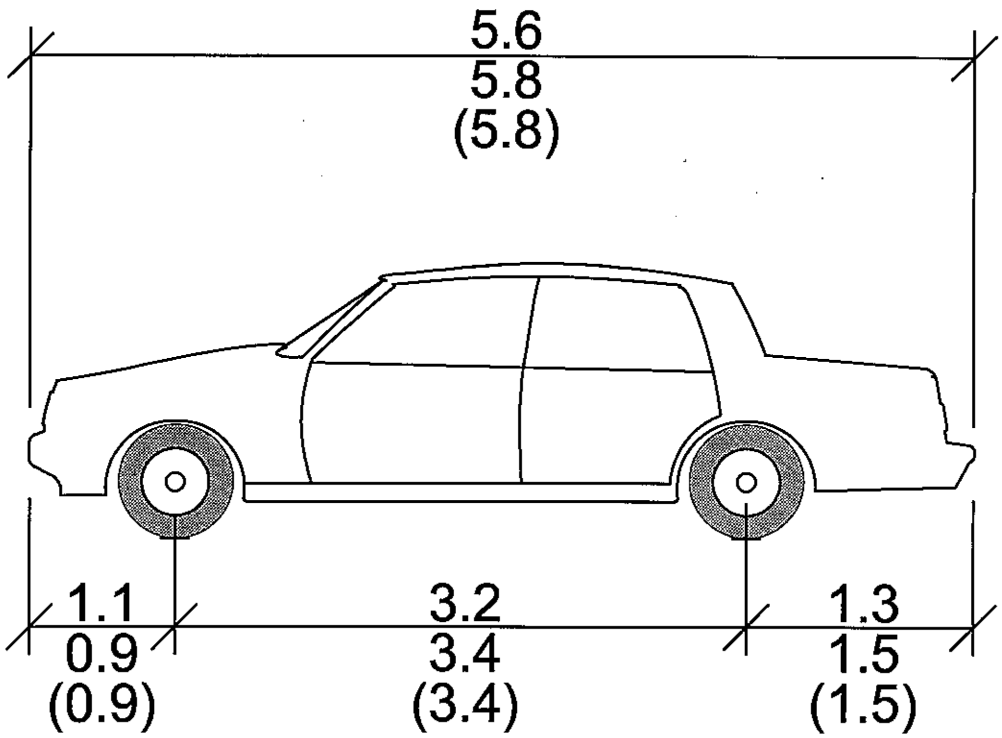


Figure 6.2 provides a comparison of the 95th percentile data from the CVIOC database with the current TAC and AASHTO dimensions. The minimum design turning radius specified for the TAC "P" vehicle (same as the AASHTO "P" vehicle) is 7.3 m. Results from the CVIOC database analysis indicate a 95th percentile minimum turning radius of 6.3 m.

FIGURE 6.2
PASSENGER CAR DIMENSIONS



LEGEND: Proposed dimensions
TAC Design Vehicle
(AASHTO Vehicle)

Notes: *All dimensions are in metres*
Figure not to scale.

Accordingly, the following dimensions are recommended for the passenger car ("P") design vehicle class:

Overall Length	5.6 m
Front Overhang	1.1 m
Wheelbase	3.2 m
Rear overhang	1.3 m
Minimum turning radius	6.3 m

These dimensions are slightly less conservative than the current TAC design vehicle for passenger cars. The revised dimensions better represent the current passenger car fleets.

6.2 COMMERCIAL VEHICLES

The following seven commercial vehicle classes are suggested for design vehicle consideration:

- Light Single-Unit Trucks
- Medium Single-Unit Trucks
- Heavy Single-Unit Trucks
- WB-19 Tractor Semitrailers
- WB-20 Tractor Semitrailers
- A-Train Doubles
- B-Train Doubles

The proposed design vehicle dimensions are summarized in Table 6.1. Figures 6.3 to 6.9 provide a comparison of the proposed design dimensions with the corresponding TAC and AASHTO dimensions (where applicable). The design dimensions suggested are based on the 95th percentile overall vehicle length (limited to the maximum legal dimension), with the remaining dimensions as close to 95th percentile measurement as possible, adjusted to yield the maximum swept path in accordance with the results of the sensitivity analysis (e.g., the tractor fifth wheel offset was set to zero).

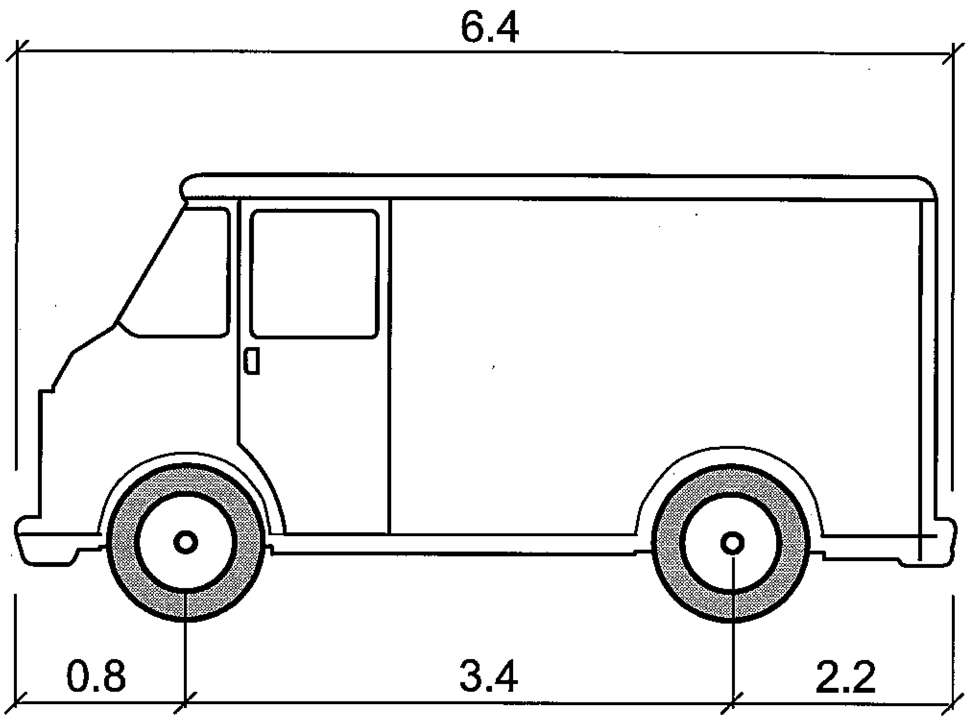
TABLE 6.1
PROPOSED DESIGN DIMENSIONS FOR COMMERCIAL VEHICLES

Dimension (m)	Single-Unit Trucks			Tractor-Semitrailers		Doubles	
	Light	Medium	Heavy	WB-19	WB-20	A-trains	B-trains
Length (m)	6.4	10.0	11.5	20.7	22.7	24.5	25.0
Front Overhang (m)	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Rear Overhang (m)	2.2	2.7	1.7	1.7	3.3	1.5	1.3
WB1 (m)	3.4	6.5	9.0	6.2	6.2	5.1	6.1
WB2 (m)	-	-	-	12.0	12.4	6.9	9.0
WB3 (m)	-	-	-	-	-	6.9	7.0
WB4 (m)	-	-	-	-	-	3.3[a]	0.8[b]

Notes: [a]*Includes 1.2 m from the rear effective axle to the hitch point, and 2.1 m from the hitch point to the lead effective axle of the following unit.*

[b]*Represents the distance from the hitch point to the lead effective axle of the following unit.*

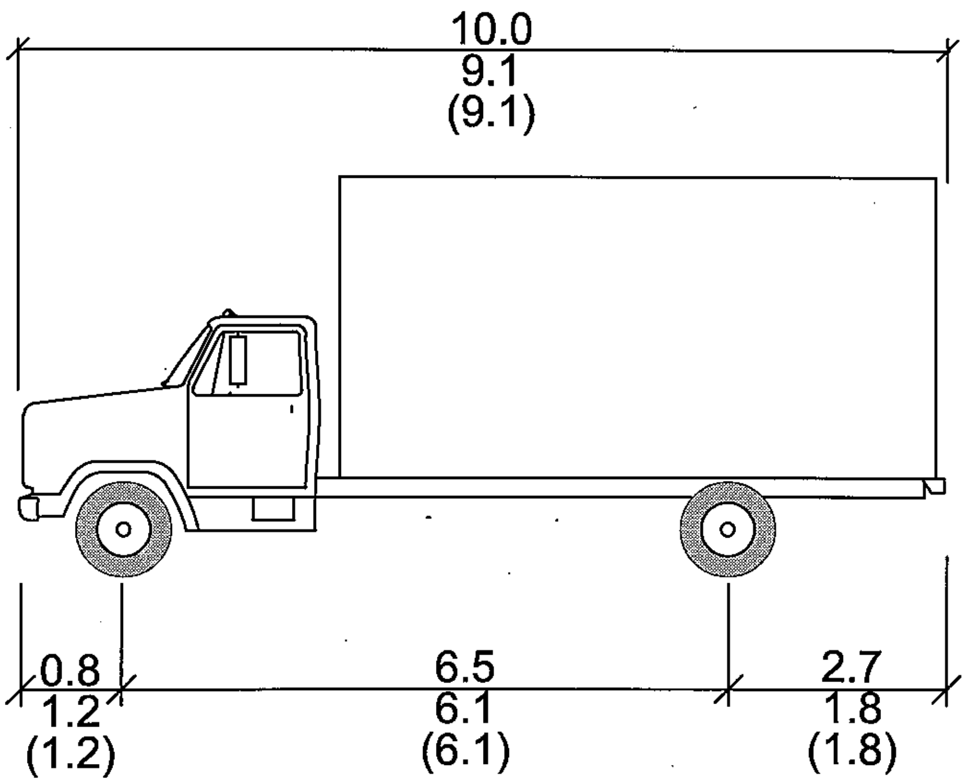
FIGURE 6.3
LIGHT SINGLE-UNIT TRUCK DIMENSIONS



LEGEND: _Proposed dimensions_

Notes: *All dimensions are in metres*
Figure not to scale.

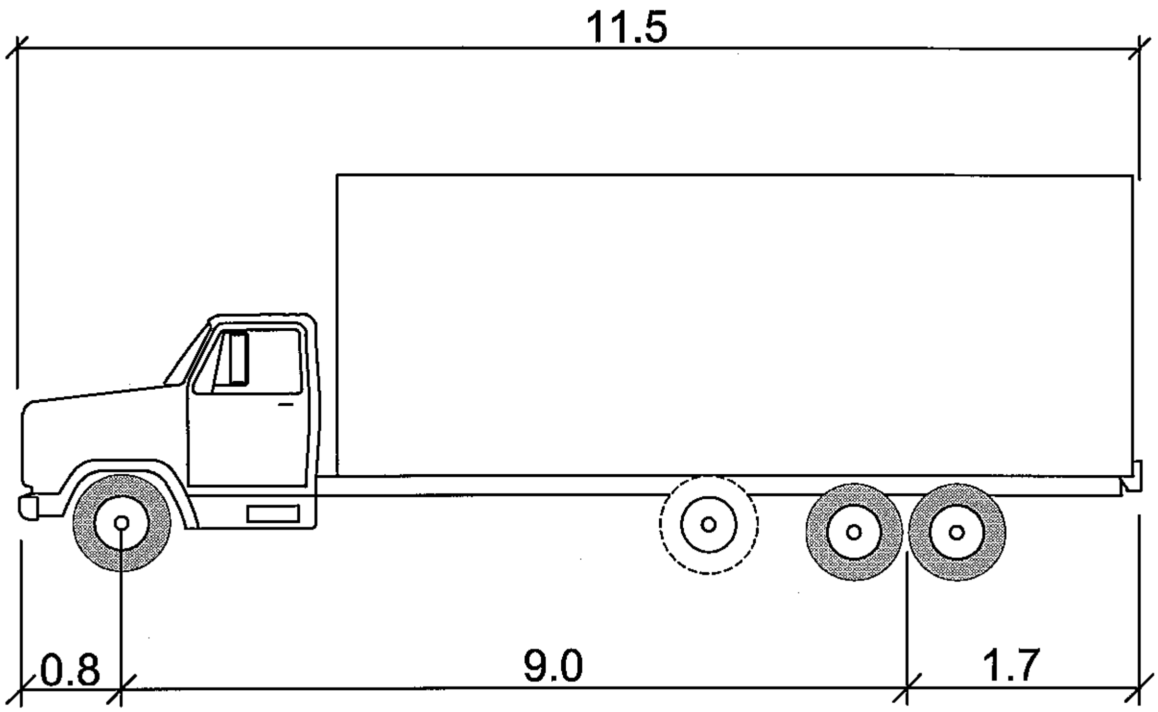
FIGURE 6.4
MEDIUM SINGLE-UNIT TRUCK DIMENSIONS



LEGEND: *Proposed dimensions*
TAC Design Vehicle
(AASHTO Vehicle)

Notes: *All dimensions are in metres*
Figure not to scale.

FIGURE 6.5
HEAVY SINGLE-UNIT TRUCK DIMENSIONS (TENTATIVE)

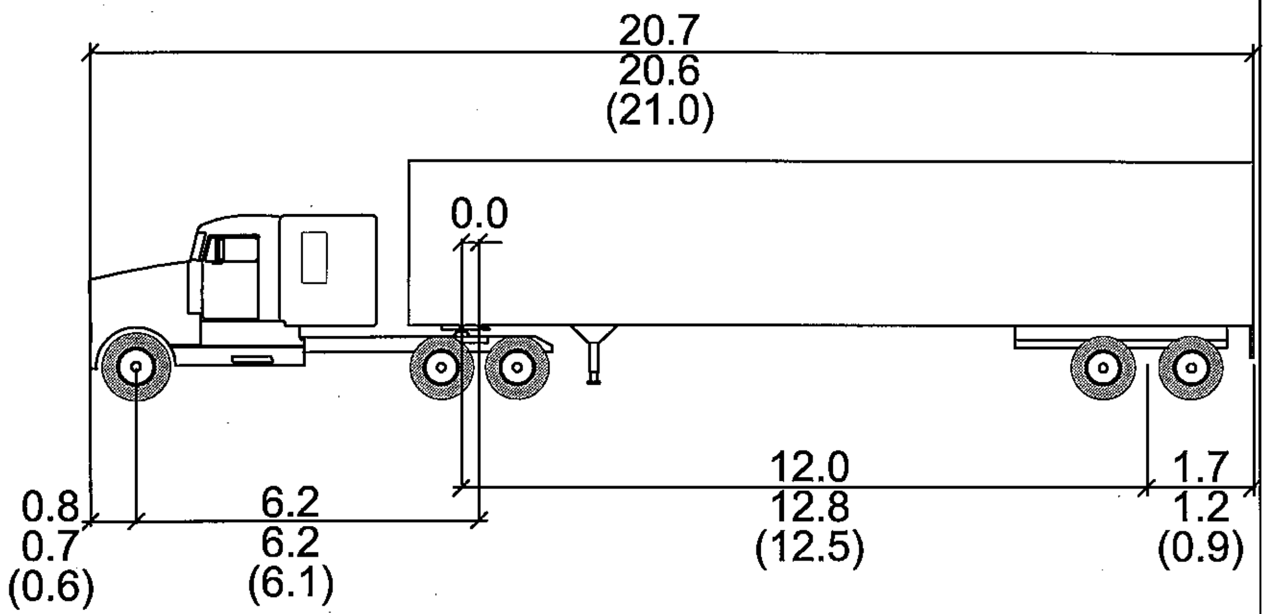


LEGEND: *Proposed dimensions*

Notes: *All dimensions are in metres*
Figure not to scale

Because of the complexity of the axle arrangement of multiple-axle/single-unit trucks, WIM data intepretation of heavy single-unit trucks is subject to considerable error. The dimensions given for heavy single-unit trucks should therefore be considered typical until they can be confirmed using other "hard" data sources, such as the 1995 CCMTA survey database. The analysis of the CCMTA database, however, could not be considered within the scope of this study due to the delay in its release (not expected to be available until 1997). It is therefore recommended that the dimensions for heavy single-unit trucks be confirmed using the CCMTA survey database, or other alternate means such as roadside observations, as work supplementary to this study.

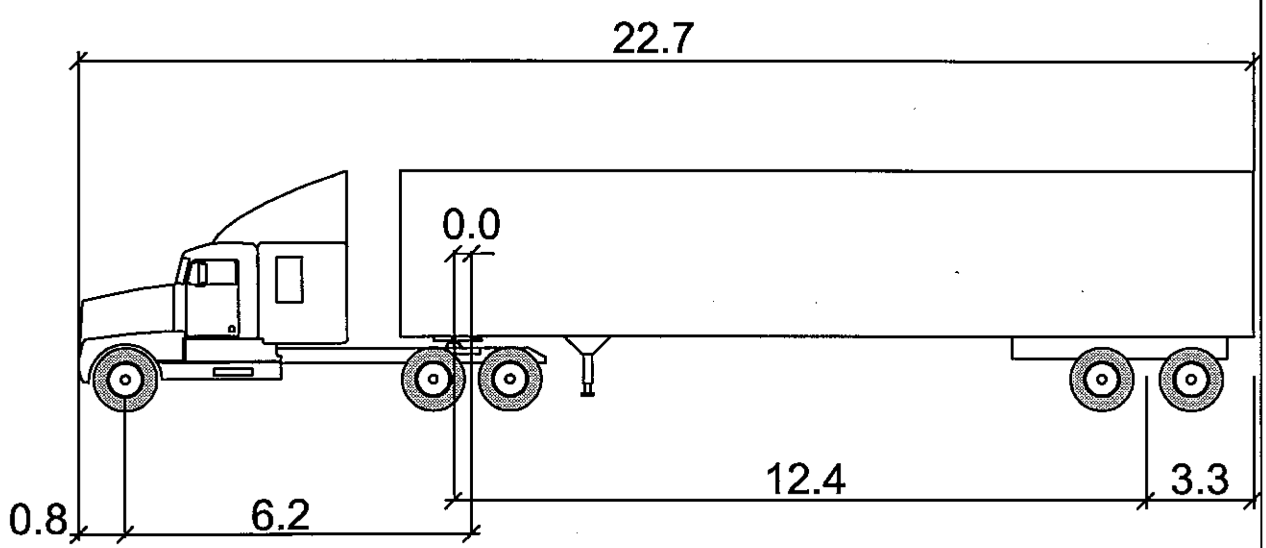
FIGURE 6.6
WB-19 TRACTOR-SEMITRAILER DIMENSIONS



LEGEND: <u>*Proposed dimensions*</u>
TAC Design Vehicle
(AASHTO Vehicle)

<u>*Notes:*</u> *All dimensions are in metres*
Figure not to scale.

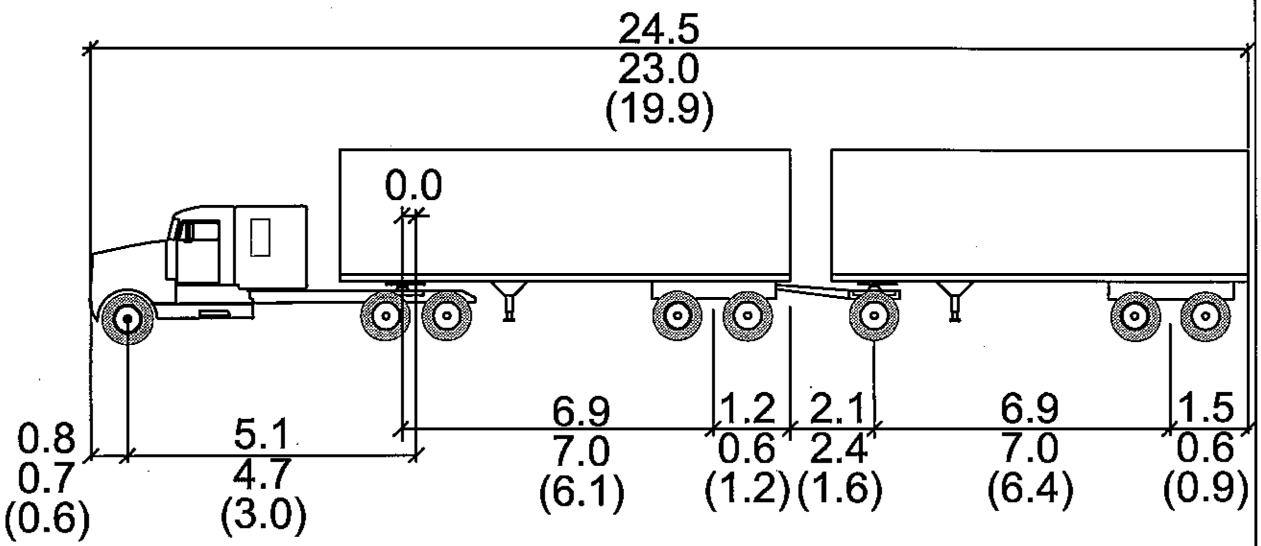
FIGURE 6.7
WB-20 TRACTOR-SEMITRAILER DIMENSIONS



LEGEND: *Proposed dimensions*

Notes: *All dimensions are in metres*
Figure not to scale.

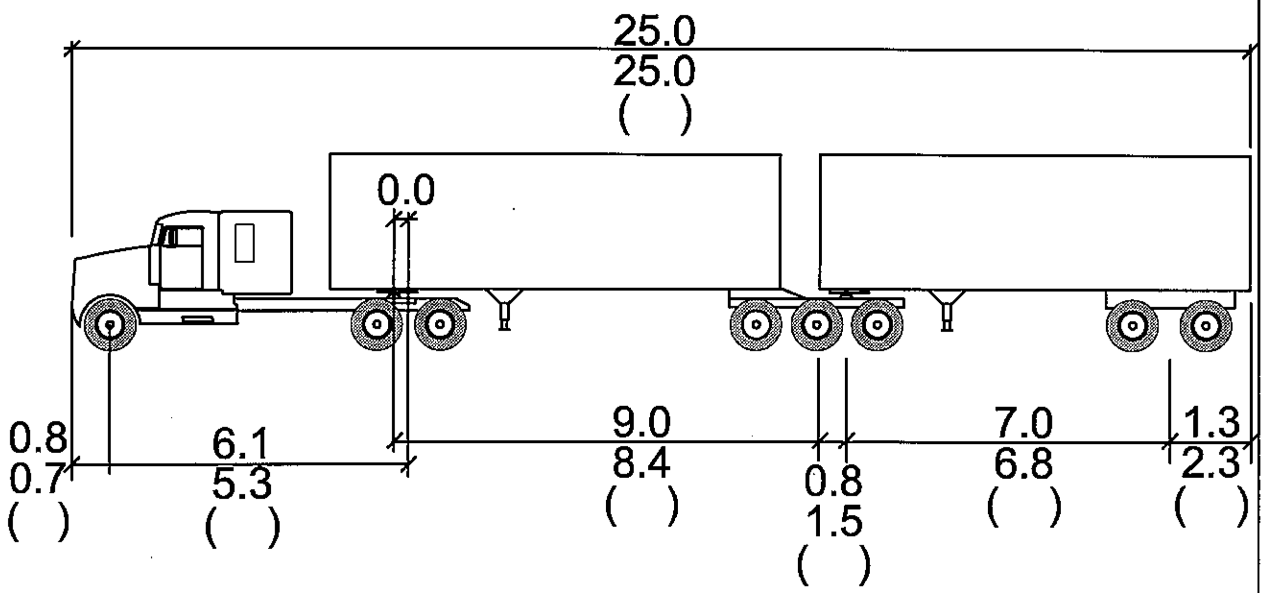
FIGURE 6.8
A-TRAIN DIMENSIONS



LEGEND: <u>*Proposed dimensions*</u>
TAC Design Vehicle
(AASHTO Vehicle)

<u>*Notes:*</u> *All dimensions are in metres*
Figure not to scale.

FIGURE 6.9
B-TRAIN DIMENSIONS



LEGEND: <u>*Proposed dimensions*</u>
TAC Design Vehicle
(AASHTO Vehicle -N/A)

Notes: *All dimensions are in metres*
Figure not to scale.

The maximum cramp angle of a single unit vehicle and its wheelbase establishes the minimum radius it can turn. Based on the data provided by truck manufacturers, a 40^0 cramp angle appears to be reasonable for design (all trucks can reach this angle of cramp or greater). Using this angle, with the dimensions proposed above, minimum design turning radii values are summarized in Table 6.2.

All design multiple-unit vehicles considered in this study can negotiate the minimum radius of turn of a 6.2 m wheelbase tractor unit in a 90^0 turn. A computer tracking program is useful to determine the minimum radius possible for greater angles of turn. The tractor radius of turn must be set so that the swept path of the inside rear-most trailer axle never reaches the centre of turn of the tractor where all forward motion would stop. Based on empirical evidence, a minimum distance of three metres between the swept path and centre of turn seems appropriate to maintain reasonable forward motion on the inside rear tire. The maximum 180^0 radii in Table 6.2 were established using this criterion.

TABLE 6.2
MINIMUM DESIGN TURNING RADII FOR REPRESENTATIVE TRUCKS
(BASED ON 95TH PERCENTILE DIMENSIONS, AND 40^{0} CRAMP ANGLE)

Truck Type	Wheelbase	Minimum Turning Radius (m) Centre of Axle	Minimum Turning Radius (m) Outside Front Wheel
Light SU	3.4	5.3	6.3
Medium SU	6.5	10.1	11.1
Heavy SU	9.0	14.0	15.0
Tractor Unit	6.2	9.6	10.7

Truck Type	Degree of Turn	Minimum Turning Radius (m) Centre of Axle	Minimum Turning Radius (m) Outside Front Wheel
WB-19	90^{0}	9.6	10.7
	180^{0}	12.8	14.0
WB-20	90^{0}	9.6	10.7
	180^{0}	13.1	14.3
A-train	90^{0}	9.6	10.7
	180^{0}	11.2	12.3
B-train	90^{0}	9.6	10.7
	180^{0}	12.5	13.6

6.3 BUSES

Three vehicle classes are suggested for design considerations:

- Standard Single-Unit Buses (B-12)
- Articulated Buses (A-BUS)
- Intercity/Highway Buses (I-BUS)

Table 6.3 summarizes the proposed design dimensions for the three classes. Figures 6.10 to 6.12 provide a comparison of the 95th percentile results from the operator data with the corresponding TAC and AASHTO dimensions (where applicable). Note that the data for intercity/highway buses are based on typical dimensions from vehicle manufacturers. The dimensions are generally comparable to the MoU specifications for intercity buses.

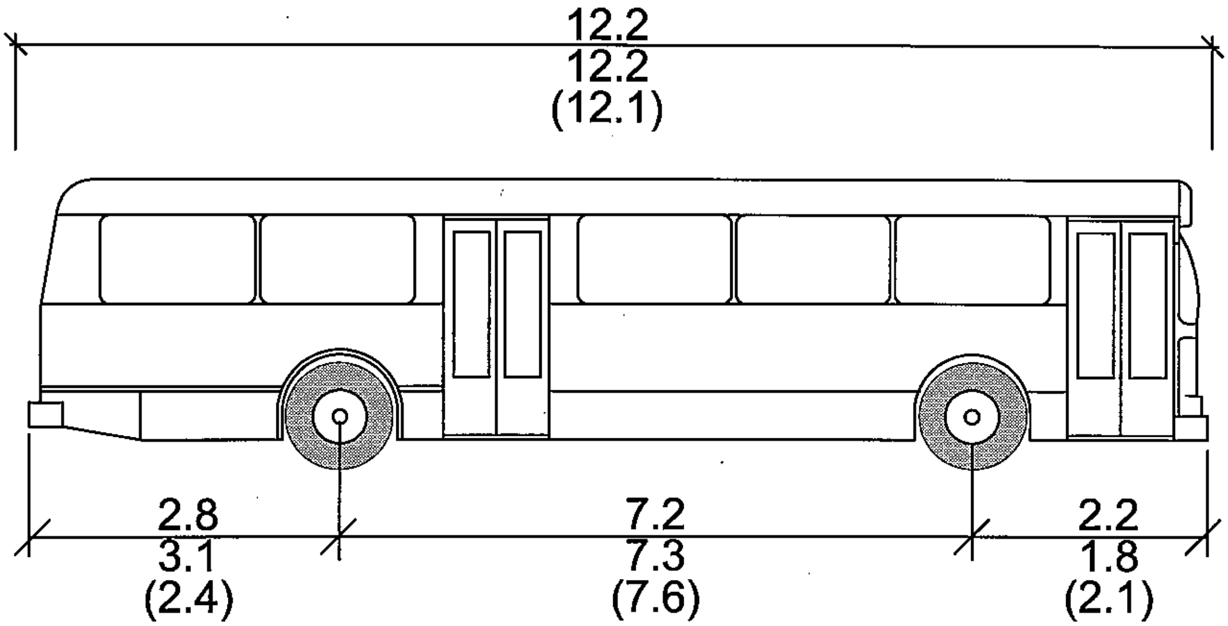
The minimum turning radii (95th percentile levels) were 12.9 m for single-unit buses and 13.1 m for articulated buses. Typical data for intercity/highway buses indicated a minimum turning radius of 13.9 m.

TABLE 6.3
PROPOSED DESIGN DIMENSIONS FOR BUSES

Dimension (m)	Single-Unit Buses	Articulated Buses	Intercity/Highway Buses
Length (m)	12.2	18.3	14.0
Front Overhang (m)	2.8	3.2	1.8
Rear Overhang (m)	2.2	3.0	4.0
WB1 (m)	7.2	5.5	8.2
S[a] (m)	-	1.8	-
T[b] (m)	-	4.8	-

Notes: [a]*Distance from the rear effective axle to the hitch point.*
[b]*Distance from the hitch point to the lead effective axle of the following unit.*

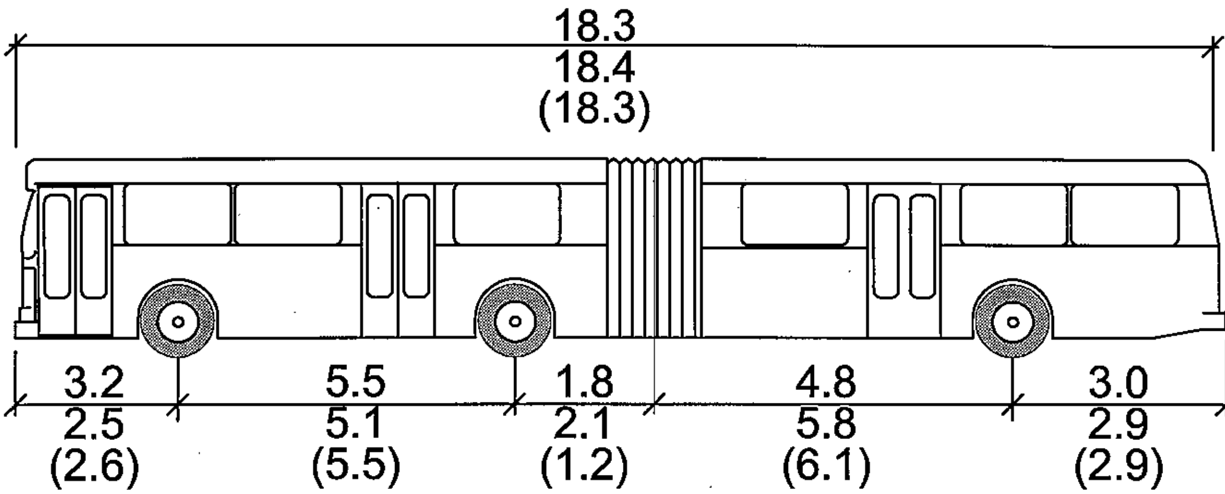
FIGURE 6.10
STANDARD SINGLE-UNIT BUS DIMENSIONS



LEGEND: *Proposed dimensions*
TAC Design Vehicle
(AASHTO Vehicle)

Notes: *All dimensions are in metres*
Figure not to scale.

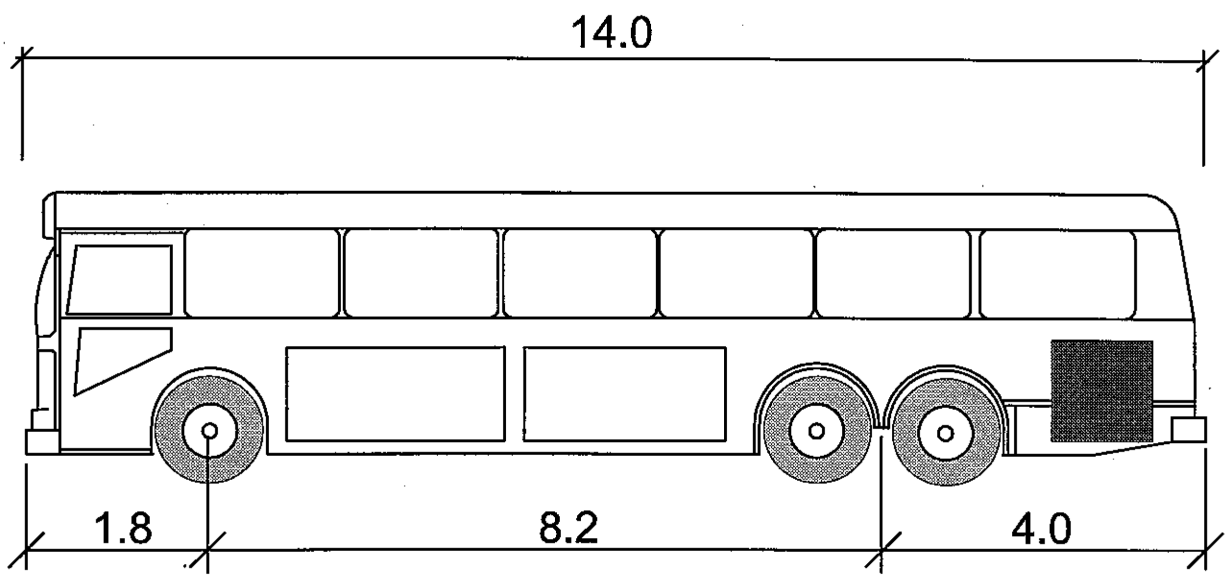
FIGURE 6.11
ARTICULATED BUS DIMENSIONS



LEGEND: *Proposed dimensions*
TAC Design Vehicle
(AASHTO Vehicle)

Notes: *All dimensions are in metres*
Figure not to scale.

FIGURE 6.12
INTERCITY BUS DIMENSIONS



LEGEND: <u>*Proposed dimensions*</u>
TAC Design Vehicle - N/A
(AASHTO Vehicle -N/A)

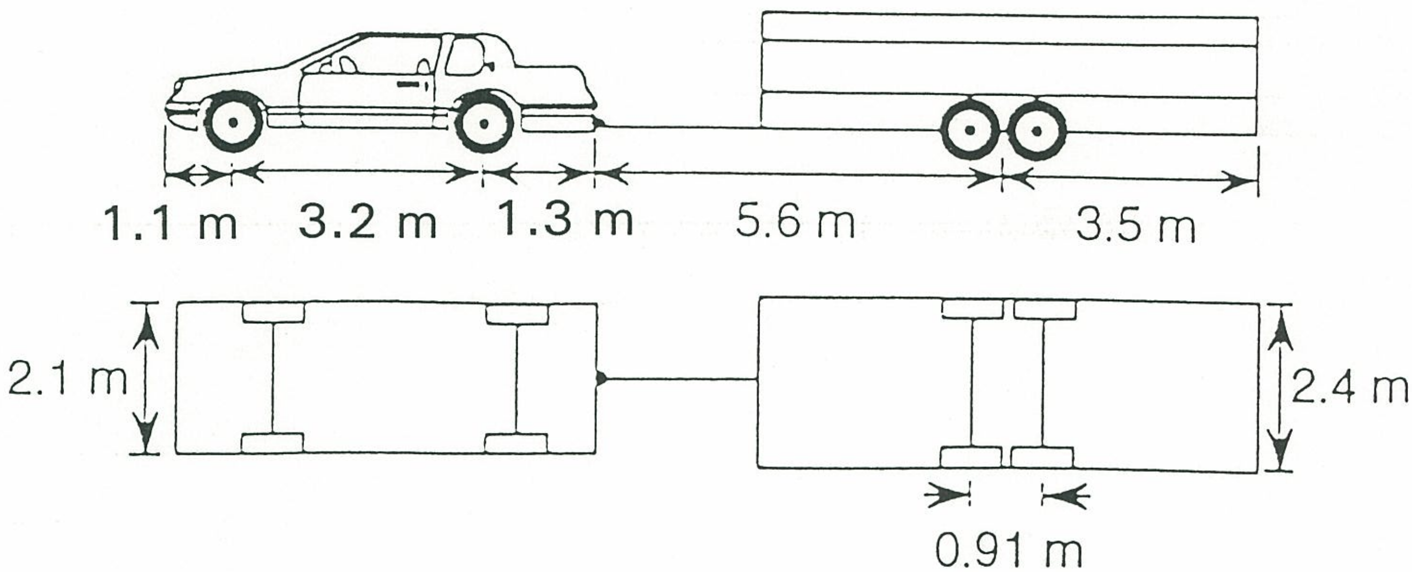
<u>*Notes:*</u> *All dimensions are in metres*
Figure not to scale.

6.4 FUTURE WORK

Design vehicle dimensions have a direct impact on a number of geometric design issues, such as clearances and turning road/ramp widths. The dimensions established in this study will need to be considered in future works related to the update of the TAC Geometric Design Guide for Canadian Roads. Additional work will be required to apply these dimensions to develop control templates for 'best-fit' curves in turning roadway/ramp design.

APPENDIX A

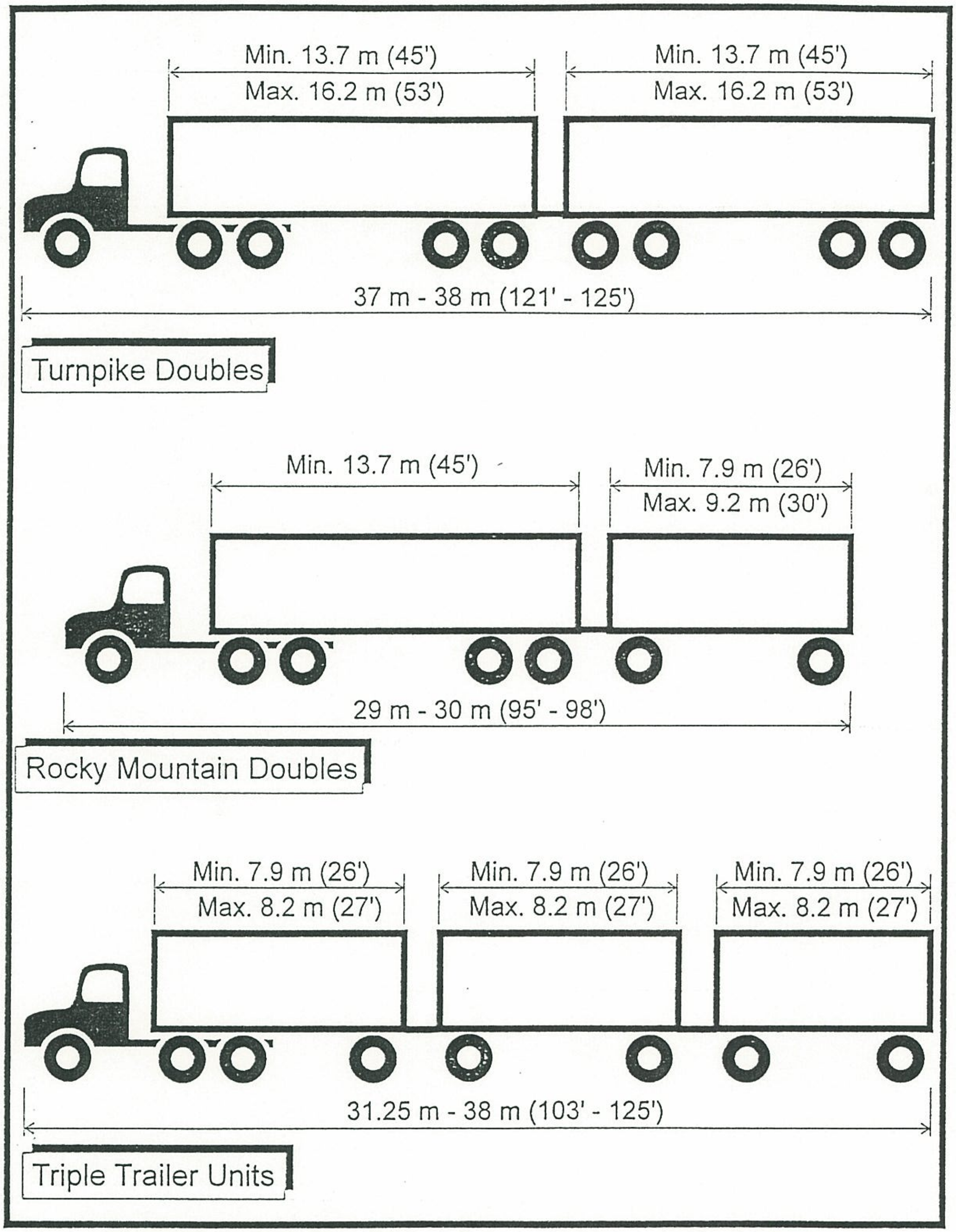
TYPICAL DIMENSIONS FOR "SPECIAL VEHICLES"



TYPICAL DIMENSIONS FOR A CAR/RECREATIONAL TRAILER

<u>Source:</u>

"Car/RT" vehicle from the TAC Vehicle Turning Vehicle Template Package, with the passenger car dimensions revised to reflect findings from this study.



COMMON LONG TRUCK CONFIGURATIONS
Source: "Long Truck Activity in Canada", Canadian Trucking Research Institute, 1995.

LONG TRUCK CONFIGURATIONS - WEIGHTS AND DIMENSIONAL REGULATIONS

Source: "Long Truck Activity in Canada", Canadian Trucking Research Institute, 1995.

(lengths in metres; weight in tonnes; distances in kilometres)

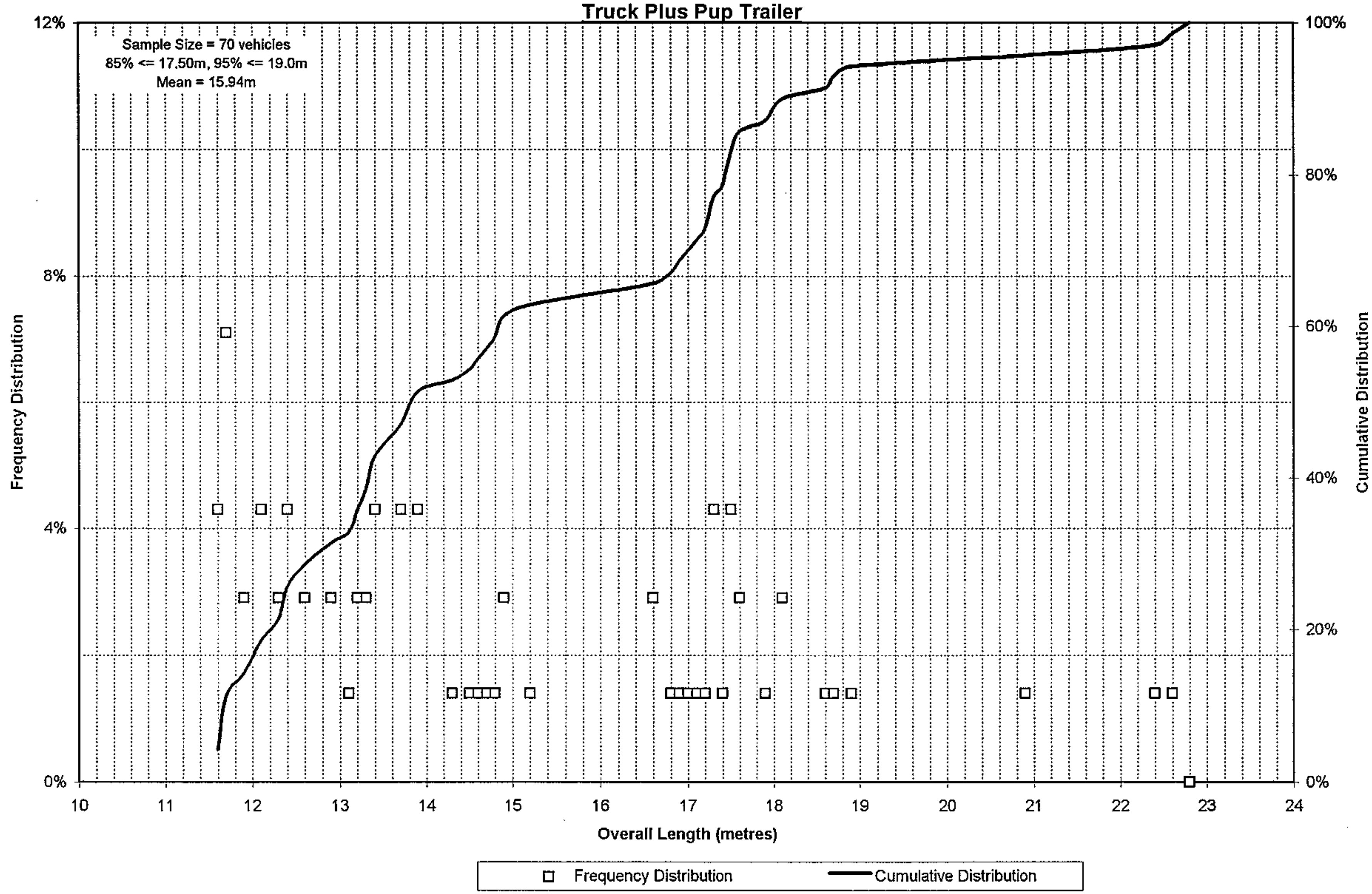
	Québec	Manitoba[1]	Saskatchewan	Alberta	NWT
Rocky Mountain doubles		[2]	[2]	[2]	[5]
Length					
- overall	NR	29	29	30	29
- trailers (max)	14.65 + 8.6	14.6 + 8.5	16.2 + 9.2	16.2	15.2
- trailers (min)	8.0		13.7 + 7.9	lead[4] 12.2	8.2
GVW					
A-train	62.5	56.5	52.0	53.5	[5]
B-train	62.5	56.5	62.5	62.5	62.5[5]
C-train	62.5	56.5	60.5	60.5	
Route Distance	? 2,200	? 691	4,180	4,200	259
Turnpike doubles					NP
Length					
- overall	NR	37	38	37	
- trailers (max)	14.65	16.2	16.2	16.2	
- trailers (min)	8.0	12.2	13.7	12.2	
GVW					
A-train	62.5	62.5	62.5	62.5	
B-train	62.5	62.5	62.5	62.5	
C-train	62.5	62.5	60.5	62.5	
Route Distance	? 2,200	783	665	1,600	
Triples			[3]		NP
Length					
- overall	NR	31.25	38	35	
- trailers (max)	8.6	8.6	9.2	NR[4]	
- trailers (min)	8.0		7.9	NR[4]	
GVW					
A-train	62.5	56.5	NP	53.5	
B-train	62.5	56.5	53.5	53.5	
C-train	62.5	56.5	53.5	53.5	
Route Distance	? 2,200	783	665	1,600	

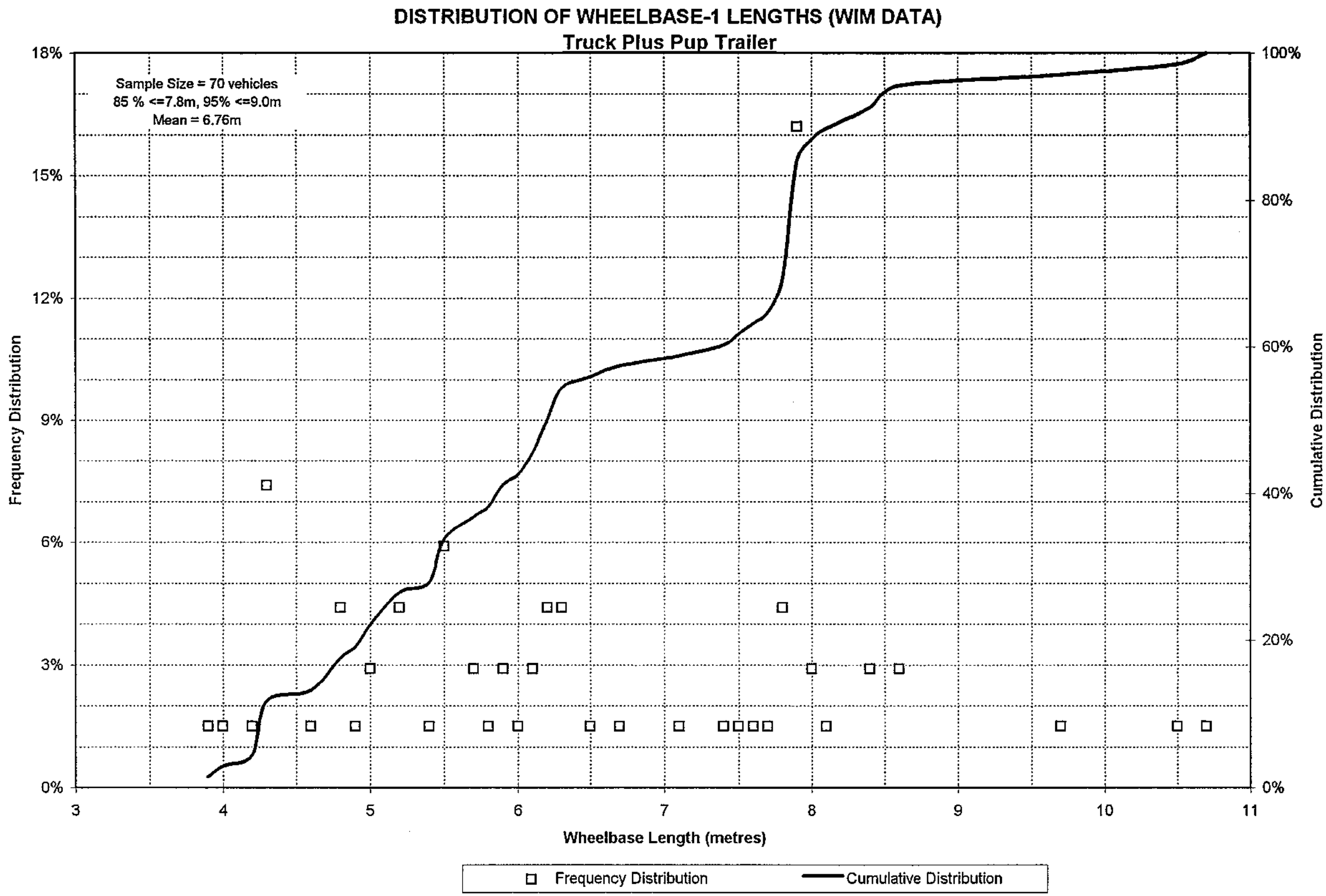
Notes:

"NR" = not regulated; "NP" = not permitted; "?" estimated or not known

1. Permit conditions in Manitoba were being revised as this chart was drawn up. It is understood that the new regulations are similar to those in Alberta.
2. Also allows "Reverse Rocky Mountain doubles" (ie, short + long trailer)
3. Also allows "Queen city triples" (long trailer + two pups)
4. Alta has replaced trailer length limits (min/max) with minimum (6.25 m) wheelbase limits.
5. As a matter of policy, NWT also allows any RMD that is legal in Alta into the territory

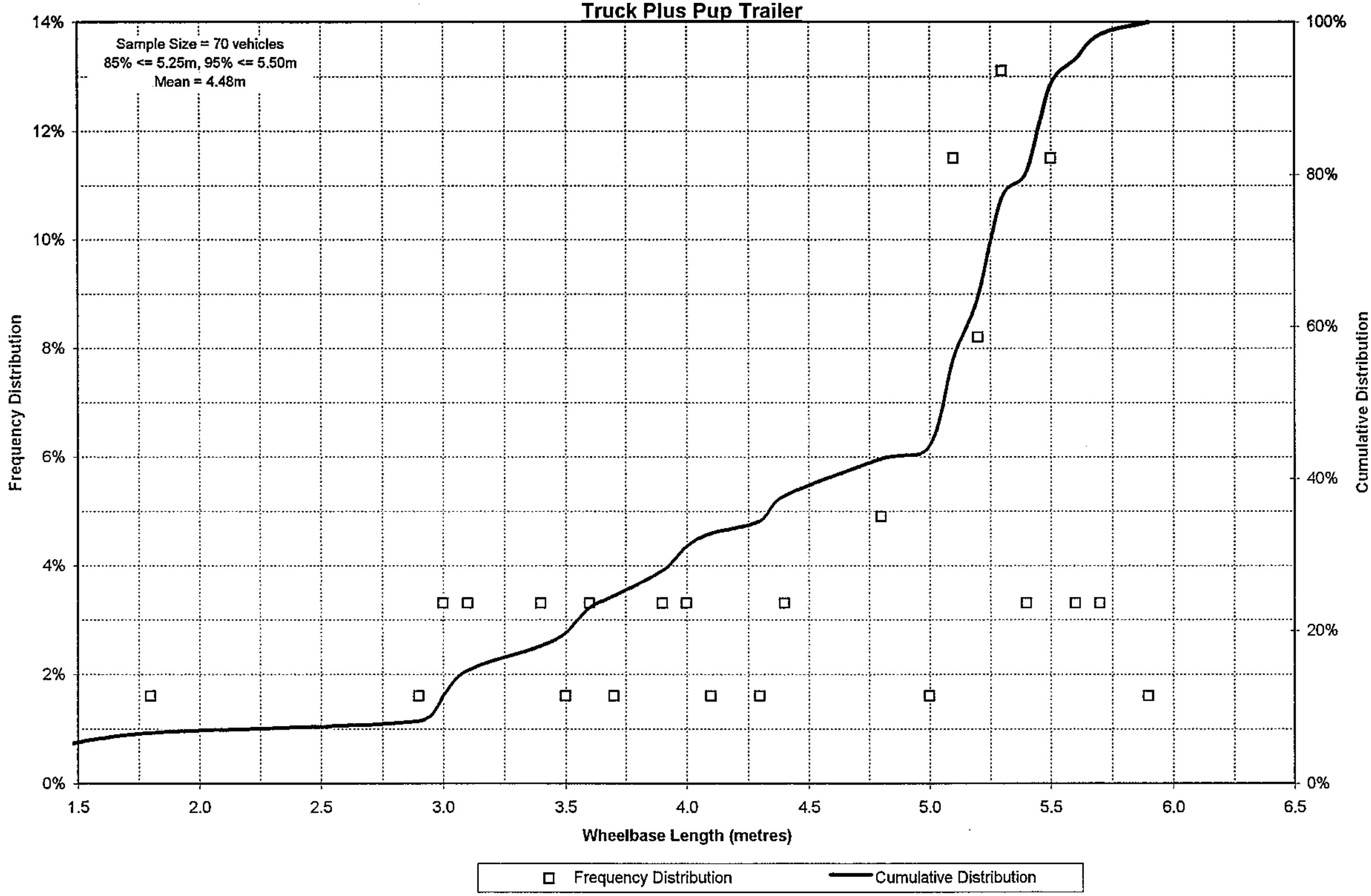
DISTRIBUTION OF OVERALL LENGTHS (WIM DATA)
Truck Plus Pup Trailer





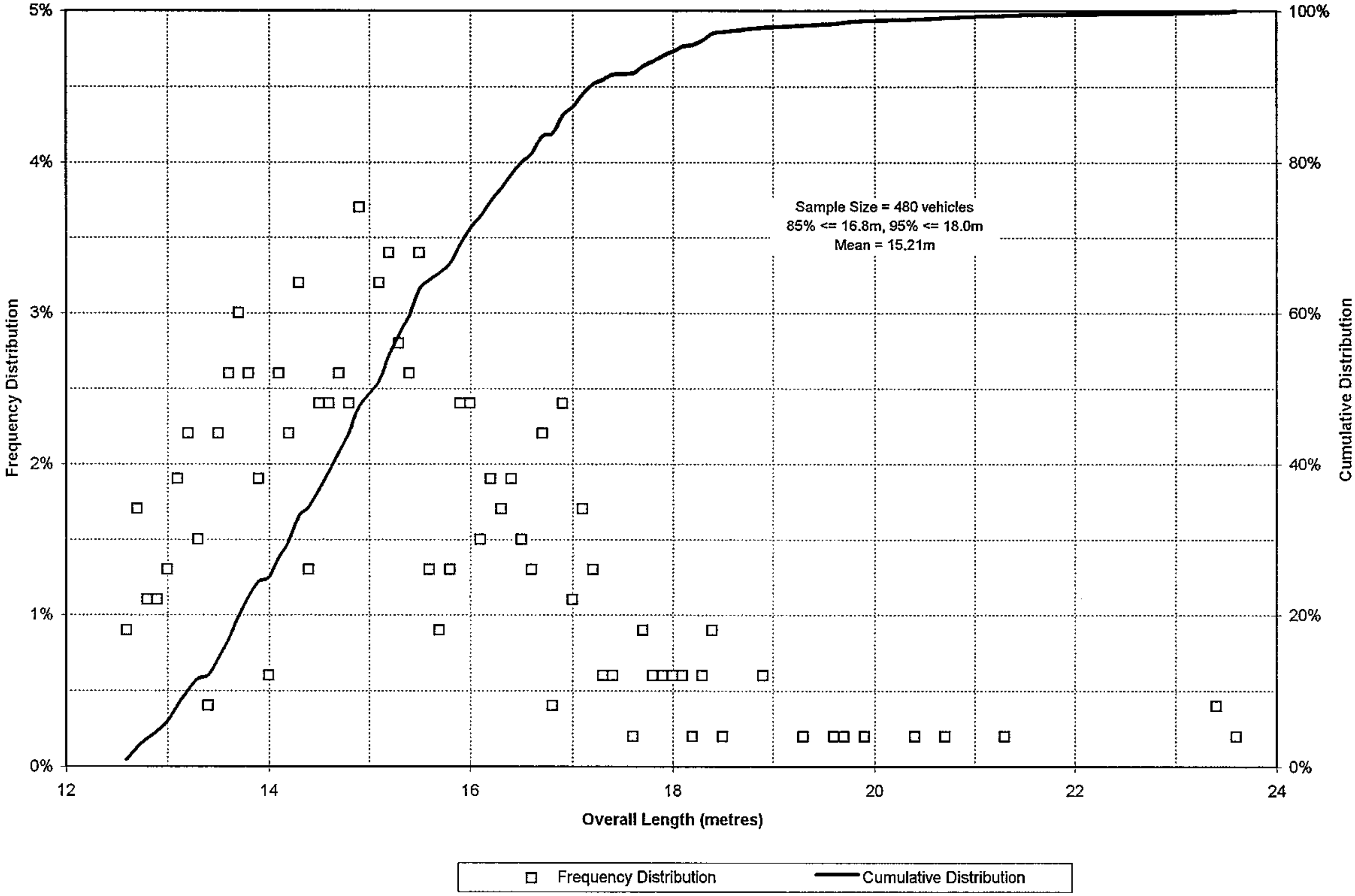
DISTRIBUTION OF WHEELBASE-1 LENGTHS (WIM DATA)
Truck Plus Pup Trailer
Sample Size = 70 vehicles
85 % <=7.8m, 95% <=9.0m
Mean = 6.76m
18%
15%
12%
9%
6%
3%
0%
Frequency Distribution
100%
80%
60%
40%
20%
0%
Cumulative Distribution
3
4
5
6
7
8
9
10
11
Wheelbase Length (metres)
Frequency Distribution
Cumulative Distribution

DISTRIBUTION OF WHEELBASE-2 LENGTHS (WIM DATA)
Truck Plus Pup Trailer

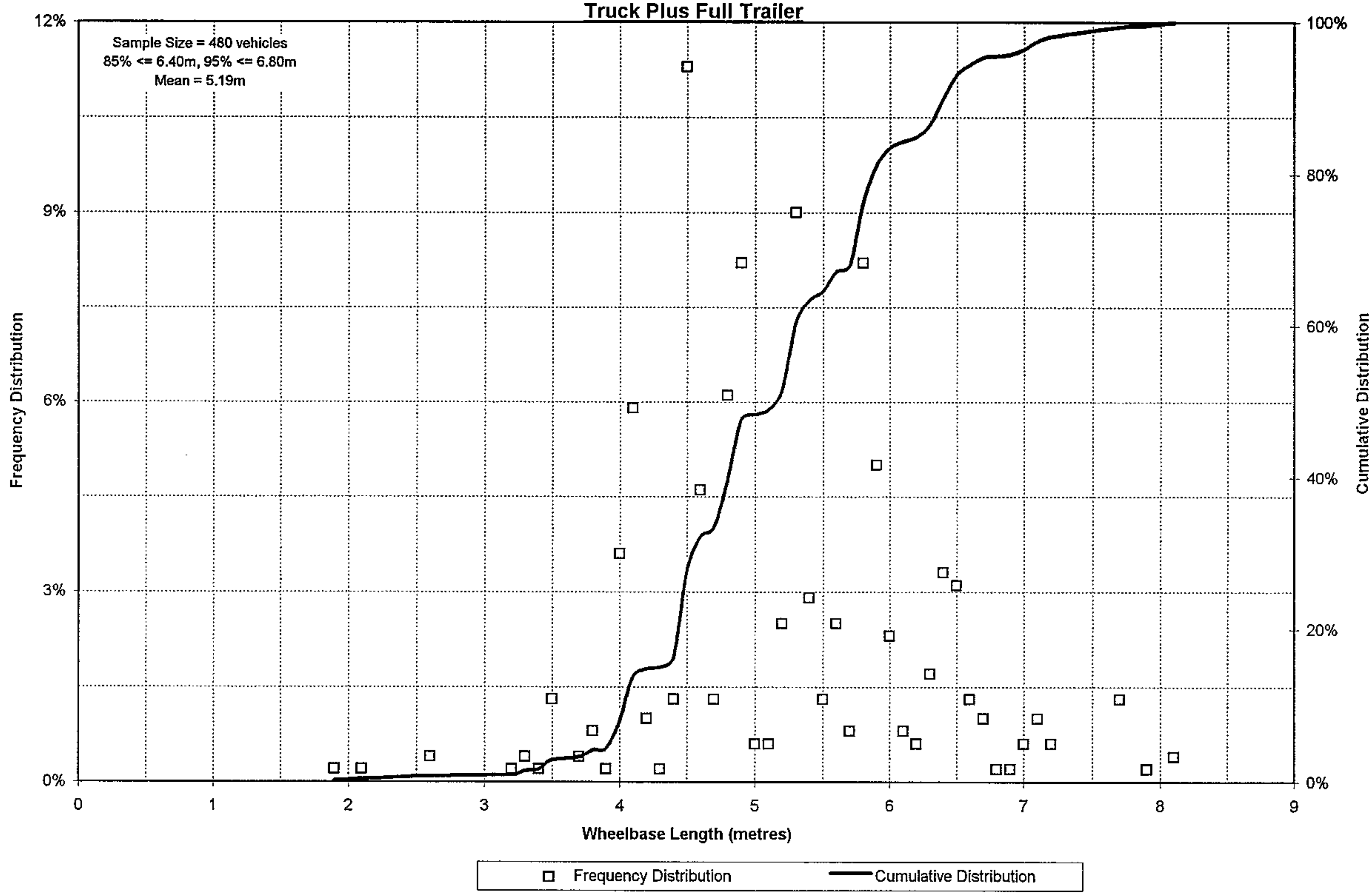


DISTRIBUTION OF OVERALL LENGTHS (WIM DATA)

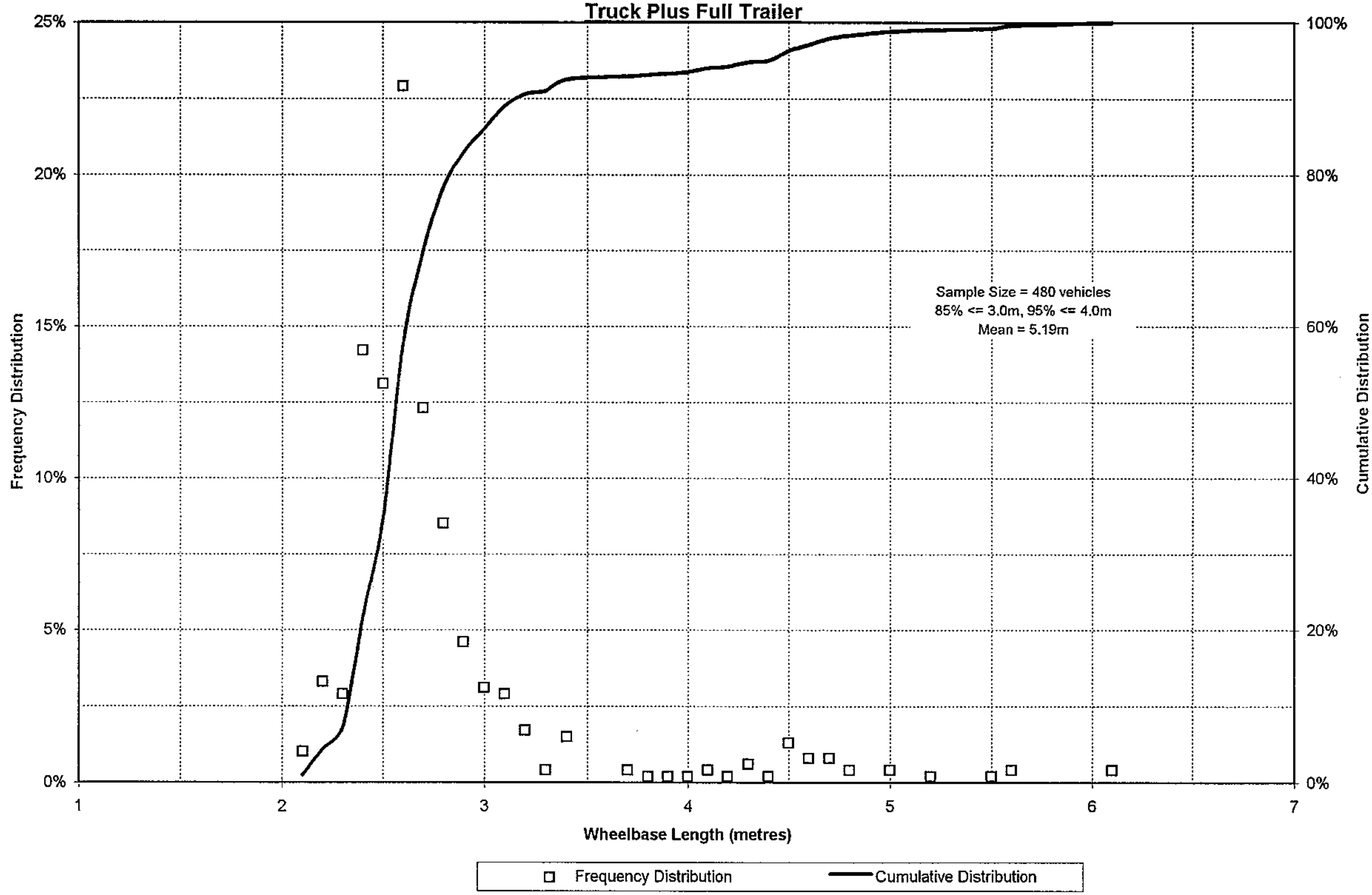
Truck Plus Full Trailer



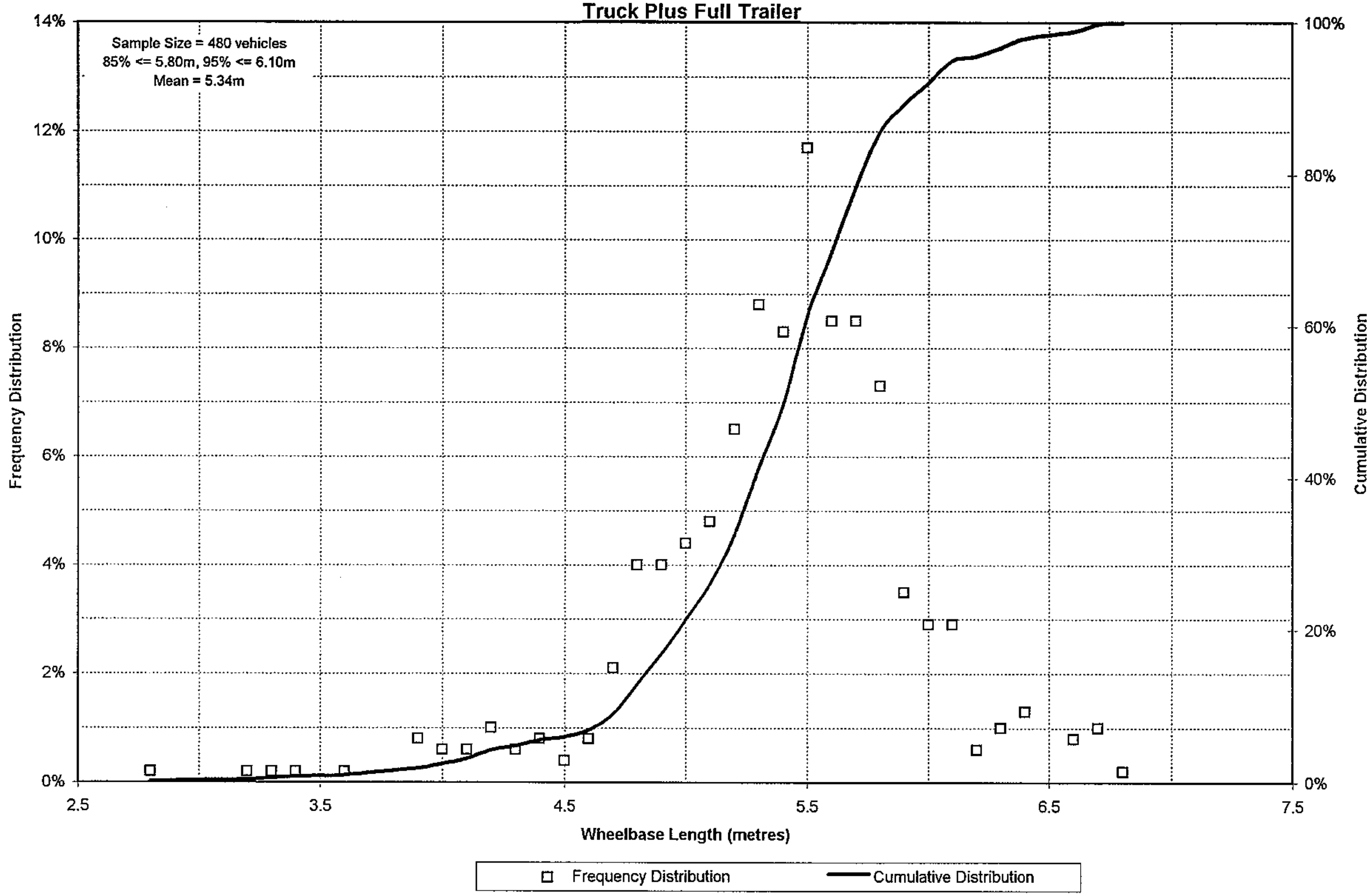
DISTRIBUTION OF WHEELBASE-1 LENGTHS (WIM DATA)
Truck Plus Full Trailer



DISTRIBUTION OF WHEELBASE-2 LENGTHS (WIM DATA)
Truck Plus Full Trailer



DISTRIBUTION OF WHEELBASE-3 LENGTHS (WIM DATA)
Truck Plus Full Trailer

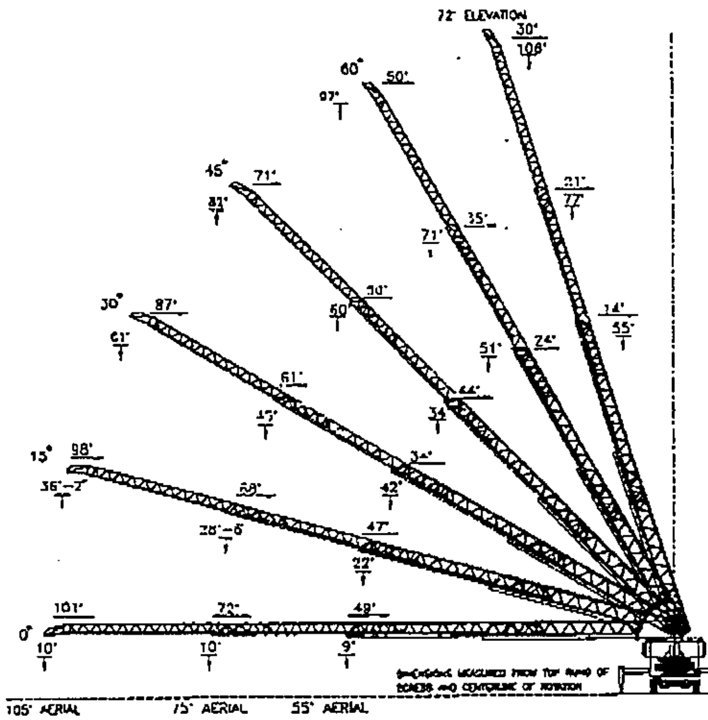


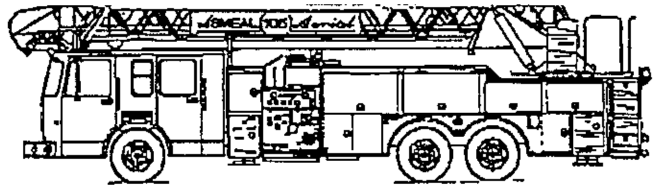
TYPICAL FIRE APPARATUS DIMENSIONS

Source: Contact with North York (Ontario) Fire Department

	Dimensions (metres)						
Unit	Length	Wheelbase	Width	Height	Front Overhang	Rear Overhang	Min. Turning Radius
Rescue Unit	8.8	5.1	2.5	3.6	1.8	1.7	18.9
Aerial Unit	15.2	5.6	2.5	3.6	1.8	2.3	25.0

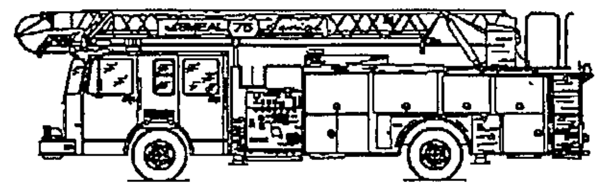
SMEAL AERIAL LADDERS





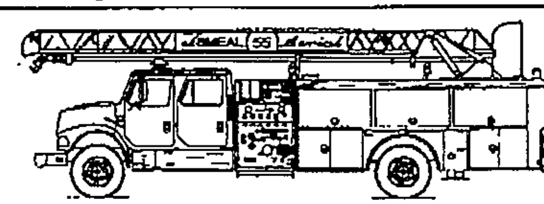
Four Section Aerial Quint with Custom Chassis

Standard Overall Length: 43'1" — Horizontal Reach: 100'
Overall Height: 126" to 142" — Working Height: 105'
Wheelbase: 210" to 240"
Axle Ratings: Front - 18,000 to 21,500 lbs., Rear - 38,000 to 44,000 lbs.



Three Section Aerial Quint with Custom or Commercial Chassis

Standard Overall Length: 37'4" — Horizontal Reach: 70'
Overall Height: 119" to 133" — Working Height: 75'
Custom Wheelbase: 200" to 220" — Commercial Wheelbase: 235" to 256"
Axle Ratings: Front - 14,000 to 21,000 lbs., Rear Single - 27,000 lbs.
Tag/Tandem - 34,000 lbs.

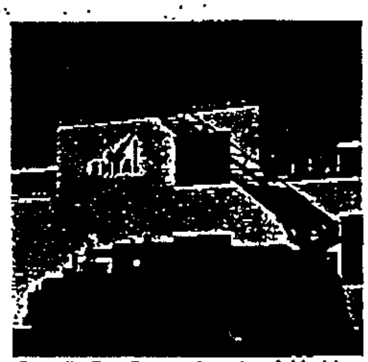


Two Section Aerial Quint with Custom or Commercial Chassis

Standard Overall Length: 33'10" — Horizontal Reach: 50'
Overall Height: 128" to 132" — Working Height: 55'
Commercial Wheelbase: 235" to 252" — Custom Wheelbase: 185" to 205"
Axle Ratings: Front - 14,000 to 18,000 lbs., Rear - 27,000 to 31,000 lbs.

The Story of Smeal

When Don Smeal opened his welding shop in 1955, his plan was to find a product that he could make and market from his hometown in Snyder, Nebraska. By 1963 he had designed several products that were selling on a regional and national level. It was then that the Snyder rural fire board approached Don to repair a leak in the volunteer department's fire truck. Don, being a volunteer himself, knew something about the needs of fire fighters. He recommended that the board buy a new chassis and he would build a fire truck that would be like no other. The new truck he designed had a tank, a pump, a totally enclosed six passenger crew cab and a 42' two section hydraulic aerial ladder. Now, this was innovation. No one had seen anything like it. Soon other towns were calling Smeal to bid their fire trucks and thus began Smeal's entry into the fire truck industry.



Smeal's first fire truck and aerial ladder.

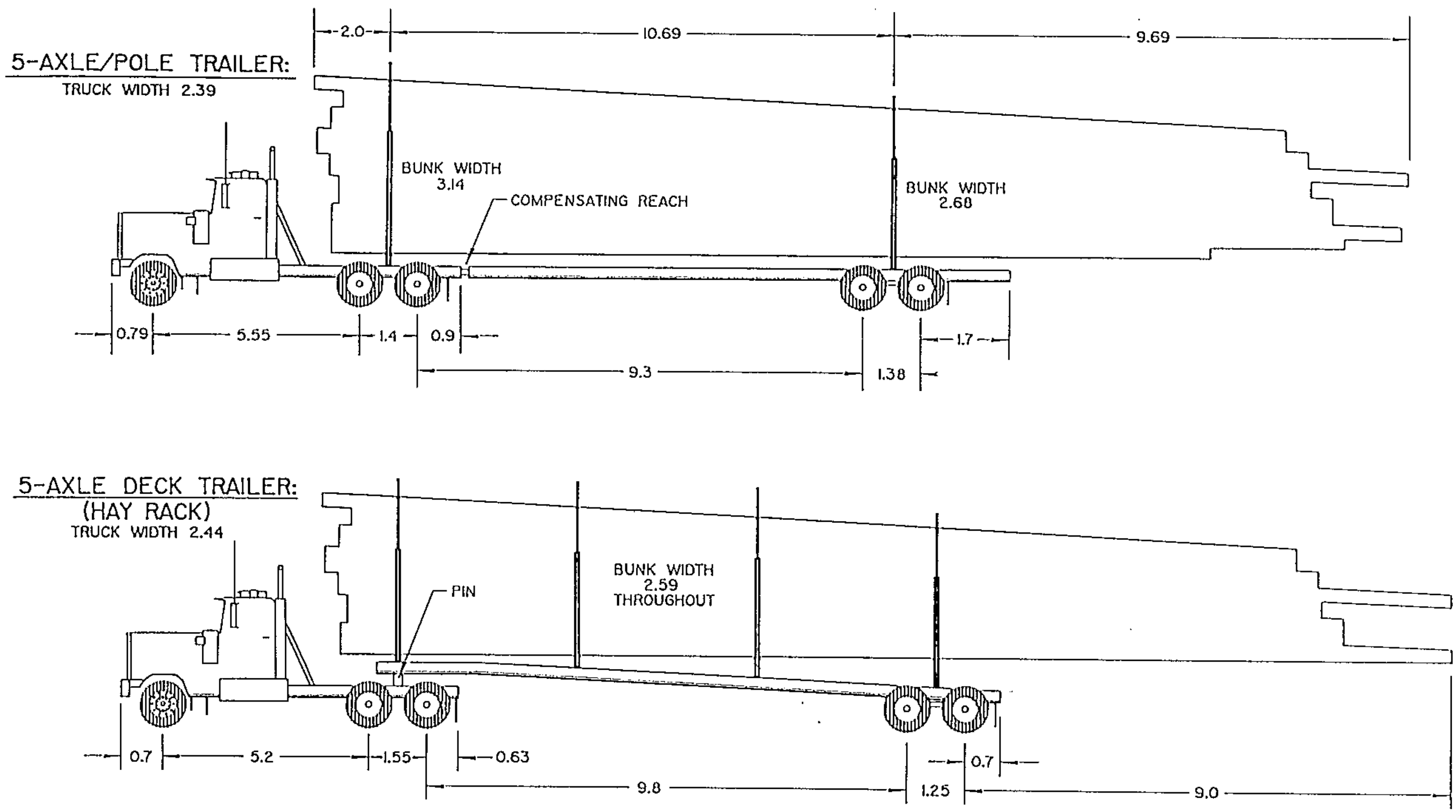
Fire trucks are not the only successful product that Don has designed and marketed. The name Smeal is on over 6,000 water well service rigs used throughout the United States and in 35 foreign countries. Smeal products are recognized worldwide for excellent engineering and quality workmanship. In fact, that first aerial ladder built over 30 years ago is still serving Snyder and the surrounding communities. Don's shop has grown in size to over 200,000 sq. ft. and there are now three Smeal generations in-house working together to carry on the hometown values.

The Smeal Plant: Over four acres under roof.

Don started a tradition with his first fire truck that is incorporated in every truck Smeal sells — we build it as if we were building it for ourselves.

smeal

P.O. BOX 8 • HIGHWAY 91 WEST • SNYDER, NEBRASKA 68664 • 402-568-2224 FAX 402-568-2346



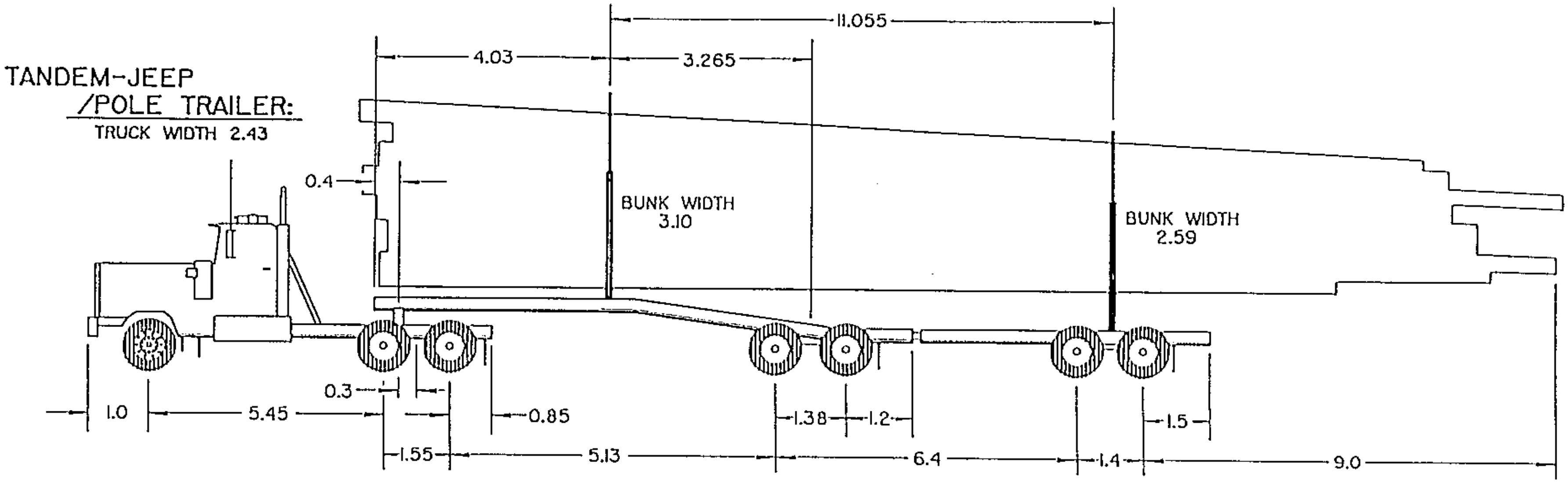
TRUCKS USED IN FIELD TEST

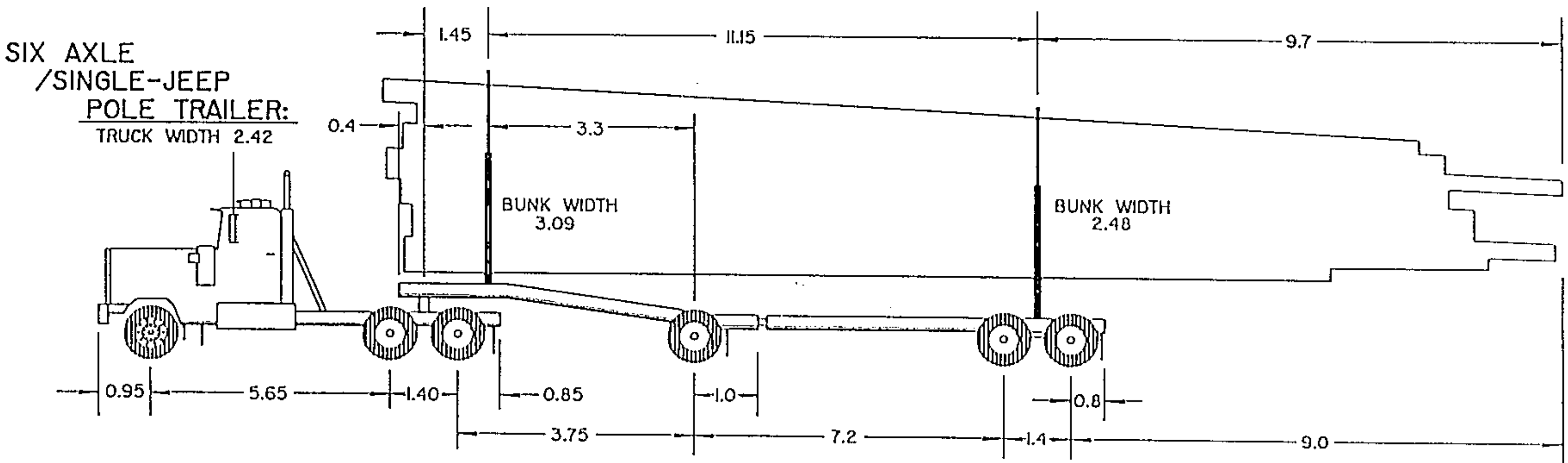
FELIX JESUALEXANDER

Drafting By: Cgk. OCT. 13, 1992

Alberta TRANSPORTATION AND UTILITIES Engineering Division

GRAPHICS FILE: del:[200,221]agreport.dgn





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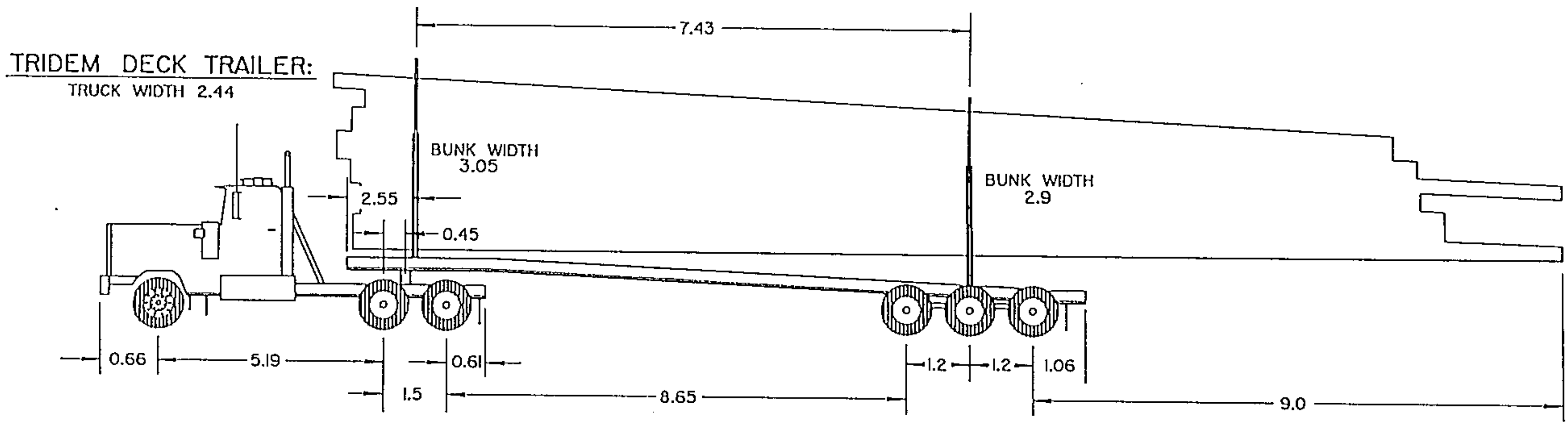

TRUCKS USED IN FIELD TEST

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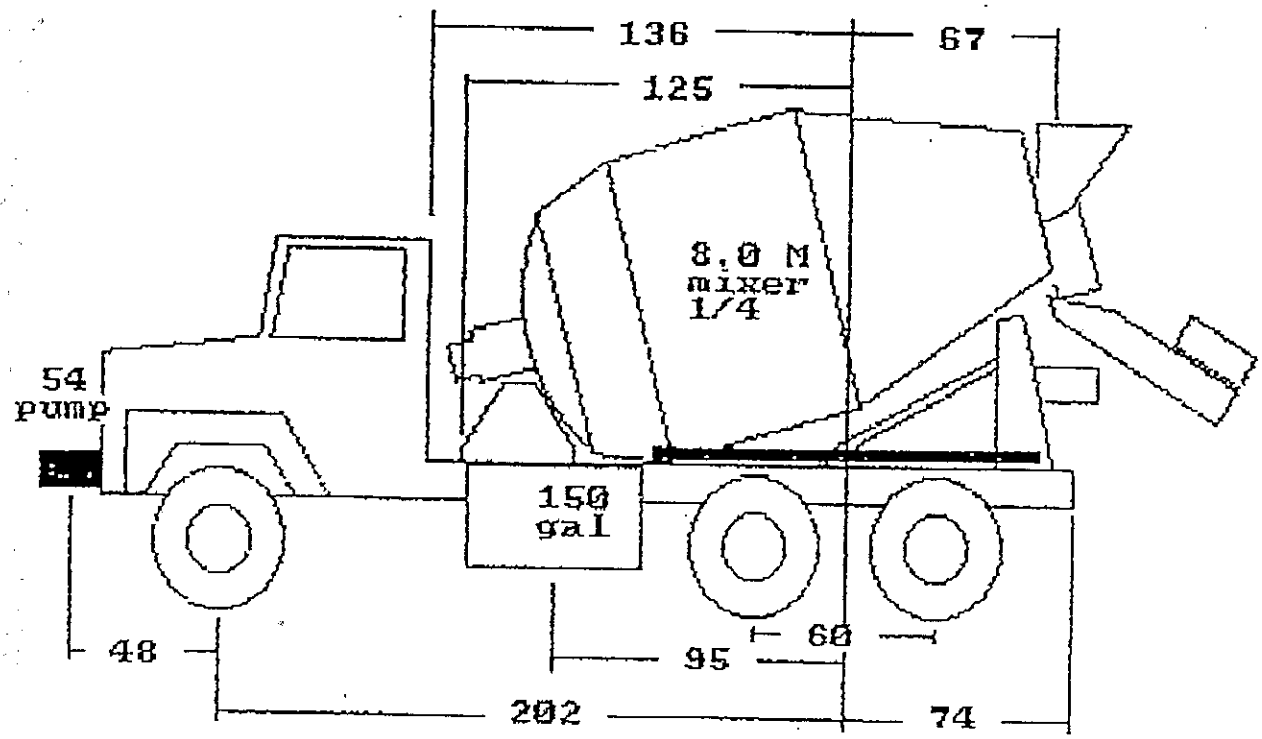
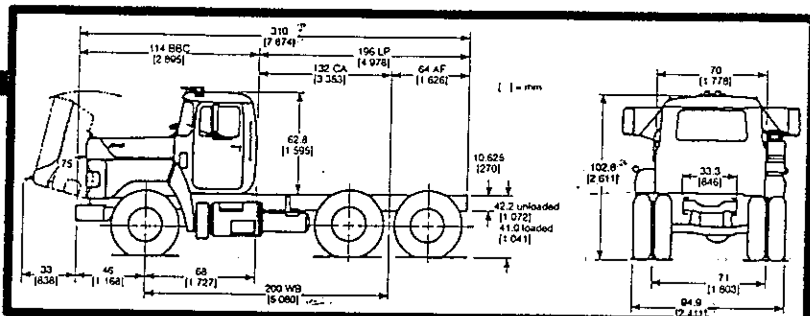


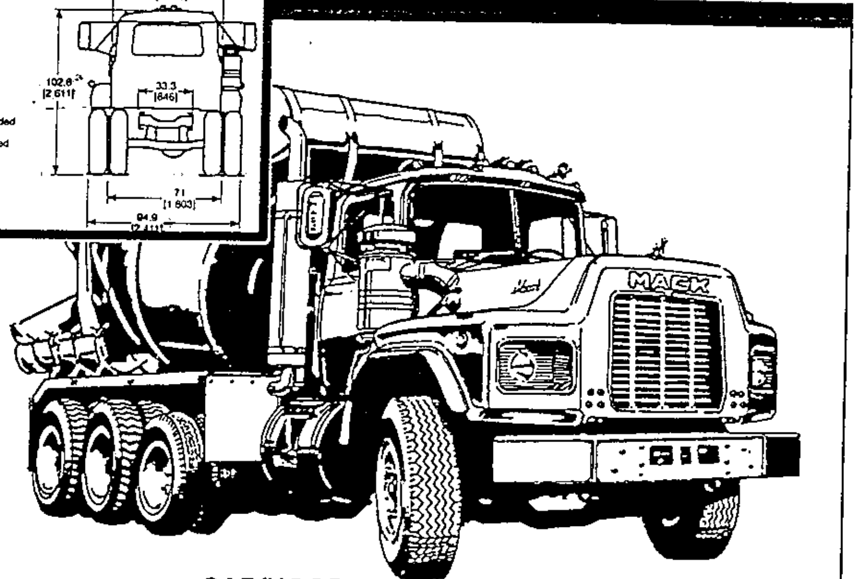
TYPICAL CONCRETE DIMENSIONS (inches)
Source: Mack Trucks

MACK®

CHASSIS

RB600S
SERIES





STANDARD SPECIFICATIONS
(Based on Model RB690S 6x4 Truck)

ENGINE
MACK EM7–300 (CMCAC)
- Horsepower, 300 HP [224 kW] at 1750 Gov. RPM
- *Peak Horsepower, 310 HP [231 kW] @ 1500 RPM*
- Max. Torque, 1425 lb/ft. [1 932 N•m] at 1020 RPM
- Lube Oil System, Full Flow ESI
  - Extended Service Interval 16,000 Miles [25 749 km]
  - Centri–Max® Centrifugal Oil Filter
- Flywheel Housing, Aluminum
- Silicone Hoses and Tubing on Engine
- Air Compressor, 13.2 cfm [6.3 l/s] min. rtg.

Starting System
- *Starter*, 12–Volt
- Batteries, (2) 12–Volt 925 CCA each
- *Alternator*, 12V 100A, Delco (21 SI)

Air Intake System
- Air Cleaner, 13" [330 mm] Single Element
  - Dry Type, External Cowl Mtd.
- Air Restriction Monitor, Grad. Lock Up Type
  - (Air Cleaner Mounted)
- *Exhaust*, Vertical (Includes Heat Shield)

Cooling System – Shutterless Type
- Radiator, 1,050 sq. in. [6 775 cm^2] Frontal Area
- Anti–Freeze to –10°F [–23°C]
- Fan Drive, Viscous
- Hoses, Heater & Radiator, Silicone
- Coolant Conditioner, Spin–on

CLUTCH
CL798, SPICER, 15.5" [394 mm] Ceramic
Dampened Disc, 2–plate, Coaxial Spring

TRANSMISSION
MACK T2060 6–speed
- Ratios: 9.02 Low – 0.60 High
- P.T.O. Side Gears (RH & LH)
- *Driveline:* Dana (Spicer) 1710 HD Main & 1710 HD Interaxle w/Coated Splines

CAB/HOOD
CAB CA49
- Conventional

Interior Features

Basic: Trim Level II
- Color, Silver Gray
- Ash Tray
- Cigar Lighter
- CB – 5–way Binding Posts
- Coat Hook
- Dispatch Box
- Overhead Console Including:
  - Location for Opt. Radio
- Air Conditioner (Red Dot) w/Integral Heater
- Dome Light w/Self–Contained Switch
- Adjustable Steering Column
- Seats:
  - Driver's, Bostrom 914, Air Susp. (Lo–Back)
  - Rider's, MACK, Non–Suspension (Lo–Back)
- Seat Belts – Driver's and Rider's
  - Lap & Shoulder w/Seat Belt Retractor & "Komfort Latch"
- Sun Visor – LH & RH
- Floor Mats, Rubber w/Closed Cell Vinyl Nitrile Backing

Operational
- T.M.C. Recommended Instrument Panel
- Air Pressure Gauge
- Voltmeter
- Fuel Level Gauge
- Engine Protecrion Alarm System (Kysor)
- Engine Oil Pressure Gauge
- Engine Coolant Temperature Gauge
- Low Air Pressure Indicator (Light and Buzzer)
- Speedometer/Trip Odometer, Electronic
- Tachometer w/Hourmeter, Electronic
- High Beam Indicator
- Parking Brake On Indicator
- Key Type Starting
- Hand Throttle Control
- Engine Shutoff, Pull–Type Control
- Courtesy Light Switch (Head & Clearance)
- Directional Signal Switch, Manual Cancelling

RB600S

CAB/HOOD (continued)

Exterior Features

Basic:
- Welded Steel Shell, Galvanized
- Mack Rust Preventative Procedures
- Vents (Screened)
  - Cowl – LH One Way Type
    - – Upper Fresh Air Inlet for Heater
  - Roof – Two Way Type
- Cab Step RH – Frame Mtd.
- Safety Glass Windows
- Tinted Windshield, Side & Rear Glass
- Windshield Wipers – Two, Fixed Arm & Blade Type
- Wiper Motor (Electric), (1), Two Speed
- Windshield Washers, Electric, Wiper Mtd. with 5 qt. [4.7 L] Reservoir
- Mirrors, West Coast Bulldog Bright Finish, RH & LH w/ Stainless Steel Arms & Brackets
- Headlamps, (2) Conventional Sealed Beam Type (7" [178 mm] Round)
- Daytime Running Lights (Canada Only)
- Identification and Clearance Lamps (5)
- Side Markers – Lamps and Reflectors
- Front Turn Signals
- 4–Way Flashers
- Horns, Air, MACK Rectangular Single Trumpet & Electric, (Single Tone)
- Doors – Galvanized Steel with:
  - Roll–Up & Vent Windows
- Grab Handles (Stainless Steel), RH & LH Behind Door
- Cab Mounting:
  - Trunion Front, Air Suspended Rear
- Hood and Fenders:
  - One Piece Fiberglass with Wheel Splash Aprons
  - Tilts Forward 75°
- Stainless Steel Grille (Heat Exchanger Mtd.)
- Rubber Fender Extensions

FRAME

WB – Wheelbase – 200" [5 080 mm]

LP – Load Platform – 196" [4 978 mm]
- CA – Cab to Axle – 132" [3 353 mm]
- AF – C/L Axles to End of Frame – 64" [1 626 mm]

Frame Rails – Steel
- Cross Section, 10–5/8" x 3–1/4" x 5/16" [270 x 83 x 8 mm]
- Frame Reinforcement – Inside Rail
  - 1/4" [6mm] Straight Steel Channel
- Section Modulus – 23.6 in.^{3} [386.7 cm^3]
- RBM (per rail) – 2,600,000 lbs. in. [294 000 N•m]
- Crossmembers –
  - Behind Cab: Steel Huck Bolted, Back to Back Type
  - Behind Rear Axle: Web Channel Type

Bumper: Steel, Swept Back Channel, 92.6" x 10" [2 352 x 254 mm]
- Extended Mounting
- BBC – Bumper to Back of Cab – 114" [2 896 mm]

Towing, Eyes – 34.5" [876 mm] Spring Centers

FUEL TANKS

Steel, 24" [610 mm] Dia. Step Type

Capacity/Location, 55 gal. [208.2 L] LH

FRONT AXLE

MACK FAW12

12,000 lb. [5 400 kg] Capacity

Brakes, "S" Cam 16.5" x 5" [419 x 127 mm]
- Rockwell "Q" Brakes
- Slack Adjusters – Haldex – Automatic

Suspension, Mack Taperleaf Spring with
- 12,000 lb. [5 400 kg] Ground Load Rating
- 34.5" [876 mm] Spring Centers

FRONT AXLE (continued)

Shock Absorbers

Oil Seals

Steering, Sheppard 392S, Integral Power, Ratio 16.6:1

Wheel Equipment, Cast Spoke

Rim, 8.25" [210 mm]

REAR AXLE

MACK SS38, 38,000 lb. [17 200 kg] Capacity Axle,

Carrier – Malleable – CRDPC92/CRD93

Ratio: 5.73

Suspension – Mack 38,000 lb. [17 200 kg] Capacity
- Camelback Spring, Anti–Sway Type
- 50" [1 270 mm] Axle Wheelbase

Oil Seals

Brakes – "S" Cam 16.5" x 7" [419 x 178 mm]
- Rockwell "Q" Brakes
- Slack Adjusters – Haldex – Automatic
- Aux. Spring Brake Chambers
  - Double Diaphragm Type, Mechanical Spring Release
  - 4 Units, 2 Mtd. Each Axle

Wheel Equipment, Cast Spoke

Rim, 8.25" [210mm]

TIRES

Front (singles)	*Size*	11R22.5 14 Ply
	Tread	Unisteel G159
	Vendor	Goodyear
Rear (Duals)	*Size*	11R22.5 14 Ply
	Tread	Unisteel G159
	Vendor	Goodyear

AIR/BRAKE

Dual Air Brake System

Air Dryer – Bendix AD–9, Heated

Air Reservoirs –
- Two, One Supply Tank Mounted Inside RH Frame Rail and One Dual Tank Compartment Primary/ Secondary Tank Mounted Under LH Frame Rail

Capacity – 5,961 in.^{3} [97.6 L]

ELECTRICAL

Aluminum Battery Box Cover – Unpainted

Chassis Electrical
- Negative Ground
- 12–Volt Electrical Circuits and Bulbs
- Circuit Breakers
- Rear Lighting, (2) Combination Stop, Tail Directional & Back–up Lights

PAINT

Cab, Hood and Fenders
- Color: Mack White, High Gloss

Chassis Running Gear
- Color: Mack Black (Water–Base)

ESTIMATED CHASSIS WEIGHT

Front – 8,436 lbs. [3 827 kg]

Rear – 7,287 lbs. [3 306 kg]

A SALES ENGINEERING PUBLICATION

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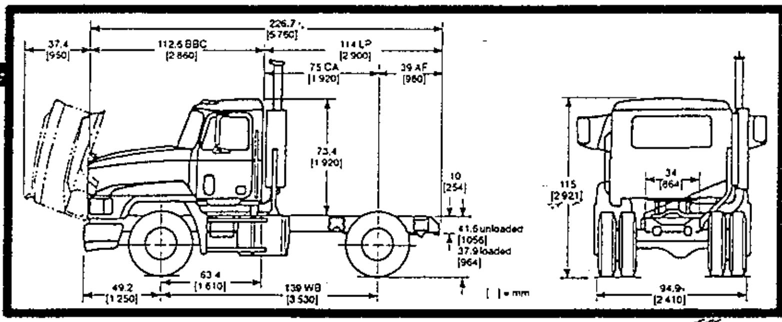
Printed in U.S.A.

MACK®

CHASSIS

CH602

SERIES



STANDARD SPECIFICATIONS

(Based on Model CH612 4x2 Tractor)

ENGINE

MACK EM7–300 V–MAC
- Horsepower, 300 HP [224 kW] at 1750 Gov. RPM
- *Peak Horsepower, 310 HP [231 kW] @ 1500 RPM*
- Max. Torque, 1425 lb/ft. [1 932 N•m] at 1020 RPM
- Lube Oil System, Full Flow ESI+
  - Extended Service Interval 25,000 Miles [40 233 km]
  - Centri–Max® Centrifugal Oil Filter
- Flywheel Housing, Aluminum
- Silicone Hoses and Tubing on Engine
- Air Compressor, 13.2 cfm [6.3 l/s] min. rtg.

Starting System
- *Starter*, 12–Volt
- Batteries, (3) Bulldog 12–Volt M/F Type, 625 CCA, Total 1875 CCA with Kalas Cables
- *Alternator*, 12V 100A, Delco (21 SI)

Air Intake System
- Air Cleaner, 11" [279 mm] Single Element
  - Dry Type, Under Hood
- Air Intake from Both Sides of Hood
- Air Restriction Monitor, Grad. Lock Up Type
  - (Air Intake Mounted)
- *Exhaust*, Vertical w/Muffler Heat Shield

Cooling System – Shutterless Type
- Radiator, 1,180 sq. in. [7 612 cm^2] Frontal Area
- Anti–Freeze to –10°F [–23°C]
- Fan Drive, Viscous
- Hoses, Heater & Radiator, Silicone
- Coolant Conditioner, Spin–on
- Coolant Recovery Tank – 6 Quart [5.7 L]

CLUTCH

CL798, SPICER, 15.5" [394 mm] Ceramic
- Dampened Disc, 2–plate, Coaxial Spring

TRANSMISSION

MACK T2090 9–speed
- Ratios: 10.69 Low – 0.71 High
- *Driveline:* Dana (Spicer) 1710 HD
  - w/Coated Splines

CAB/HOOD

CAB CA65
- Conventional
- **Interior Features**
- Basic: Economy Trim Level
  - Color, Silver Gray
  - Ash Tray
  - Cigar Lighter
  - CB – 5–way Binding Posts
  - Coat Hook
  - Dispatch Box
  - Overhead Console Including:
    - AM/FM Radio w/Cassette (w/Roof Mtd. Antenna)
  - Air Conditioner, (Red Dot) with Integral Heater
  - Dome Light w/Self–Contained Switch, "On"
    - when Driver or Rider Side Door is Open
  - Door Mounted Courtesy Lamp – "On"
    - when Driver or Rider Side Door is Open
  - Steering Wheel, 18" Dia. 2–Spoke Soft Feel
  - Adjustable Tilt Telescope Steering Column
  - Seats:
    - Driver's, Bostrom 915 (Lo–Back)
    - Rider's, Non–Suspension (Lo–Back)
  - Seat Belts – Driver's and Rider's
    - Lap & Shoulder w/Seat Belt Retractor & "Komfort Latch"
  - Sun Visor – Left Side
  - Floor Mats, Rubber w/Closed Cell Vinyl Nitrile Backing
  - **Operational**
  - T.M.C. Recommended Instrument Panel
  - Air Pressure Gauge
  - Voltmeter
  - Fuel Level Gauge
  - Engine Oil Pressure Gauge
  - Engine Coolant Temperature Gauge
  - Low Air Pressure Indicator (Light and Buzzer)
  - Speedometer/Trip Odometer, Electronic
  - Tachometer w/Hourmeter, Electronic
  - High Beam Indicator
  - Parking Brake On Indicator
  - Key Type Starting
  - Engine Shutoff, Key–Type Control
  - Courtesy Light Switch (Head & Clearance)
  - Directional Signal Switch, Manual Cancelling

CH602

CAB/HOOD (continued)
Exterior Features
Basic:
- Welded Steel Shell, Galvanized
- Mack Rust Preventative Procedures
- Fresh Air Vent LH Door
- Safety Glass Windows
- Tinted Windshield, Side and Rear Windows
- Windshield Wipers – Dual Arcuate Arms, Cowl Mtd.
- Wiper Motor (electric), (1), Two Speed
- Windshield Washers, Electric, Wiper Arm Mtd.
  with Reservoir Mounted Under Hood
- Mirrors, West Coast Bulldog Bright Finish,
  RH & LH w/ Stainless Steel Arms & Brackets
  (Brackets will accommodate 96" [2 438 mm]
  and 102' [2 591 mm] width trailers)
- Headlamps – Halogen – Single Rectangular w/ Lexan Lens
  (Replaceable Bulb) Bezel – Bright Finish (molded plastic)
  Flush Mtd., Axle Back Configuration Only
- Daytime Running Lights (Canada Only)
- Identification and Clearance Lamps (5)
- Side Markers – Lamps and Reflectors
- Front Integral Turn Signals with Fender
- 4–Way Flashers
- Horns, (2), MACK Rectangular Single Trumpet Air Horns,
  Electric, (Single Tone)
- Doors – Fiberglass with:
  - Roll–Up Windows & Vent Windows
  - Peep Window in RH Door
- Grab Handles (Stainless Steel), RH & LH Behind Door
- Rear Cab Glass (Non–Tinted)
- Cab Mounting:
  - Two Mounting Brackets at Front,
  - Air Isolation at Rear
- Hood and Fenders:
  - SMC (Sheet Molding Compound)
  - One Piece Fiberglass with Wheel Splash Aprons
  - Tilts Forward 75° with Spring Assist
- Grille – Hood Mounted Bright Finish

FRAME
WB – Wheelbase – 139" [3 530 mm]
LP – Load Platform – 114" [2 900 mm]
- CA – Cab to Axle – 75" [1 920 mm]
- AF – C/L Axles to End of Frame – 39" [980 mm]

Frame Rails – Steel
- Cross Section, 10.0" x 3.38" x .24"
  [254 x 86 x 6 mm]
- Section Modulus – 10.44 in.^{3} [171 cm^3]
- RBM (per rail) – 1,150,000 lbs. in. [130 000 N•m]
- Tapered Frame Rail Ends – 45° cut off

Bumper: Non–Metallic Flexible (Argent Color)
- Flush Mounting
- BBC – Bumper to Back of Cab – 112.6" [2 860 mm]

Towing, Clevis (2)

FUEL TANKS
- Aluminum, 25" [640 mm] Dia.
- *Capacity/Location,* 84 gal. [320 L] LH & RH

FRONT AXLE
MACK FAW12
- 12,000 lb. [5 400 kg] Capacity
- *Brakes,* "S" Cam 15" x 4"[1] [381 x 102 mm]
  - Rockwell "Q" Brakes
  - Slack Adjusters – Haldex – Automatic
- *Suspension,* Mack Taperleaf Spring with
  12,000 lb. [5 400 kg] Ground Load Rating
- Shock Absorbers
- Oil Seals
- *Steering,* Sheppard M100P or Ross TAS65, Integral Power
- *Wheel Equipment,* Steel Disc, Accuride 10–hole
- *Rim,* 8.25" [210 mm]

[1]15" x 4" [381 x 102 mm] Brakes available for Tractor Applications Only

REAR AXLE
MACK RA23,
- 23,000 lb. [10 400 kg] Capacity Axle
- *Carrier* – Malleable – CRD93A
- *Ratio:* 3.86
- *Suspension* – Mack 23,000 lb. [10 400 kg] Capacity
  Multileaf Spring
- Oil Seals
- *Brakes* – "S" Cam 16.5" x 7" [419 x 178 mm]
  - Rockwell "Q" Brakes
  - Slack Adjusters – Haldex – Automatic
  - Aux. Spring Brake Chambers
    30/30 Double Diaphragm Type,
    Mechanical Spring Release; 2 Units
- *Wheel Equipment,* Steel Disc, Accuride 10–hole
- *Rim,* 8.25" [210mm]

TIRES
Front (singles)	*Size* 295/75R22.5 14 Ply
	Tread Unisteel G159
	Vendor Goodyear
Rear (Duals)	*Size* 295/75R22.5 14 Ply
	Tread Unisteel G159
	Vendor Goodyear

AIR/BRAKE
Dual Air Brake System
Air Reservoirs –
- Two Steel, Horizontal Mtd. on RH Rail Forward
  of Fuel Tank, Primary – Single Compartment Tank,
  Supply/Secondary – Two Compartment

Capacity – 4,631 in.^{3} [75.9 L]
Air Dryer – Bendix AD–9, Heated
Cushioned Clamps on All Hoses and Wiring
Semi–Trailer Connection Package
- Air Brake Grouping
  - Chassis Mtd. Pogo Stick
  - 12–Ft. Air Hose (2)
  - Glad Hand (2)
  - Glad Hand storage Bracket
    (B.O.C. – LH – Ground Reachable)

Breakaway Safety Valve
Hand Control Valve for Trailer Brakes
Electrical Grouping
- 12–Ft. (7–Wire) Cord
- 7–Wire Plugs

ELECTRICAL
Steel Battery Box with Molded Plastic Cover Mtd.
  Forward of LH Fuel Tank
Chassis Electrical
- Negative Ground
- 12–Volt Electrical Circuits and Bulbs
- Circuit Breakers
- Rear Lighting, (2) Combination Stop,
  Tail Directional & Back–up Lights

Trailer Electrical Package for Doubles Operation

PAINT
Cab, Hood and Fenders
- Color: Mack White, High Gloss (Base/Clear)

Chassis Running Gear
- Color: Mack Black (Water–Base)

ESTIMATED CHASSIS WEIGHT
- Front – 7,742 lbs. [3 512 kg]
- Rear – 3,892 lbs. [1 766 kg]

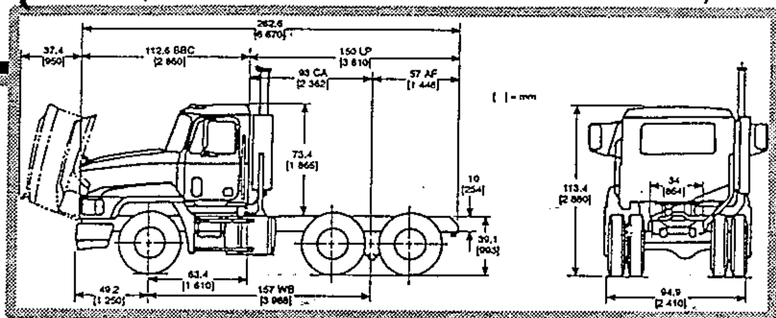
A SALES ENGINEERING PUBLICATION

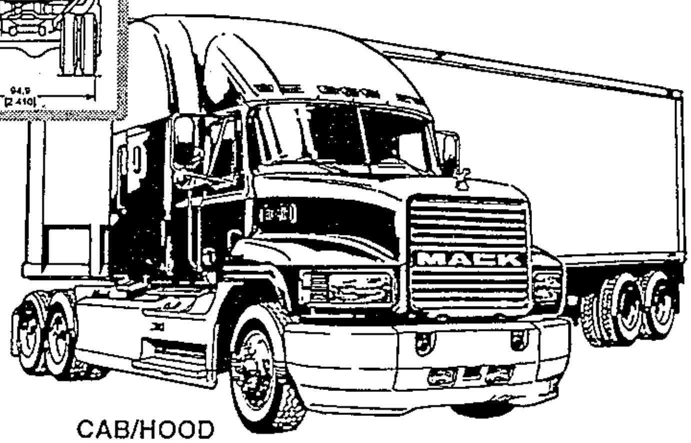
CHA049 0793 5M

Printed in U.S.A.

CONVENTIONAL
SET BACK AXLE
6–WHEEL TRACTOR
A B S (ANTI-LOCK BRAKE SYSTEM)

CH603
SERIES





STANDARD SPECIFICATIONS

▸ BVS CODE 002 0210

(Based on Model CH613 6x4 Tractor)

ENGINE

MACK EM7–300 V–MAC
- Horsepower, 300 HP [224 kW] at 1750 Gov. RPM
- *Peak Horsepower, 310 HP [231 kW] @ 1500 RPM*
- Max. Torque, 1425 lb/ft. [1 932 N•m] at 1020 RPM
- Lube Oil System, Full Flow ESI+
  - Extended Service Interval 25,000 Miles [40 233 km]
  - Centri–Max® Centrifugal Oil Filter
- Flywheel Housing, Aluminum
- Silicone Hoses and Tubing on Engine
- Air Compressor, 13.2 cfm [6.3 l/s] min. rtg. with Air Governor Mounted on Compressor

Starting System
- *Starter*, 12–Volt
- Batteries, (3) Bulldog 12–Volt M/F Type, 625 CCA, Total 1875 CCA with Kalas Cables
- *Alternator*, 12V 100A, Delco (21 SI)

Air Intake System
- Air Cleaner, 11" [279 mm] Single Element Dry Type, Under Hood
- Air Intake from Both Sides of Hood
- Air Restriction Monitor, Grad. Lock Up Type (Air Intake Mounted)
- *Exhaust*, Vertical w/Muffler Heat Shield

Cooling System – Shutterless Type
- Radiator, 1,180 sq. in. [7 612 cm²] Frontal Area
- Anti–Freeze to –10°F [–23°C]
- Fan Drive, Viscous
- Hoses, Heater & Radiator, Silicone
- Coolant Conditioner, Spin–on
- Coolant Recovery Tank – 6 Quart [5.7 L]

CLUTCH

CL798, SPICER, 15.5" [394 mm] Ceramic Dampened Disc, 2–plate, Coaxial Spring

TRANSMISSION

MACK T2090 9–speed
- Ratios: 10.69 Low – 0.71 High
- *Driveline:* Dana (Spicer) 1760 Main & 1710 HD Interaxle w/Coated Splines

CAB/HOOD

CAB CA65
- Conventional

Interior Features
- Basic: Economy Trim Level
  - Color, Silver Gray
  - Ash Tray
  - Cigar Lighter
  - CB – 5–way Binding Posts
  - Coat Hook
  - Dispatch Box
  - Overhead Console Including:
    - AM/FM Radio w/Cassette (w/Roof Mtd. Antenna)
  - Air Conditioner, (Red Dot) with Integral Heater w/ R134a Refrigerant
  - Dome Light w/Self–Contained Switch, "On" when Driver or Rider Side Door is Open
  - Door Mounted Courtesy Lamp – "On" when Driver or Rider Side Door is Open
  - Steering Wheel, 18" Dia. 2–Spoke Soft Feel
  - Adjustable Tilt Telescope Steering Column
  - Seats:
    - Driver's, Bostrom Talladega 915 (Mid–Back)
    - Rider's, Non–Suspension (Mid–Back)
  - Seat Belts – Driver's and Rider's
    - Lap & Shoulder w/Seat Belt Retractor & "Komfort Latch"
  - Sun Visor – Left Side
  - Floor Mats, Rubber w/Closed Cell Vinyl Nitrile Backing

Operational
- T.M.C. Recommended Instrument Panel
- Air Pressure Gauge
- Voltmeter
- Fuel Level Gauge
- Engine Oil Pressure Gauge
- Engine Coolant Temperature Gauge
- Low Air Pressure Indicator (Light and Buzzer)
- Speedometer/Trip Odometer, Electronic
- Tachometer w/Hourmeter, Electronic
- High Beam Indicator
- Parking Brake On Indicator
- Key Type Starting
- Engine Shutoff, Key–Type Control
- Courtesy Light Switch (Head & Clearance)
- Directional Signal Switch, Manual Cancelling

CAB/HOOD (continued)

Exterior Features

Basic:
- Welded Steel Shell, Galvanized
- Mack Rust Preventative Procedures
- Safety Glass Windows
- Tinted Windshield, Side and Rear Windows
- Windshield Wipers – Dual Arcuate Arms, Cowl Mtd.
- Wiper Motor (electric), (1), Two Speed
- Windshield Washers, Electric, Wiper Arm Mtd. with Reservoir Mounted Under Hood
- Mirrors, West Coast Bulldog Bright Finish, RH & LH w/ Stainless Steel Arms & Brackets (Brackets will accommodate 96" [2 438 mm] and 102' [2 591 mm] width trailers)
- Headlamps – Halogen – Single Rectangular w/ Lexan Lens (Replaceable Bulb) Bezel – Bright Finish (molded plastic) Flush Mtd., Axle Back Configuration Only
- Daytime Running Lights (Canada Only)
- Identification and Clearance Lamps (5)
- Side Markers – Lamps and Reflectors
- Front Integral Turn Signals with Fender
- 4–Way Flashers, Electromechanical
- Horns, (2), MACK Rectangular Single Trumpet Air Horns, Electric, (Single Tone)
- Doors – Fiberglass with:
  - Roll–Up Windows & Vent Windows
  - Peep Window in RH Door
- ▶ Grab Handles (Aluminum), RH & LH Behind Door
- Rear Cab Glass (Non–Tinted)
- Cab Mounting:
  - Two Mounting Brackets at Front, Air Isolation at Rear
- Hood and Fenders:
  - SMC (Sheet Molding Compound)
  - One Piece Fiberglass with Wheel Splash Aprons
  - Tilts Forward 75° with Spring Assist
- Grille – Hood Mounted Bright Finish

FRAME

WB – Wheelbase – 157" [3 988 mm]
LP – Load Platform – 150" [3 810 mm]
- CA – Cab to Axle – 93" [2 362 mm]
- AF – C/L Axles to End of Frame – 57" [1 448 mm]

Frame Rails – Steel
- Cross Section, 10.0" x 3.38" x .24" [254 x 86 x 6 mm]
- Section Modulus – 10.44 in.^{3} [171 cm^3]
- RBM (per rail) – 1,150,000 lbs. in. [130 000 N•m]
- Tapered Frame Rail Ends – 45° cut off

Bumper: Non–Metallic Flexible (Argent Color)
- Flush Mounting
- BBC – Bumper to Back of Cab – 112.6" [2 860 mm]

Towing, Clevis (2)

FUEL TANKS

Aluminum, 25" [640 mm] Dia.
Capacity/Location, 84 gal. [320 L] LH & RH

FRONT AXLE

MACK FAW12
- 12,000 lb. [5 400 kg] Capacity
- *Brakes,* "S" Cam 15" x 4"[1] [381 x 102 mm]
  - Rockwell "Q" Brakes
  - Slack Adjusters – Haldex – Automatic
- *Suspension,* Mack Taperleaf Spring with 12,000 lb. [5 400 kg] Ground Load Rating
- Shock Absorbers
- Oil Seals - Chicago Rawhide
- *Steering,* Sheppard M100P or Ross TAS65, Integral Power Ratio 18.9:1
- *Wheel Equipment,* Steel Disc, Accuride 10–hole
- *Rim,* 8.25" [210 mm]

REAR AXLE

MACK SAL38,
- 38,000 lb. [17 200 kg] Capacity Axle
- *Carrier* – Malleable – CRDPC92/CRD93
- *Ratio:* 3.86
- *Suspension* – Mack 40,000 lb. [18 100 kg] Capacity
  - AL401 Air Suspension w/4 Shock Absorbers and Height Control Kit
- 52" [1 321 mm] Axle Wheelbase
- Oil Seals - Chicago Rawhide
- *Brakes* – "S" Cam 16.5" x 7" [419 x 178 mm]
  - Rockwell "Q" Brakes
  - Slack Adjusters – Haldex – Automatic
  - Aux. Spring Brake Chambers
    - Double Diaphragm Type, Mechanical Spring Release
    - 2 Units
- *Wheel Equipment,* Steel Disc, Accuride 10–hole
- *Rim,* 8.25" [210mm]

TIRES

Front (singles)	*Size* 295/75R22.5 14 Ply	
	Tread Unisteel G159	
	Vendor Goodyear	
Rear (Duals)	*Size* 295/75R22.5 14 Ply	
	Tread Unisteel G159	
	Vendor Goodyear	

AIR/BRAKE

A B S (Anti-Lock Brake System)[2]
Dual Air Brake System
Air Reservoirs –
- Two Steel, Horizontal Mtd. on RH Rail Forward of Fuel Tank, Primary – Single Compartment Tank, Supply/Secondary – Two Compartment

Capacity – 4,631 in.^{3} [75.9 L]
Air Dryer – Bendix AD–9, Heated
Cushioned Clamps on All Hoses and Wiring
Semi–Trailer Connection Package
- Air Brake Grouping
  - Chassis Mtd. Pogo Stick
  - 12–Ft. Air Hose (2)
  - Glad Hand (2)
  - Glad Hand storage Bracket (B.O.C. – LH – Ground Reachable)

Breakaway Safety Valve
Hand Control Valve for Trailer Brakes
Electrical Grouping
- 12–Ft. (7–Wire) Cord
- 7–Wire Plugs

ELECTRICAL

Steel Battery Box with Molded Plastic Cover Mtd. Forward of LH Fuel Tank
Chassis Electrical
- Negative Ground
- 12–Volt Electrical Circuits and Bulbs
- Fuse Protected Circuits
- Breaker Protected Headlamp & Windshield Wiper Circuits
- Rear Lighting, (2) Combination Stop, Tail Directional & Back–up Lights

Trailer Electrical Package for Doubles Operation

PAINT

Cab, Hood and Fenders
- Color: Mack White, High Gloss (Base/Clear)

Chassis Running Gear
- Color: Mack Black (Water–Base)

ESTIMATED CHASSIS WEIGHT

Front – 7,791 lbs. [3 534 kg]
Rear – 6,459 lbs. [2 930 kg]

[1]15" x 4" [381 x 102 mm] Brakes available for Tractor Applications Only
2Available for Tractor Application Only

APPENDIX B

SENSITIVITY ANALYSIS OF SWEPT PATH WIDTH TO VARIATIONS IN TURNING CONTROL PARAMETERS

SWEPT PATH SENSITIVITY ANALYSIS

1.0 Sample Calculation (A-Train)

w = vehicle width
f = front overhang
b1,b2,b3 + effective wheelbases
L = tractor fifth wheel offset
h = 1st trailer hitch length
d = drawbar length

rf = radius of front overhang
r1,r2,r3 = radii of front pivot point of each unit
rL = radius of rear drive axle
rh = radius of front of hitch
rd = radius of front of drawbar
rr = radius of rear effective axle

$r1 := 14 \cdot m$ $\quad b1 := 5.3 \cdot m$ $\quad h := 1.2 \cdot m$

$f := .8 \cdot m$ $\quad L := 0 \cdot m$ $\quad d := 2.1 \cdot m$

$w := 2.6 \cdot m$ $\quad b2 := 6.9 \cdot m$ $\quad b3 := 6.9 \cdot m$

$\theta 1 := \operatorname{asin}\left(\frac{b1}{r1}\right)$

$$rf := \sqrt{r1^2 + f^2 + \left(\frac{w}{2}\right)^2 - 2 \cdot r1 \cdot \sqrt{f^2 + \left(\frac{w}{2}\right)^2} \cdot \cos\left[\pi - \theta 1 + \left(\operatorname{atan}\left(2 \cdot \frac{f}{w}\right)\right)\right]}$$

$rL := \sqrt{r1^2 - b1}$

$r2 := \sqrt{rL^2 + L}$

$rh := \sqrt{r2^2 - b2}$

$rd := \sqrt{rh^2 + h}$

$r3 := \sqrt{rd^2 - d}$

$rr := \sqrt{r1^2 - b1^2 + L^2 - b2^2 + h^2 - d^2 - b3}$

$rr = 8.35 \, m$

$$s := \sqrt{r1^2 + f^2 + \left(\frac{w}{2}\right)^2 - 2 \cdot r1 \cdot \sqrt{f^2 + \left(\frac{w}{2}\right)^2} \cdot \cos\left[\pi - \theta 1 + \left(\operatorname{atan}\left(2 \cdot \frac{f}{w}\right)\right)\right]} - \sqrt{r1^2 - b1^2 + L^2 - b2^2 + h^2 - d^2 - b3^2} + \frac{w}{2}$$

$s = 8.458 \, m$

2.0 Sensitivity Analysis

a) s vs f

$rl := 14 \cdot m$ $\quad b1 := 5.3 \cdot m$ $\quad h := 1.2 \cdot m$

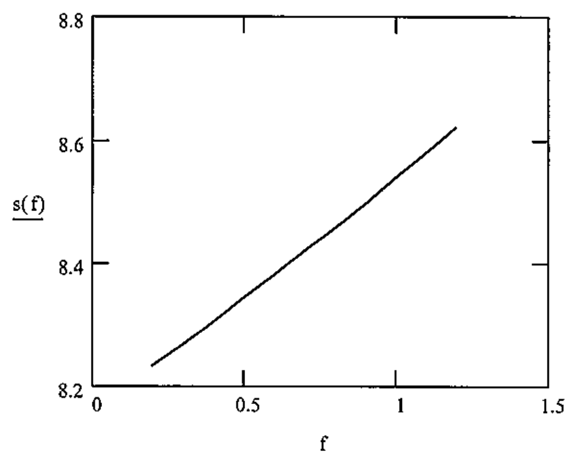
$f := .8 \cdot m$ $\quad L := 0 \cdot m$ $\quad d := 2.1 \cdot m$

$w := 2.6 \cdot m$ $\quad b2 := 6.9 \cdot m$ $\quad b3 := 6.9 \cdot m$

$f := .2 \cdot m, .3 \cdot m .. 1.2 \cdot m$

$$s(f) := \sqrt{rl^2 + f^2 + \left(\frac{w}{2}\right)^2 - 2 \cdot rl \cdot \sqrt{f^2 + \left(\frac{w}{2}\right)^2} \cdot \cos\left[\pi - \operatorname{asin}\left(\frac{b1}{rl}\right) + \left(\operatorname{atan}\left(2 \cdot \frac{f}{w}\right)\right)\right]} - \sqrt{rl^2 - b1^2 + L^2 - b2^2 + h^2 - d^2 - b3^2} + \frac{w}{2}$$

f	s(f)
0.2·m	8.232·m
0.3·m	8.268·m
0.4·m	8.305·m
0.5·m	8.343·m
0.6·m	8.381·m
0.7·m	8.419·m
0.8·m	8.458·m
0.9·m	8.498·m
1·m	8.538·m
1.1·m	8.579·m
1.2·m	8.62·m



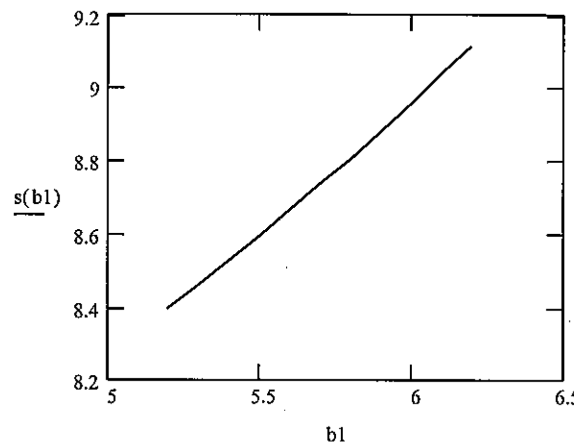
b) s vs b1

$r1 := 14 \cdot m$	$b1 := 5.3 \cdot m$	$h := 1.2 \cdot m$
$f := .8 \cdot m$	$L := 0 \cdot m$	$d := 2.1 \cdot m$
$w := 2.6 \cdot m$	$b2 := 6.9 \cdot m$	$b3 := 6.9 \cdot m$

$b1 := 5.2 \cdot m, 5.3 \cdot m .. 6.2 \cdot m$

$$s(b1) := \sqrt{r1^2 + f^2 + \left(\frac{w}{2}\right)^2 - 2 \cdot r1 \cdot \sqrt{f^2 + \left(\frac{w}{2}\right)^2} \cdot \cos\left[\pi - \operatorname{asin}\left(\frac{b1}{r1}\right) + \left(\operatorname{atan}\left(2 \cdot \frac{f}{w}\right)\right)\right]} - \sqrt{r1^2 - b1^2 + L^2 - b2^2 + h^2 - d^2 - b3^2} + \frac{w}{2}$$

b1	s(b1)
5.2·m	8.394·m
5.3·m	8.458·m
5.4·m	8.524·m
5.5·m	8.592·m
5.6·m	8.661·m
5.7·m	8.732·m
5.8·m	8.805·m
5.9·m	8.88·m
6·m	8.956·m
6.1·m	9.035·m
6.2·m	9.115·m



c) s vs L

$r1 := 14 \cdot m$ $\quad$ $b1 := 5.3 \cdot m$ $\quad$ $h := 1.2 \cdot m$

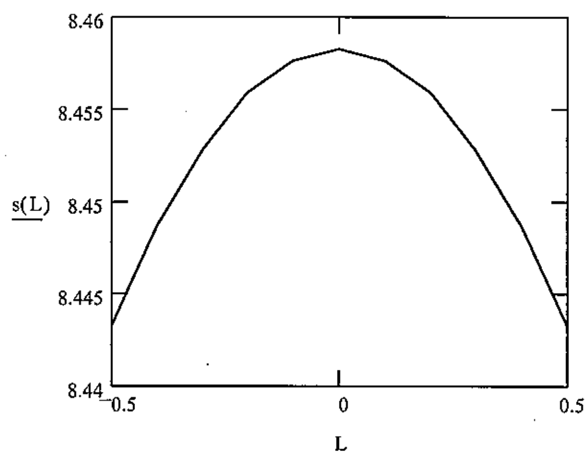
$f := .8 \cdot m$ $\quad$ $L := 0 \cdot m$ $\quad$ $d := 2.1 \cdot m$

$w := 2.6 \cdot m$ $\quad$ $b2 := 6.9 \cdot m$ $\quad$ $b3 := 6.9 \cdot m$

$L := -.5 \cdot m, -.4 \cdot m .. .5 \cdot m$

$$s(L) := \sqrt{r1^2 + f^2 + \left(\frac{w}{2}\right)^2 - 2 \cdot r1 \cdot \sqrt{f^2 + \left(\frac{w}{2}\right)^2} \cdot \cos\left[\pi - \operatorname{asin}\left(\frac{b1}{r1}\right) + \left(\operatorname{atan}\left(2 \cdot \frac{f}{w}\right)\right)\right]} - \sqrt{r1^2 - b1^2 + L^2 - b2^2 + h^2 - d^2 - b3^2} + \frac{w}{2}$$

L	s(L)
-0.5·m	8.443·m
-0.4·m	8.449·m
-0.3·m	8.453·m
-0.2·m	8.456·m
-0.1·m	8.458·m
0·m	8.458·m
0.1·m	8.458·m
0.2·m	8.456·m
0.3·m	8.453·m
0.4·m	8.449·m
0.5·m	8.443·m



d) s vs b2

$r1 := 14 \cdot m$ $\quad$ $b1 := 5.3 \cdot m$ $\quad$ $h := 1.2 \cdot m$

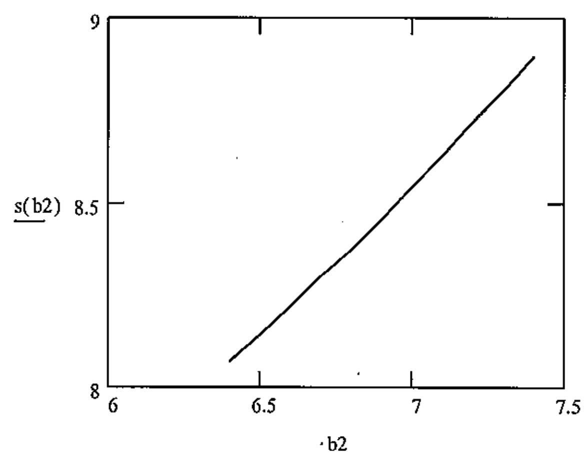
$f := .8 \cdot m$ $\quad$ $L := 0 \cdot m$ $\quad$ $d := 2.1 \cdot m$

$w := 2.6 \cdot m$ $\quad$ $b2 := 6.9 \cdot m$ $\quad$ $b3 := 6.9 \cdot m$

$b2 := 6.4 \cdot m, 6.5 \cdot m .. 7.4 \cdot m$

$$s(b2) := \sqrt{r1^2 + f^2 + \left(\frac{w}{2}\right)^2 - 2 \cdot r1 \cdot \sqrt{f^2 + \left(\frac{w}{2}\right)^2} \cdot \cos\left[\pi - \operatorname{asin}\left(\frac{b1}{r1}\right) + \left(\operatorname{atan}\left(2 \cdot \frac{f}{w}\right)\right)\right]} - \sqrt{r1^2 - b1^2 + L^2 - b2^2 + h^2 - d^2 - b3^2} + \frac{w}{2}$$

b2	s(b2)
6.4·m	8.069·m
6.5·m	8.143·m
6.6·m	8.219·m
6.7·m	8.297·m
6.8·m	8.377·m
6.9·m	8.458·m
7·m	8.542·m
7.1·m	8.628·m
7.2·m	8.715·m
7.3·m	8.806·m
7.4·m	8.898·m



e) s vs h

$r1 := 14 \cdot m \qquad b1 := 5.3 \cdot m \qquad h := 1.2 \cdot m$

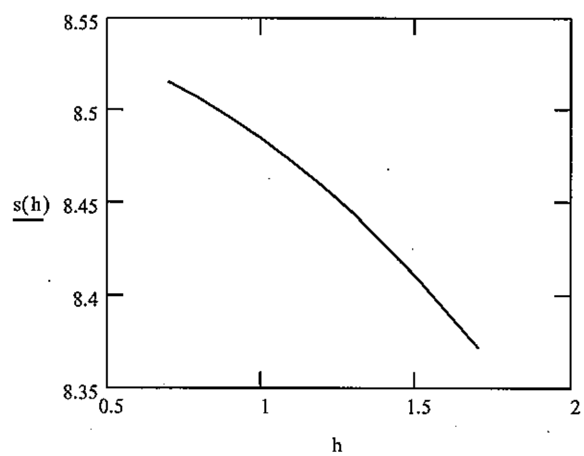
$f := .8 \cdot m \qquad L := 0 \cdot m \qquad d := 2.1 \cdot m$

$w := 2.6 \cdot m \qquad b2 := 6.9 \cdot m \qquad b3 := 6.9 \cdot m$

$h := 0.7 \cdot m, 0.8 \cdot m .. 1.7 \cdot m$

$$s(h) := \sqrt{r1^2 + f^2 + \left(\frac{w}{2}\right)^2 - 2 \cdot r1 \cdot \sqrt{f^2 + \left(\frac{w}{2}\right)^2} \cdot \cos\left[\pi - \operatorname{asin}\left(\frac{b1}{r1}\right) + \left(\operatorname{atan}\left(2 \cdot \frac{f}{w}\right)\right)\right]} - \sqrt{r1^2 - b1^2 + L^2 - b2^2 + h^2 - d^2 - b3^2} + \frac{w}{2}$$

h	s(h)
0.7·m	8.515m
0.8·m	8.506m
0.9·m	8.496m
1·m	8.485m
1.1·m	8.472m
1.2·m	8.458m
1.3·m	8.443m
1.4·m	8.427m
1.5·m	8.41·m
1.6·m	8.391·m
1.7·m	8.372m



f) s vs d

$r1 := 14 \cdot m$ $\quad b1 := 5.3 \cdot m$ $\quad h := 1.2 \cdot m$

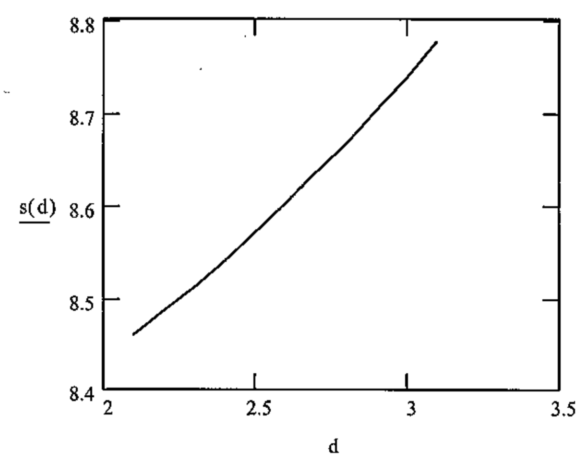
$f := .8 \cdot m$ $\quad L := 0 \cdot m$ $\quad d := 2.1 \cdot m$

$w := 2.6 \cdot m$ $\quad b2 := 6.9 \cdot m$ $\quad b3 := 6.9 \cdot m$

$d := 2.1 \cdot m, 2.2 \cdot m .. 3.1 \cdot m$

$$s(d) := \sqrt{r1^2 + f^2 + \left(\frac{w}{2}\right)^2 - 2 \cdot r1 \cdot \sqrt{f^2 + \left(\frac{w}{2}\right)^2} \cdot \cos\left[\pi - \operatorname{asin}\left(\frac{b1}{r1}\right) + \left(\operatorname{atan}\left(2 \cdot \frac{f}{w}\right)\right)\right]} - \sqrt{r1^2 - b1^2 + L^2 - b2^2 + h^2 - d^2 - b3^2} + \frac{w}{2}$$

d	s(d)
2.1·m	8.458m
2.2·m	8.484m
2.3·m	8.511·m
2.4·m	8.539m
2.5·m	8.569m
2.6·m	8.6·m
2.7·m	8.633m
2.8·m	8.666m
2.9·m	8.701·m
3·m	8.738m
3.1·m	8.776m



g) s vs b3

$r1 := 14 \cdot m$ $\quad b1 := 5.3 \cdot m$ $\quad h := 1.2 \cdot m$

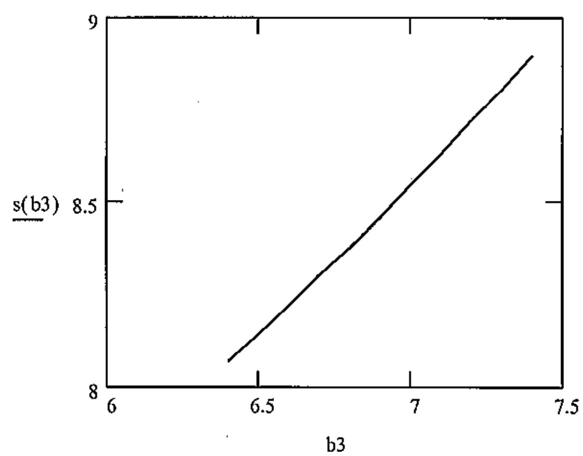
$f := .8 \cdot m$ $\quad L := 0 \cdot m$ $\quad d := 2.1 \cdot m$

$w := 2.6 \cdot m$ $\quad b2 := 6.9 \cdot m$ $\quad b3 := 6.9 \cdot m$

$b3 := 6.4 \cdot m, 6.5 \cdot m .. 7.4 \cdot m$

$$s(b3) := \sqrt{r1^2 + f^2 + \left(\frac{w}{2}\right)^2 - 2 \cdot r1 \cdot \sqrt{f^2 + \left(\frac{w}{2}\right)^2} \cdot \cos\left[\pi - \operatorname{asin}\left(\frac{b1}{r1}\right) + \left(\operatorname{atan}\left(2 \cdot \frac{f}{w}\right)\right)\right]} - \sqrt{r1^2 - b1^2 + L^2 - b2^2 + h^2 - d^2 - b3^2} + \frac{w}{2}$$

b3	s(b3)
6.4·m	8.069m
6.5·m	8.143m
6.6·m	8.219m
6.7·m	8.297m
6.8·m	8.377m
6.9·m	8.458m
7·m	8.542m
7.1·m	8.628m
7.2·m	8.715m
7.3·m	8.806m
7.4·m	8.898m



MEMORANDUM

TO: ALL HOLDERS OF THE TECHNICAL REPORT – *DESIGN VEHICLE DIMENSIONS FOR USE IN GEOMETRIC DESIGN*

FROM: JOHN KIZAS

DATE: JULY 13, 1998

SUBJECT: MULTIPLE AXLE / SINGLE UNIT TRUCK DIMENSIONS

The technical report entitled *Design Vehicle Dimensions for Use in Geometric Design* was published by the Transportation Association of Canada (TAC) and has been available for sale since December 1997. At that time, there was insufficient data to determine design vehicle dimensions for the Multiple Axle / Single Unit Truck.

This information became available with the release of the Canadian Council of Motor Transport Administrators (CCMTA) Survey Data. The attached report provides proposed design vehicle dimensions for the Multiple Axle / Single Unit Truck and completes TAC's project to recommend new design vehicle dimensions.

Should you have any questions regarding this report, please do not hesitate to contact me at (613) 736-1350 or jmkizas@tac-atc.ca.

John Kizas
Project Manager, Roadway Engineering

Transportation Association of Canada
2323 St. Laurent Blvd Ottawa, Canada K1G 4J8
Tel. (613) 736-1350 ■ Fax (613) 736-1395

Association des transports du Canada
2323, boul. St-Laurent, Ottawa, Canada K1G 4J8
Tél (613) 736-1350 ■ Télécopieur (613) 736-1395

Design Vehicle Dimensions for Use in Geometric Design

Analysis of Multiple Axle / Single Unit Truck Dimensions Using CCMTA Data

July 1998

Introduction

The critical dimensions of commercial vehicles for use in geometric design from the *Design Vehicle Dimensions for Use in Geometric Design* study were established using Weigh-in-Motion (WIM) data. WIM data interpretation of the wheelbase (WB) dimension was found to be associated with considerable error because of the complexity of the axle arrangement of multiple axle / single unit trucks. As such, the study proposed a typical dimension for multiple axle / single unit trucks and recommended subsequent confirmation of the proposed dimension based on the Canadian Council of Motor Transport Administrators (CCMTA)'s road side truck survey data (which was not available during the study).

The objective of this supplementary study was to verify the proposed typical dimensions of multiple axle / single unit trucks and recommend revised dimensions, as required, based on the CCMTA truck survey data.

Data Sources

The 1995 National Roadside Survey was undertaken by transportation officials of the federal, provincial and territorial governments in order to produce a profile of the volume and characteristic of truck traffic using Canada's highways. The data was collected in the summer and fall of 1995 at 148 sites across Canada.

Data Analysis

Based on the CCMTA database analysis, the total single unit truck population with three or more axles was 8,201 in 1995. Of this, about 2% of the trucks were four or more axle single unit trucks. These fleet populations were estimated from a sample size of 357 (out of the 357 sample, 11 were four or more axle units). The data quality analysis identified a total of 101 samples that are classified as unknown or have a wheelbase range greater than 12.0 m. The current national standards for vehicle weights and dimensions contained in the 1997 federal-provincial-territorial Memorandum of Understanding (MoU) limit the maximum overall length of a straight truck to12.0 m. Therefore, these observations were assumed as suspect data and excluded from the analysis. The final analysis was based on the remaining 256 observations. The CCMTA database does not provide overall length information. The wheelbase distribution is shown in Figure 1.

The wheelbase and overall length are summarized in Table 1.

Table 1: Summary of Multiple / Axle Single Unit Truck Dimensions

	Dimension	Mean	85th Percentile	95th Percentile
CCMTA	Length (m)	--	--	--
	WB (m)	6.8	7.7	8.4
WIM	Length (m)	10.7	11.1	11.5
	WB (m)	6.8	8.4	9.5

Conclusion

The proposed design vehicle dimensions for multiple axle / single unit trucks is shown in Figure 2. The dimensions are based on the analysis of both the CCMTA and WIM database. The presence of liftable axles for four or more axle straight trucks normally introduces considerable error in the measurement of the WB dimension by WIM equipment. Therefore, more hard data sources, such as the 1995 CCMTA survey was used to estimate the 85^{th} and 95^{th} percentile value of wheelbase dimensions. The overall length distribution was obtained from the WIM data analysis previously carried out for the TAC Design Vehicle Dimension Study.

The proposed design dimensions for multiple axle / single unit trucks are listed below:

Length (m)	11.5
Front Overhang (m)	0.8
Rear Overhang (m)	2.3
WB (m)	8.4

FIGURE 1: DISTRIBUTION OF WHEELBASE LENGTH FOR HEAVY SINGLE-UNIT TRUCKS
(CCMTA DATA)

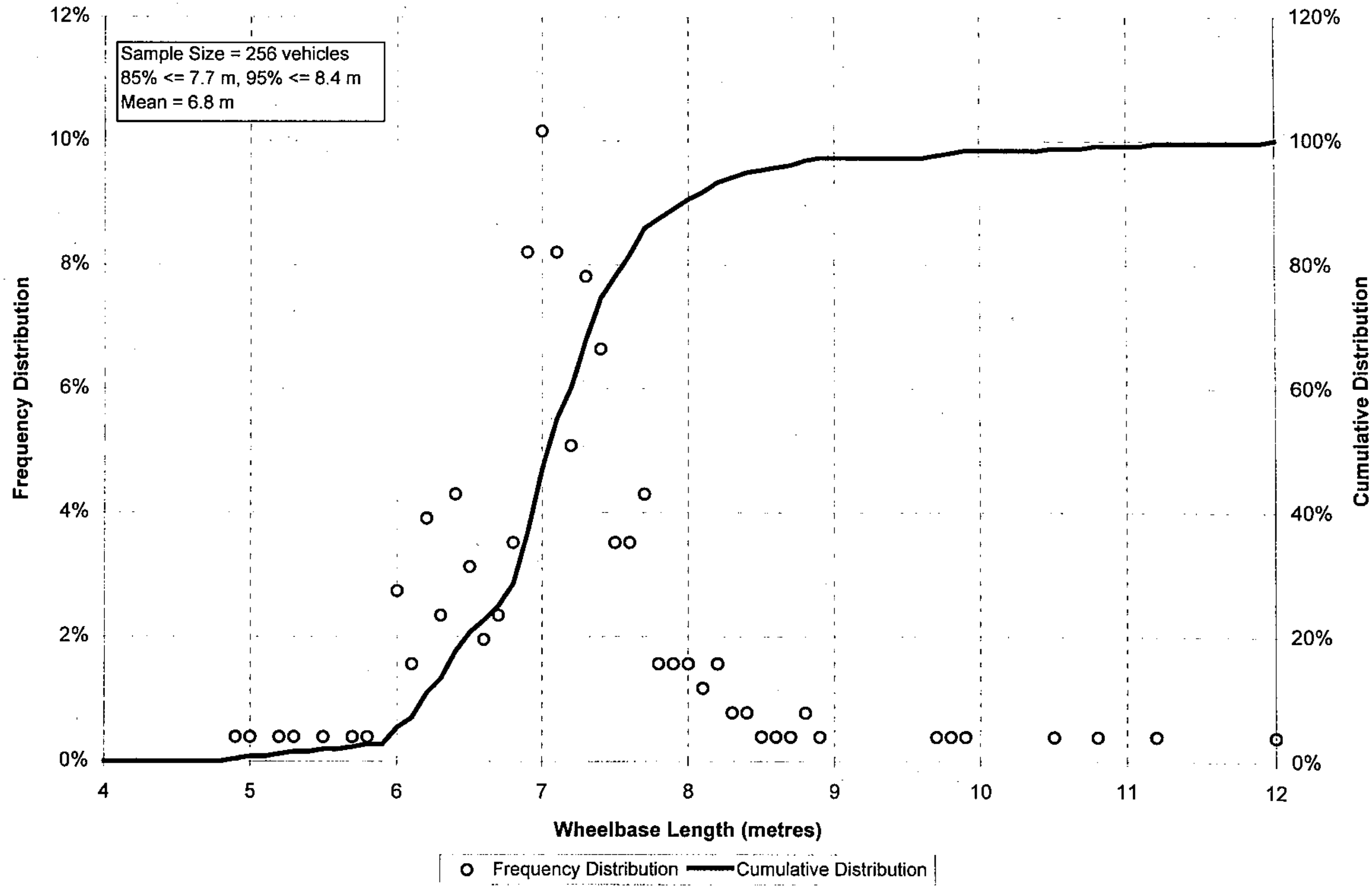
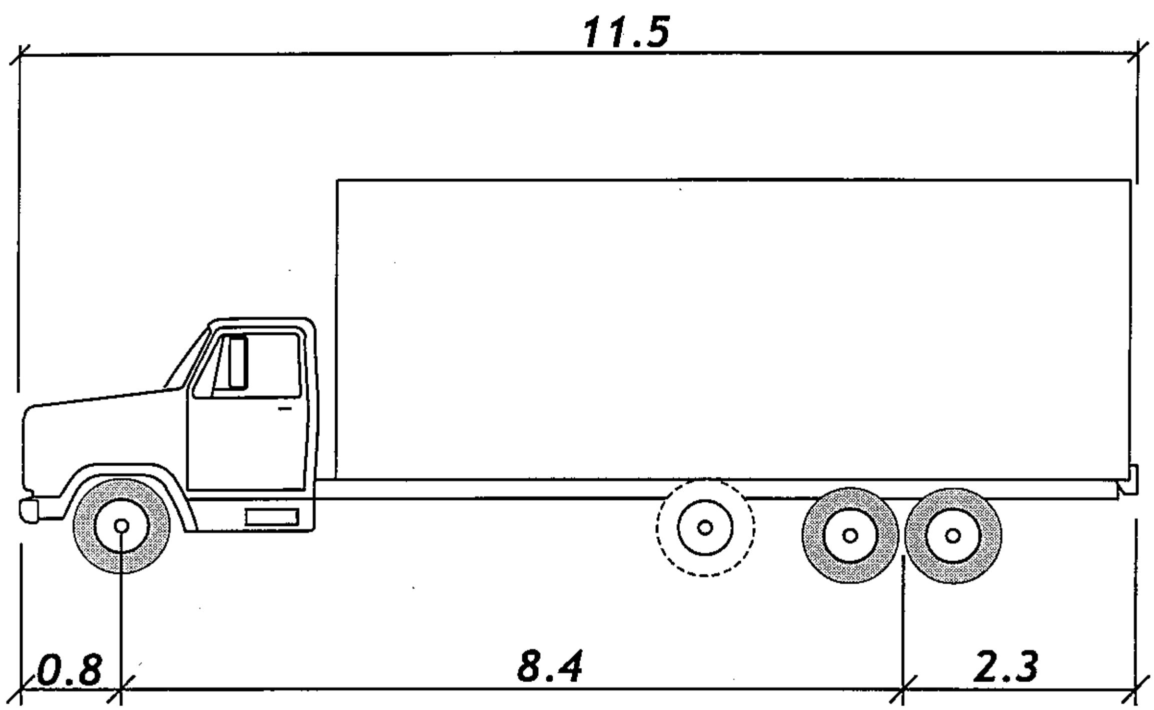


FIGURE 2
PROPOSED HEAVY SINGLE UNIT TRUCK DIMENSIONS



LEGEND: *Proposed dimensions*

Notes: All dimensions are in meters; figure not to scale