M A S T E R   C O P Y

UNIVERSITY OF SOUTHAMPTON

EFFECTS OF CURVATURE ON VEHICLE/DRIVER BEHAVIOUR

by George Mintsis

A Thesis submitted for
the degreee of
Doctor of Philosophy

Department of Civil Engineering
March 1982

TO MY FATHER †

for his continuous care, encouragement and support.

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF CIVIL ENGINEERING AND APPLIED SCIENCE

CIVIL ENGINEERING

Doctor of Philosophy

EFFECTS OF ROAD CURVATURE ON VEHICLE/DRIVER BEHAVIOUR

by George Mintsis

This study is concerned with the behaviour of the vehicle/driver combination on open road curves. The associations between behavioural parameters and geometry, traffic flow and environmental factors are examined in order to evaluate current British driving practice. All the curves considered had radii less than 500 metres and overlapped limits used in current British design standards.

Information on the performance of vehicle/driver combinations found was collected at a total of 56 directional single carriageway and 22 directional dual carriageway public road sites located throughout Great Britain. Cars and goods vehicles were treated separately and a total of about 10,500 vehicle movements were studied. In addition a test vehicle/driver combination was used to collect information at a large number of sites to relate between-site variation to other factors.

A series of bivariate and multivariate linear and curvilinear models were fitted to the data and relationships between behavioural parameters and curve geometry, traffic flow and environmental parameters were determined. Highly significant associations were obtained between speeds on the curve/lateral acceleration and curvature. Speeds on the approach link were also found to be a significant determinant of vehicle/driver behaviour around open road curves. Other geometric parameters such as verge width, road width, sight distance and curve length were found to have only marginal effects. No significant difference was observed between left and right-hand curves nor between uphill and downhill conditions.

Driver behaviour appeared to be in accord with the current design practice for alignments based on design speeds of 85.0 k.p.h. or more. For alignments with lower design speeds drivers were found to adopt speeds in excess of the design speed.

ACKNOWLEDGEMENTS

First and foremost, I am deeply grateful to my supervisor Dr. M. McDonald, for his valuable help and continuous encouragement throughout this project.

I would also like to acknowledge the assistance and the encouragement given to me by Professor T. E. H. Williams and the members of the Transportation Research Group.

This research has been based on the Department of Transport's data base on driving practices around open road curves. The permission to use this data is gratefully acknowledged. My thanks are especially due to Mr. D. Simpson and to Mr. N. C. Duncan for the valuable discussions I had with them.

Finally I would like to thank my parents and my fiancée Voula whose continuous encouragement and support was of vital importance in the production of this thesis.

CONTENTS

Page

LIST OF TABLES

Table		Page

LIST OF FIGURES

NOTATION

The following symbols have been used throughout the text. Any deviations or additions are defined locally.

V	Vehicle Speed, k.p.h.
$V(i)$	i-th Percentile Vehicle Speed (i.e. 50th, 85th,...)
ASP	Vehicle Approach Speed, k.p.h.
AS_C	Car Approach Speed, k.p.h.
AS_{FC}	Free Car Approach Speed, k.p.h.
AS_G	Goods Vehicle Approach Speed, k.p.h.
ESP	Vehicle Curve Entry Speed, k.p.h.
V_{CE}	Car Curve Entry Speed, k.p.h.
V_{FCE}	Free Car Curve Entry Speed, k.p.h.
V_{GE}	Goods Vehicle Curve Entry Speed, k.p.h.
MSP	Vehicle Curve Middle Speed, k.p.h.
V_{CM}	Car Curve Middle Speed, k.p.h.
V_{FCM}	Free Car Curve Middle Speed, k.p.h.
V_{GM}	Goods Vehicle Curve Middle Speed, k.p.h.
A	Vehicle Curve Middle Lateral Acceleration, m/sec^2
$A(i)$	i-th Percentile Vehicle Curve Middle Lateral Acceleration, m/sec^2 (i.e. 50th, 85th,...)
A_{CM}	Car Curve Middle Lateral Acceleration, m/sec^2
A_{FCM}	Free Car Curve Middle Lateral Acceleration, m/sec^2
A_{GM}	Goods Vehicle Curve Middle Lateral Acceleration, m/sec^2
f	Vehicle Curve Middle Side Friction Factor, g
$f(i)$	i-th Percentile Vehicle Curve Middle Side Friction Factor, g (i.e. 50th, 85th,...)
f_{CM}	Car Curve Middle Side Friction Factor, g
f_{FCM}	Free Car Curve Middle Side Friction Factor, g
f_{GM}	Goods Vehicle Curve Middle Side Friction Factor, g
DS	Design Speed, k.p.h.
CoV	Coefficient of Vehicle Speed Variation
r	Coefficient of Correlation
r^2	Coefficient of Determination
s	Standard Error of the Estimate
ENL	Curve Entry Vehicle Lateral Placement, m
ML	Curve Middle Vehicle Lateral Placement, m
EXL	Curve Exit Vehicle Lateral Placement, m

R	Curve Radius, m
C	Curvature, degrees per 100 feet
TA	Total Angle, radians
RCTA	Rate of Change of Total Angle, rad/km
L	Curve Length, m
RW	Lane or Carriageway Width, m
VW	Verge Width, m
E	Superelevation, m/m
GRA	Gradient, per cent
SD	Sight Distance, m
FL	Traffic Flow, Vehicles per hour
g	Acceleration of gravity, m/sec^2 ($g=9.81 m/sec^2$)

CHAPTER ONE

INTRODUCTION

1.1 GENERAL BACKGROUND

Speed and the way it changes with time (acceleration/deceleration), are the basic parameters by which vehicle movement along a road can be expressed. Speeds adopted by drivers on long, level, straight road sections are mainly dependent upon their attitudes, which in turn may be related to journey purpose and vehicle/driver capabilities, and may include a variable level of safety. In reality, roads are rarely straight and level but include features such as curves and gradients and therefore vehicle speeds are also dependent upon road geometry. Other factors, such as pedestrian activities, environmental conditions and speed limits, may be significant. The interactions with other vehicles on the road may also be a restraining feature which cannot be considered as being independent of the other variables, as the build up of congestion is mainly influenced by factors such as road geometry, traffic control, and roadside development. The geometric features of road curves are none-the-less key elements in the design process and relate to both economic and operational evaluations.

A better appreciation of the dynamic interaction between vehicle/driver and road geometry could allow the development of less conservative designs with consequent benefits. The Advisory Committee on Trunk Road Assessment(1) aiming towards the reduction of construction cost and environmental impact of roads recommended the adoption of a more flexible approach to design practices. It is essential, that the effects of variations in standards are known, if the resulting designs are to provide a safe and efficient performance. This study forms part of the work supported by the Department of Transport to assess the ways in which different levels of curvature affect vehicle/driver behaviour.

1.2 OBJECTIVES

Initially, the objectives of this study were defined as:

a. The recording of actual spot speeds into curves, between 50 and 500m radius and varying superelevation (to establish trends).

b. The derivation of values of actual tyre/road surface friction on curves between 50 and 500m radius and varying superelevation (needed for internal DT_p purposes).

c. The recording of actual spot speeds into the curve sites used in the recent TE sponsored study 'Effects on Safety of Marginal Design Elements'(2).

It was necessary to collect a substantial amount of roadside information (see Chapter 3) to meet these objectives. In the event, the data proved to be of a sufficiently high quality for extended analyses to be undertaken of driver/vehicle behaviour on curves.

The amount and consistency of the information collected enabled the study to be expanded to include the following:

a. The examination of vehicle speed and lateral acceleration distributions and their forms at various locations around a road curve over a wide range of curvatures.

b. The variations of vehicle speeds before and within road curves to ensure the adequacy of the 'uniform design speed' assumption made by most of the current design policies.

c. The determination of meaningful relationships expressing possible associations between vehicle speed and road curvature geometry. These relationships were also to be examined with changes in environmental conditions and traffic flow in order for the effects of between-vehicle interactions on these associations to be assessed.

d. The examination of possible associations between behavioural parameters such as lateral acceleration and road curve geometry in an effort to identify the factors which significantly affect drivers' decisions when negotiating road curves.

e. The consideration of vehicle lateral placement at specific locations within road curves and their relations to vehicle speed which would allow the validity of the basic 'point-mass' design equation to be tested and the influence of road curvature on to vehicle path to be determined.

f. Finally, the derivation of a series of simple prediction models by which vehicle speeds at different locations within road curves could be estimated with adequate accuracy.

1.3 THE STUDY

The results of the study were to be used for design and evaluation purposes for public road conditions. Our studies were, therefore, concentrated on the collection and analysis of information of public road vehicles/drivers under normal highway conditions. In addition to this public road data, a test driver/vehicle combination was used for a separate between-site evaluation over an extended sample of curves.

The study described here was undertaken after an assessment of previous work, reported in detail in Chapter 2.

Two types of road were examined:

a. Rural single carriageways were considered with road width varying between 6.52m and 11.04m for 2 and 3 lane conditions. In all 49 directional curves were studied on 2-lane single carriageways and 7 directional curves on 3-lane single carriageways.

b. Dual carriageways with carriageway width varying between 5.6m and 8.42m. In all 22 directional curves were studied.

Most of the rural curves considered were chosen from a total of about 200 directional curves on both single and dual carriageways, with radius less than 500m, used by Halcrow Fox and Associates in their recent study " Effects on Safety of Marginal Design Elements"(2) undertaken on behalf of the Department of Transport. These were supplemented with a number of local directional single carriageway curves considered in our preliminary study(3). Two more single and two dual carriageway curves were added to give a consistent distribution of curve radii over the range required. All sites were selected on the basis that vehicle/driver behaviour would not be affected by the presence of alignment, roadside or traffic factors on the approach to the curves.

Most of the geometric data for all the study curves required in the analysis was obtained either from Halcrow Fox and Associates or our preliminary study data base. Additional measurements of superelevation, verge and road width as well as a complete geometric record for the four new sites were obtained during the surveys.

Public road data consisting of vehicle speeds on the approach to and within road curves and of vehicle lateral placements at different locations around road curves was collected in two separate phases. The first phase was completed during the 1980/1981 winter and the second in the summer of 1981. Data was collected separately for cars and goods vehicles and the levels of traffic interactions were noted i.e. the flowing mode. Site selection together with data collection produces are detailed in Chapter 3.

Additionally, more vehicle speed data over the entire Halcrow Fox sample of curves with radius less than 500 metres was collected by means of a test-vehicle. It is hoped that test-vehicle speed data could be successfully introduced in the Halcrow-Fox accident model.

Public and test-vehicle road data was manually checked and coded. Data reduction was performed on the University ICL main computer. Data manipulation and reduction procedures are described in Chapter 4.

Bivariate and multiple statistical analyses were performed to determine the associations between the key design behavioural parameters of speed, lateral placement and lateral acceleration and such factors as curve geometry, traffic and environmental conditions.

Analyses were performed on sub-sets of the data where the sample sizes were adequate. The methods of analysis and the results of the study are described in Chapters 5 and 6 respectively.

Chapter 7 contains a brief discussion of the current design policies with emphasis given mainly to the new British Highway Link Design Departmental Standard as compared to the findings of this study.

The main conclusions of the study are contained in Chapter 8.

The parameters used in this study are defined in Appendix A.

CHAPTER TWO

PREVIOUS RESEARCH

2.1 INTRODUCTION

This chapter reviews the development of the main concepts concerning rural road design and the design of highway curves.

2.2 PART I: THE DEVELOPMENT OF BASIC DESIGN CONCEPTS AND THE DESIGN STANDARDS

2.2.1 The Beginning of Modern Road Design Research

Advances were soon made in providing suitable road surfaces with the introduction of the motor vehicles, but no provision was made for realigning existing roads to cater for higher speeds. Although several bodies pointed out the need to adopt policies for road design, very little research was carried out until the early 1930's when the first decisive steps towards the development of uniform design standards were made.

Good[4] in his reviewing report states that:

> *"The retention of unsuitable geometric standards during the first quarter of this century was partly attributable to the lack of organisation with State-wide or national responsibility for highways or co-ordination of research."*

During that time vehicle speeds were entirely controlled by regulation. In Britain the speed limit was raised in 1903 from 14 to 20 m.p.h. Bird[5]. In the United States, it varied between 15 and 40 m.p.h. (Public Roads[6]).

2.2.2 Design Speed

Alignment was an important part of the design process during the development of an extensive road network in the United States in the early 1930's. Attention was given to individual elements such as minimum radius, superelevation, sight distance and curve widening. All alignment improvements were however subject to local policy considerations and no uniform safe speed was adopted.

Downs[7] proposed the adoption of a 'superelevation speed' for superelevating road curves, which would be such that a sight-braking distance compatibility would be secured.

The design practice in Minnesota, Anon[8], was to superelevate road curves to compensate entirely for a speed of 27 m.p.h., a value very close to the then U.S. legal speed limit of 25 m.p.h. Speed limit remained as a design control parameter until Young[9] proposed the adoption of a uniform design speed as a basis for road design. He also proposed that for a road section, preferably between towns, all curves should be superelevated for the same theoretical speed.

Moyer[10] recommended the adoption of 'maximum permissible speeds' for the determination of design elements such as minimum sight distance and maximum curvature. He suggested a range of speeds from 45 to 80 m.p.h. for different terrain types.

Baldock[11], reporting on design practices in Oregon, referred to three different speeds required to be considered in the design process. They were given as critical, design, and recommended speeds and referred to different driver groups in terms of their skill.

The most influential work on the concept of 'design speed' was carried out by Barnett[12] who defined the 'assumed design speed' as:

> *"...the maximum reasonable uniform speed which would be adopted by the fast driving group of vehicle operators, once clear of urban areas."*

Barnett's definition of design speed is basically that in use today. He considered that the adoption of a uniform speed, rather than a variable speed, changing from one curve to the next, is the aim of all drivers. Barnett's 'design speed' concept was soon adopted by the U.S. road authorities and appeared in a slightly revised form, in AASHO's design policy in 1941[13].

> *"The assumed design speed of a highway is considered to be the maximum approximately uniform speed which probably will be adopted by the faster group of drivers but not, necessarily, by the small percentage of reckless ones."*

In the 1954 edition of AASHO's[14] design policy, design speed was re-defined as being:

> *"...the maximum safe speed that can be maintained over a specified section of highway when conditions are so favourable that the design features of the highway govern"* and as

> *"...a speed used for design and correlation of the physical features of a highway that influence vehicle operation."*

Design speeds ranged between 30 and 70 m.p.h. These definitions are retained in the current AASHO[15] design policy with design speed being extended to 80 m.p.h.

In Britain the Ministry of Transport[16] required that:

> *"The standards of design, superelevation, visibility, should be correlated for any particular road at an appropriate design speed."*

The requirement has been recently, Highway Link Design[17], revised so that:

"The road alignment shall be designed as to ensure that standards of curvature, visibility, superelevation etc. are provided for a Design Speed which shall be consistent with the anticipated vehicle speeds on the road."

Design speeds range between 60 and 120 k.p.h. and are the speeds which are expected not to be exceeded by more than the 85 per cent of all drivers in wet weather and for the particular roadside and geometric features.

Following American practice, NAASRA[18] defined the design speed as the speed at which a vehicle can travel;

"...without being exposed to hazards arising from curtailed sight distance, inappropriately superelevated curves, severe grades, or pavements too narrow to accommodate the design volume."

The range of speeds contemplated by NAASRA for rural roads is from 40 to 130 k.p.h.

Since 1936, there seems to have been a change in the definition of design speed. It is now no longer considered as being a 'behavioural' measure as proposed by Barnett, but as being a procedural value used for the 'design and correlation of design elements' which is also a 'maximum safe speed'.

Good[4] stated that:

"With the advent of the design speed concept it was possible for the road designer to cater for the needs of hypothetical design-speed driver who traversed the highway at a uniform speed."

2.2.2.1 *Discussion*

Clearly the simplicity and ease of application of the 'design speed' concept seems to be the main reason for the wide adoption of this approach. There has, however, been considerable criticism of the concept, in that it did not represent actual conditions.

AASHO[15] recognises these deficiencies by stating that:

"A low design speed, however, should not be assumed for a secondary where the topography is such that drivers are apt to travel at high speeds. Drivers do not adjust their speeds to the importance of the highway but to the physical limitations and traffic thereon."

NAASRA[18] also stated that:

"All isolated curves should be designed for the likely speed of travel where this is higher than the general design speed ruling for the road."

In New South Wales, the Department of Main Roads has abandoned the design speed concept, as reported by Mullin[19], for rural roads other than freeways on the basis that:

> *"...though the designer knows the design speed of the road, the driver does not, and he travels the road at a speed he believes appropriate to the conditions as he sees them on the road."*

Generally, on long straight road sections, or flat horizontal road curves, the usually high design speed value which is chosen is satisfactory as the majority of drivers will travel at speeds lower than the design speed. The problems arise at lower design speed levels where the desired co-ordination of the design elements such as maximum curvature, sight distance and superelevation may break down. In such situations, drivers do not respond to the hypothesized uniform speed chosen by the designer but to prevailing local geometry which determines actual vehicle speeds. The co-ordination of the design elements is mainly dependent on the correlation of each of them with driver behaviour. Since curvature is expected to be the dominant factor in determining speeds selected by drivers, designing for speeds above the permitted curvature maximum but with near minimum sight distance, could lead to unsafe speeds being adopted.

Armstrong[20], in his work on designing low cost rural roads, introduced the concept of an 'envrionment speed' to be used in road design. This represents a percentile value of speed taken from an actual distribution of speeds adopted by drivers.

Glennon[21] examining the adequacy of present design policies found the centripetal force (point-mass) equation, which governs road curve design, to be inadequate for curvatures greater than 4 degrees.

McLean[22] in his comprehensive work on speeds on rural curves in Australia, discussed the inadequacy of the design speed concept and gave three main criticisms:

(a) *"Designing according to the design values permitted by a specified design speed does not necessarily ensure consistent alignment standards."*

(b) *"Designing according to the design values permitted by a specified design speed does not necessarily ensure compatibility between the standards for combination of design elements"* and

(c) *"Free vehicle operating speeds and design speed are not necessarily synonymous."*

The basis of these criticisms will be discussed in detail in the second part of this chapter.

Good[4] proposed, as an alternative to the traditional 'assumed design speed concept', the adoption of a comprehensive speed selection model from which speed percentiles could be predicted on the basis of geometric, traffic and environmental data.

In their recent revised horizontal design standards, the Department of Transport[17] incorporated a model by which the 85th percentile journey speed of a road section, recommended to be longer than 2 km, can be predicted from a number of average alignment and roadside parameters. These include average curvature, gradient, visibility, degree of access and carriageway and verge width.

2.2.3 Safe Speeds on Curves

The practice of superelevating curves was adopted for use in the design of roads as it was recognised from railway practice that superelevation made high speed travel on curves safer and more comfortable. The initial practice, however, was to superelevate road curves to a level which would balance all the centrifugal force developed by vehicles travelling at the so-called 'hands-off' or 'superelevation' speed.

Downs[7] suggested that curves should be superelevated to compensate entirely for centrifugal effects at his 'safe stopping speed', which was calculated on the basis of predetermined 'safe sight distance', different curvatures and a deceleration rate of 0.067 g.

It appears from early reports, however, that there was a conflict of opinion on how speeds would be affected by the provision of superelevation. Luedke and Harrison[23] favoured the idea that a lack of superelevation would restrict vehicle speeds, thus promoting safety. However, accident records were found to contradict this theory.

Another approach, suggested by Young[9] in his 'mile-per-hour road' concept was to superelevate to compensate entirely for the centrifugal forces developed by the fastest moving vehicles.

Leeming[24], however, had already suggested a compromise between the two methods by proposing that curves should be superelevated to provide safe travel for vehicles moving at the 'most probable average speed'. This approach introduced the need for some consideration to be given to the concept of 'side friction' developed between tyres and the road surface. The side-friction accounts for the unbalanced side-force which would result from speeds different to the 'superelevation speed' at a particular curve.

Initially side-friction was used as a skidding criterion and 'safe speed' was therefore considered to be the speed at which skidding was imminent.

E.L. Leeming[25], one of the first researchers who considered side-friction in a quantitative manner suggested that safe speeds on road curves would be obtained by equating the side-friction factor to a coefficient of friction equal to 0.25. However, he went on to say that:

"...it could be conceived that the value of the coefficient of friction would even approach 0.5..."

Good in 1978[4] commenting on Purcell's[26] report on curve superelevation practices in California suggested that the criterion for safe speed was a side-friction factor of f = 0.16, independent of speed.

In Britain design practice was highly influenced by Royal-Dawson's[27] work in the 1930's. He thought that safe speeds should be determined more by the rate of change of radial acceleration during the transition to a circular path and not by the side-friction factor itself. He then proposed that superelevation should account for 40 per cent of the centrifugal force, i.e. f = 0.15, with a maximum superelevation e = 0.10. This remained the British practice until very recently.

The designing of road curves with the side-friction factor being used as a skidding criterion was soon thought to be an unsatisfactory process and research was directed towards the newly introduced approach where side-friction factor was considered as a comfort criterion.

Moyer[10] carried out the first extensive tests in 1934 to determine the side-friction factors actually developed at the front and the rear wheels of a car negotiating a curve and compared those values with the ones obtained from the mass-point design equation.

$$E + f = \frac{V^2}{127R}$$

He concluded from tests in which he drove blindfolded passengers around curves that at f = 0.3,

"...a decided side pitch was encountered by the driver and passenger which was distinctly uncomfortable."

He then suggested that safe speed should be calculated by means of f = 0.3 comfort criterion which can be achieved if the pavement is capable of supplying a coefficient of friction of 0.6 at 30 m.p.h. He later[28] reduced the value of f to 0.10 for practical purposes.

Barnett[12] followed Moyer's approach of a 'critical side pitch' when he summarised the results of a series of tests conducted in 1935 by the U.S. Bureau of Public Roads. He defined 'safe speed' on curves as:

"...the minimum speed at which the centrifugal force, created by the movement of a vehicle around the curve causes the driver or passenger to feel a side pitch outward."

He then continued:

"Skidding occurs at much higher speeds and it was felt, therefore, that an ample margin of safety against

skidding would be present at the speeds at which side pitch is first encountered."

Barnett's main hypotheses were:

(a) The maximum safe speed is the speed at which 'discomfort' is felt.

(b) This 'discomfort' is manifested by the feeling of a 'side pitch outward'.

(c) The feeling of side pitch is determined by the unbalanced side-friction.

He calculated side-friction factors from measured curvature and superelevation and by grouping observed speeds into 5 m.p.h. bands. They are shown plotted against speed in Figure 2.1. As averages, they do not show the magnitude of the variations within each group which could be greater than the variation of the averaged data which ranged from 0.7 to 0.20. Barnett suggested a maximum constant value of f = 0.16 up to a speed of 60 m.p.h., and then decreasing linearly. His results are difficult to justify and several of his subsequent findings contradicted the initial hypotheses. Figure 2.2 shows the results for three sets of observers under dry and wet weather conditions. Barnett justified the lower side-friction factor found for wet road conditions by saying that:

"The unexpected results may be attributed to the fact that the average observer is likely to be more alert on wet pavement and imagine he feels side pitch at lower speeds than those at which side pitch actually occurs."

Barnett's findings are in conflict with those of Wiley[29] who considered a range of curvature between 3 and 24 degrees. He found a considerable variation in side-friction factor values when plotted against speed in Figure 2.3(a), and also a high correlation between speed and radius, Figure 2.3(b), which indicated that superelevation had very little effect on the speeds. With regard to Barnett's 'safe speed' criterion Wiley reported that:

"The speeds at which side pitch first becomes noticeable are slower than necessary for comfort or safety."

He also suggested that a maximum value of f = 0.15 should be used for designing road curves.

Haile[30] discussing Barnett's paper suggested an alternative approach based on a decreasing relationship between speed and side-friction factor extracted from observed average side-friction data.

Two further points should also be noted in addition to the criticisms made on the above mentioned studies:

(a) Design recommendations were only made on the basis of average speed, with no account taken of higher percentile values.

(b) Even though very poor correlation existed between side-friction factor and speed, no effort was made to find a better alternative.

Moyer and Berry[31] reported on the use of a ball-bank indicator in providing road curves with advisory speed signs. A ball-bank indicator is a curved glass tube containing a steel ball and damping fluid. It is fixed laterally to the body of the car such that the 0 degree reading is obtained at a level position of the car. When the car is in a steady-state turn the ball-bank angle represents a measure of the unbalanced lateral force experienced by the occupants. Moyer and Berry initially recommended that the safe speeds for road curves should be determined by the '10^{o} criterion' where a 10 degree ball-bank angle corresponded to a value of f between 0.14 and 0.16. Later they modified that criterion to a 14 degree angle (f = 0.21) for speeds up to 20 m.p.h. and 12 degree angle (f = 0.18) for speeds between 25 and 30 m.p.h. The effect of the body roll was found to be small resulting in a maximum difference of 3 m.p.h. Moyer and Barry never gave any reasonable justification for the use of that technique but they simply stated that:

"It has generally been accepted by engineers who have conducted curve tests."

Meyer[32] also suggested a curvilinear relationship between speed and side-friction factor. It was based on Moyer and Berry's recommended ball-bank angles and the average body roll angles reported by Fox[33].

Stonex and Noble[34] reported on tests they carried out on the Pennsylvania Turnpike where a few automobiles in perfect mechanical condition were driven by highly skilled professional drivers around road curves following the path of the roadway as accurately as possible. Most road curves were flat and vehicle handling performance and drivers' comfort were tested at very high speeds. An average speed of 103 m.p.h. with a 'cornering ratio' (unbalanced centrifugal ratio) of 0.30 on a 3 degree curve and an average speed of 85 m.p.h. with a 'cornering ratio' of 0.39 on a 6 degree curve were observed. The authors did not feel that these values were suitable for average drivers and they recommended that, while designing new rapid highways, a cornering ratio of 0.10 should not be exceeded when the design speed was 70 m.p.h. or more.

Early design policies were highly influenced by Barnett's recommendation that a maximum constant value of f = 0.16 should be used in the design of road curves up to a design speed of 60 m.p.h.[13]. In 1954 the revised edition of AASHO's design policy[14] included a linear design relationship between speed and side-friction factor shown in Figure 2.4. The design relationship labelled 'Arisona' in that figure represented the practice of the Arizona Highway Department.

Describing the diagram shown in Figure 2.4 AASHO concluded:

"While some variation is noted, all are in agreement that the side-friction factor for high speed design should be

lower than for the low speed design. A recommended straight line relation, shown solid, is superimposed on the analyses curves. It provides a reasonably good margin of safety at the higher speeds and gives somewhat lower rates for the low design speeds than some other curves."

They justified the adoption of lower side-friction values at low speed levels by saying:

"The lower rates at the low speeds are desirable since drivers tend to overdrive low design speed highways."

The desired co-ordination between the design elements was thus accepted as not being continuous throughout the range of design speeds. Their 1965 revision retained the 1954 criteria without any change, except that the design speed range was extended to 80 m.p.h. and a maximum f = 0.11 was recommended.

In Australia the 1973 NAASRA(18) revised edition of the 'Policy for Geometric Design of Rural Roads' (Metric Units) extended the range of design speed to cover speeds from 40 k.p.h. to 130 k.p.h. The NAASRA and AASHO f values are almost identical with the exception that NAASRA values for speeds below 60 k.p.h. do not follow the linear form assumed in the American Policy.

These values were justified with regard to comfort as follows:

(a) *"The maximum value of f which most drivers will tolerate in negotiating a curve ranges from 0.19 at 40 k.p.h. to 0.11 at 130 k.p.h.*

(b) *"Passengers experience discomfort when f exceeds 0.19 if they are not restrained by seat belts."*

They also stated that the coefficient of friction at impending skid would vary with vehicle speed and would range from about 0.67 at 30 k.p.h. to about 0.30 at 110 k.p.h. No support for these values was given.

Very similar policies are adopted by the Country Roads Board in Victoria in the latest edition of their Road Design Manual(35). The only exception is that they recommended lower f values at high design speed levels.

In New South Wales, the Department of Main Roads(36), abandoned the use of the usual design speed concept following the results of a study on curves with radii between 250 and 1500 ft. Instead they recommended that the curve radius should be associated with a speed that a driver *"believes appropriate to the conditions as he sees them on the road"*(19). These values were taken to be the 85th percentile of the observed speed distributions. Side-friction factors were then calculated for a range of curve radii. Table 2.1 contains the details of the new practice. When these values were compared with those reported from the particular study it became obvious that the Department of Main Roads had chosen a lower percentile speed for design curves with radius less than 1000 ft. No reason had been given for this.

In Britain, the Ministry of Transport Manual(16) adopted Royal Dawson's(27) recommendations requiring a maximum side-friction factor of 0.15 to be used for designing road curves and suggested that superelevation should normally balance out 40 per cent of the centrifugal force.

The recently published Departmental Standard on Highway Link Design(17) retained Royal-Dawson's basic recommendation of applying a constant maximum side-friction value for the safe design of road curves. The change from the 1968 Policy is that three different minimum radii criteria are now defined, each corresponding to a constant value of lateral acceleration (V^2/R). Table 2.2 shows the minimum values of the geometric parameters which the Department recommends for a range of Design Speeds varying from 50 to 120 k.p.h.

Defining these criteria the Department states:

> *"The Design Speed bands 120, 100, 85 k.p.h. etc., dictate the minimum geometric parameters for the design, according to Table 3(2.2), which shows Desirable and Absolute Minimum Values. Desirable values represent the comfortable values dictated by the Design Speed, whilst Absolute Minimum values, which are acceptable using minimum dynamic parameters are identical to the Desirable values for one Design Speed step below the Design Speed. In the case of horizontal radius of curvature, however, there is an additional lower level which has been designated Limiting Radius, equivalent to a further step below the Design Speed."*

The maximum recommended superelevation for the 'Desirable Minimum' design level is restricted to 5 per cent with 7 per cent being recommended for the 'Absolute Minimum' and 'Limiting Radius' design levels. The corresponding f values are 0.06 for the 'Desirable Minimum', 0.09 for the 'Absolute Minimum' and 0.15 for the 'Limiting Radius' design level which is identical to the value recommended by Royal Dawson in 1932. The only variation between these recommendations is that the proportion of the sideways friction taken by superelevation is slightly different than the 40 per cent suggested by Royal-Dawson. It ranges from 44.9 per cent for the 'Desirable' and 'Absolute Minimum' to 31.8 per cent for the 'Limiting Radius'.

The justification given by the Department for adopting these specific f limiting-values is interesting:

> *"The V^2/R values shown in Table 3(2.2) simply represent a convenient means of identifying the relative levels of design parameters, irrespective of Design Speed."*

This returns to Barnett's[12] earlier suggestion that side-friction does not vary with speed and that a constant value of f can be safely used in the design of maximum curvature road curves.

In Germany, in the 1973 edition of the 'Guidelines for the Lay-Out of Land Roads' (RAL-L)[37] a curvilinear relationship between Design Speed and side-friction factor is used with f values ranging from 0.15 at 40 k.p.h. to 0.05 at 140 k.p.h. for the recommended maximum superelevation of 6 per cent. Table 2.3 shows the recommended minimum curve radii and maximum side-friction factors which are in use in West Germany. The 7 per cent superelevation limit is recommended only in difficult cases.

2.2.3.1 *Discussion*

The adequacy of the geometric design standards imposed by various road authorities has been criticised in the past by various investigators. Their work will be briefly mentioned in this section and will be sufficiently detailed in the second part of this chapter.

In their review of the AASHO[15] geometric design policy, Weinberg and Tharp[35] recommended a lowering of design speeds on the basis that the over-turning of trucks with high centres of gravity and the disparity between design speed and safe speed under icy conditions should be considered in curve design procedures. In general, they agreed with the AASHO f - V relationship used in road design stating:

> *"Having examined the typical lateral acceleration values used in highway design .... and the history of the development of current practice, there seems to be no reason to suggest any change."*

Glennon[21] carried out a more thorough examination of the state of knowledge in order to evaluate the validity of the design criteria for horizontal road curves recommended by the 1965 AASHO policy. Questioning the validity of the centripetal force equation and the adequacy of the design f values he made the following conclusions:

(a) *"It appears that minimum curve design standards do not provide an adequate factor of safety for the range in operational conditions encountered on our highways."*

(b) *"The standard centripetal force equation is reasonably valid if the curve radius is large relative to the dimensions of the vehicle. Its validity has not been substantiated for curves greater than 4 degrees."*

(c) *"The typical relationship between tyre-pavement friction capability and vehicle speed employed by the AASHO Policy has no objective relation to the actual highway conditions. Measurements made in one state indicate that only 55 per cent of the state's pavements satisfy this typical friction capability level."* (Figure 2.6)

(d) *"The use of friction demand design values that correspond to that point at which side forces cause driver discomfort has no objective factor of safety relationship to the side-friction capability of the tyre-pavement interface."*

(e) *"The AASHO Policy employs the explicit assumption that vehicles will follow the design path of the highway curve with geometric exactness. This assumption does not account for corrective manoeuvres that are occasionally found necessary when drivers have misjudged the degree of the highway curve."* (Figure 2.7.)

Emmerson(39) reporting on his work of passenger car speeds on six road curves with radii ranging from 70 to 1150 ft. noted that, for curve radii below 330 ft., 90 per cent of cars exceeded the value of 0.15 with a measurement as high as 0.45 being recorded. He concluded:

"On those curves with a much shorter radius, that is where design speeds are less than 40 m.p.h., the adoption of a much higher side-friction factor might be justified."

Good(40,41) carried out well controlled experiments with test drivers negotiating small radius test-curves. A main conclusion was that the correlation between vehicle speed and maximum lateral acceleration was very poor which, as he suggested, should raise questions about the validity of the current design practices. He also pointed out the inaccuracies that may occur from side-friction data averaged over a number of passengers, since, as he said, *"a different population of drivers is likely to be sampled in different speed ranges"*.

McLean(22) reporting on his research into vehicle speeds on two-lane rural curves in Australia suggested that f values computed by the centripetal force equation ($E + f = V^2/127R$) could only provide an estimate of the actual tyre-pavement friction being utilised by the vehicle. He justified his statement on the basis that highway curve and vehicle paths do not coincide, and that deviations of vehicle paths from road geometry are mainly dependent on the speeds adopted and the radii of the curves. It must be noted, however, that he did not conduct tests on actual paths and may have reached his conclusion in trying to explain the high variation found in his observed f data. McLean examined the validity of the design f-V relationship by comparing it to the observed 85th percentile as shown in Figure 2.8.

McLean also examined the adequacy of the safety level provided by the design policies. He compared observed vehicle operating speed with curve speed standard, the latter being regarded as the maximum speed at which a vehicle can negotiate a curve without exceeding the NAASRA(18) f criterion. This relationship is shown in Figure 2.9. He concluded:

"For curves with speed standards greater than about 90 k.p.h., 85th percentile car speeds tend to be less than the curve speed standard, while for curves of lower standard, 85th percentile car speeds tend to be in excess of the speed standard."

"Car 85th percentile side-friction factors show a a much more marked decrease with increasing 85th percentile speed than is assumed for the design side-friction factor vs design speed relationship. For 85th percentile curve speeds below about 90 k.p.h., the corresponding side-friction factors are in excess of the values assumed for design purposes."

"The reality of driver behaviour (for Australian drivers at least) is such that many drivers do operate with a very small friction safety margin on low standard curves."

2.2.4 Superelevation and Curvature Relationships

The railway practice of superelevating rail curves was initially adopted by road designers in the United States and in France in the early 1920's. In those early days there was a reasonable agreement as to the maximum superelevation which could be safely used, and superelevation of 1 in 16 was reported to be common practice.

It was reported from Minnesota(8) that it was common to provide maximum superelevation of 3/4 in. per foot of width for curves with curvature between 2 and 7 degrees in order that the superelevation should balance out the total centrifugal force developed at a speed of 27 m.p.h. For curves with curvature between 7 and 29 degrees, the maximum superelevation was selected so as to compensate for speeds decreasing uniformly from 27 to 12 m.p.h.

In Pennsylvania(42), designers used to superelevate road curves with radii ranging from 50 ft. to 30 ft. with an amount of superelevation varying from 12½ in. to 10 in. respectively for a standard 18 ft. road width.

Myers(43) suggested that each traffic lane should be superelevated in a parabolic rather than a plane manner and that the maximum superelevation applied should range between 1/2 and 3/4 in. per foot of width depending on the lateral position taken in the lane.

Leeming(24) was the first to argue that Britain should follow the United States and France in superelevating road curves. He recommended that curves should be superelevated to compensate for the total centrifugal force developed by vehicles travelling at 20 m.p.h. a figure he thought corresponded to an average traffic speed.

Young(12) following his recommendations on design speed argued that superelevation should be designed to balance out three-quarters of the design speed without the maximum available values being exceeded. He insisted on a maximum curvature allowance of 6.3 degrees and a maximum side-friction of 0.16 at the appropriate design speed level. As Good[4] commented in 1978, one consequence of this policy is that the superelevation applied to curves of the same radius would be different for road sections with different design speeds.

In 1936, Royal-Dawson[44,45] introduced his '0.4 rule' in which assuming a maximum superelevation of 0.10, the 'centrifugal ratio' should never exceed 0.25. He argued that by keeping the ratio between superelevation and 'centrifugal ratio' equal to 0.4, consistency in road design could be achieved. Royal-Dawson's basic concept was thus identical to Barnett's 'three-quarter' rule with the exception that superelevation would compensate for 63 per cent of the design speed and not 75 per cent as suggested by Barnett.

Stonex and Noble[34] writing on the Pennsylvania Turnpike test recommended the use of a maximum superelevation value of 0.10 with intermediate values being established on the basis of providing a 'reasonable' linear f-V relationship for each friction value assumed. They also made the following observation:

> *"...it has been observed that drivers of their own volition will generally develop higher friction values on highly superelevated curves than on curves with flat superelevation."*

They attributed this difference to the different sensation produced by varying body roll levels developed when travelling around road curves with different superelevation levels. Unfortunately, they never substantiated their statement with empirical evidence.

The first AASHO Policy gave no guidance as to how superelevation should be applied on road curves with different degrees of curvature. Only a maximum limit of 0.12 was suggested.

By contrast the AASHO's 1954 revised edition, which remained largely unchanged in the latest 1965 AASHO design Policy, contained an extensive discussion of superelevation/curvature relationships. The four different relationships discussed are shown in Figure 2.10 and have been described as:

1. *"Superelevation rate is directly proportional to the degree of curve.*

2. *"Superelevation rate is such that a vehicle travelling at design speed has all centrifugal force counteracted by superelevation on curves up to that requiring the maximum e(E), and maximum e(E) provided on all sharper curves."*

3. *"Same as method 2 except based on average running speed."*

4. *"Superelevation rate is in a curvilinear relation with the degree of curve, with values between those of methods 1 and 2."*

Figure 2.10(A) shows the relationships between curvature and superelevation. The relationships between the corresponding side-friction factor and curvature for vehicles travelling at design and at running speeds are shown in Figures 2.10(B) and 2.10(C) respectively. The basic merit of method 1 is its simplicity, as the Policy states:

> *"...its success depends upon each vehicle in the traffic stream maintaining a constant speed regardless of whether travel is upon a tangent, a curve of intermediate degree, or one with the maximum curvature for that design speed."*

This comment once more highlights the inadequacy of the design speed approach to design. Method 2 is the same as Young's[9] proposal, and method 3 is that originally adopted by Barnett[12]. The main disadvantage of both these approaches is that friction increases slightly up to about the middle point of the curvature range and then illogically rises very rapidly when curvature increases to an allowable maximum. Method 4 is a compromise between the second and the third methods ensuring a logical increase of the required friction as curvature increases up to a maximum value.

In Britain, the Ministry of Transport[16] stated that superelevation should balance out 40 per cent of the centrifugal force as in the original Royal-Dawson's '0.4 rule'. The implied linear relationship - AASHO method 1 - was also retained in their recent revision[17] with maximum superelevation of 7 per cent for the 'Limiting Radius' amd 'Absolute Minimum' values and 5 per cent for the 'Desirable Minimum' value. Also, as described earlier, the '0.4 rule' has been slightly altered to 0.32 for lower and 0.45 for higher curve designs.

In Victoria the CRB Manual[35] recommended the use of a curvilinear relationship between superelevation and curvature which for an unjustified reason produces lower superelevation values for a given design speed and curvature than those provided by the AASHO Policy.

The NAASRA Policy[18] does not recommend any specific method of providing superelevation over the entire curvature range but simply suggests that *"the maximum superelevation should range from 0.12 in mountainous terrain to 0.06 in flat country"*.

In New South Wales the Department of Main Roads[36] recommends the use of a maximum superelevation value of 0.07 for all curves with radii less than 1500 ft., decreasing proportionally with curvature for flatter curves in a way similar to AASHO's third method.

2.2.5 Pavement Skid Resistance

One of the basic requirements of the geometric design standards is to ensure that side-friction factors that are likely to be developed at a particular road curve will not exceed the friction level which the road pavement is expected to provide. It is not the purpose of the study to investigate this particular subject in detail but reference will be made to key studies so that comments on the magnitude of safety margins adopted by drivers can be made.

Pavement skid resistance is usually expressed as a skid number, or sideway-force coefficient. The values of these parameters depend on the method which is used but they are all approximately equal to the wet tyre-pavement coefficient of friction multiplied by 100.

Schulze and Beckman(46) measured the friction capability of 600 pavements in West Germany for a series of speeds. Their results, which were found to justify AASHO (1965) friction capability policy, are shown in Figure 2.11.

In 1967, Kummer and Meyer(47) recommended a set of 'minimum skid numbers' for American highways as a function of mean traffic speed. They range from 50 at 16 k.p.h. to 31 at 130 k.p.h. and as stated they were derived from a consideration of the technical and economic feasibility of achieving levels of skid resistance, the likely frictional demands of traffic and the existing practices within U.S. State Highway Departments. As can be seen from Table 2.4, they are generally lower than the target values of sideway-force coefficients proposed by the Marshall Committee(48). They are also lower than the sideway-force coefficient values measured in 1976 during a routine SCRIM carried out on the arterial road network in Victoria(22). Surprisingly, these values remained fairly constant over a range of speeds between 40 and 80 k.p.h. Although Kummer and Meyer's values can be regarded as a conservative estimate of friction capabilities of road pavements, the variations with respect to values of the other studies can be partly attributed to the difference in measurement techniques for skid number and sideway-force coefficient.

Glennon's(21) work on sideway-force coefficients, Figure 2.6, also considered the adequacy of the safety margin recommended by the design policies, especially in the case of high design speeds.

Finally, the relationship between sideway-force coefficient and speed for three different road surfaces under wet weather conditions in the Soviet Union produced by Babkov and Zaluga(49) is shown in Figure 2.12. It is interesting to note that for concrete pavements sideway-force coefficient decreases more rapidly with speed than for coarse textured surfaces.

2.3 PART II: EMPIRICAL VEHICLE/DRIVER BEHAVIOUR STUDIES ON ROAD CURVES

2.3.1 Introduction

It is clear from the earlier part of this chapter that horizontal alignment design policies have been developed without the aid of much direct observations of road user behaviour. Various investigators,such as Stonex and Noble(34), tried to incorporate the behaviour of road users, but failed to determine the dynamic interaction between the vehicle/driver combination and the road. Empirical studies of this dynamic interaction are reviewed in this section.

2.3.2 Speed Variation around Road Curves

Prior to 1950, empirical studies had concentrated on speed measurements taken at the mid point of a road curve, based on the assumption that vehicles negotiate curves at a constant speed. This assumption has been carried forward to current design policies.

Taragin[50] was the first to examine the validity of the constant speed design assumption by comparing vehicle speeds measured at several locations around a road curve. During the first phase of his work he sampled 15 horizontal curves in the State of New York, with curvatures ranging from 3 to 29 degrees and sight distances from 200 to 655 feet. Curve length ranged from 400 to 900 feet and in no case did the approach gradient exceed 3 per cent. There were also no sections where horizontal and vertical curvature were combined. Only speeds of free-flowing cars (i.e. those with time headways of 9 seconds or more) were recorded at 100 feet intervals over a distance of 1000 feet, starting 500 feet ahead of the centre of the curves and ending 500 feet beyond. The study curves did not have spiral transitions. The main conclusion that Taragin made was;

> *"Drivers of free-moving passenger cars do not change their speed appreciably after entering a horizontal curve even when the curvature is as sharp as 15 degrees. Most of the adjustment in speed that is made, whether because of the curvature, limited sight distance, or other reason, is made on the approach to the curve."*

Taragin did not present any measures of the approach and exit speed so that the extent of the speed adjustment before and after the curve can not be quantified.

Kneebone[51] reporting on a speed study before-and-after the erection of advisory signs at a road curve in New South Wales showed that vehicle speeds were not constant, but that there were small fluctuations with the minimum value at the centre of the curve (Figure 2.13).

Tharp and Harr[52] also observed variable speed distributions at three horizontal curves. On the two flatter curves (1270 feet and 1090 feet radius) they found that speed continued changing for a substantial distance inside the curves. No information was given about the exit speed but as Good[4] stated, if a symmetrical behaviour at the exit is assumed, then only 20 per cent of the total curve length would have been travelled at a constant speed. On the third curve with a radius of only 42 feet, a rather different speed pattern was observed, similar to that found by Leeming and Black's[53] vehicle behaviour study at sharp transitional curves. Vehicles entering the curve were decelerating to a minimum speed near the centre of the curve before accelerating to an almost constant speed near the exit tangent.

Studies of speeds adopted on horizontal curves were made at the Road Research Institute in Sweden from 1965 to 1967 with left-hand traffic conditions being the common feature. It was found that, in most cases, vehicle speeds were adjusted before the curve, and were then maintained at a constant level. Furthermore, the difference in speed between the vehicles travelling in the inner and outer traffic lanes was very small.

Contrary to these findings, Holmquist[54] reported from Sweden on studies made after the conversion to right-hand driving that:

> *"The speed adoption did not cease at the end of the straight road section, but continued after the entrance of the vehicle into the curve."*

He also observed symmetrical behaviour at the entrance and the exit sections of road curves, with constant speed between. The length of this central section where speeds were found to remain constant, was, on average, equal to one-quarter of the arc length of the curve, as Tharp and Harr[52] found in 1965. Good[4] commented that this fixed length proportion, taken to be irrespective of curve length, was highly improbable.

Neuhardt, Herrin and Rockwell[55] studied speed distributions over a section of road containing curves ranging in radius from 380 feet to 640 feet. Two groups of drivers were tested operating under different driving scenarios. Drivers operating under an emergency driving scenario reached a minimum speed near the centre of the curve, whereas more relaxed drivers reached that minimum speed some distance beyond the centre. In general, a continuous variation of forward speed was observed.

These findings were in close agreement with McLean's[56] comments about measurements made by the Department of Main Roads in New South Wales indicating that:

> *"...vehicles generally decelerated through the approach half of the curve, reaching their minimum speed on the departure side of the curve centre. Passenger cars tended to accelerate through the remainder of the curve, while commercial vehicles maintained minimum speed."*

Good and Joubert also studied the speed variations along curves with varying geometric characteristics in their vehicle/driver behaviour studies in free path turns[40] and in restricted path turns[41]. They found that:

> *"The speed distributions on many curves were symmetrical, involving continuous deceleration or acceleration. However, there were other curves for which the speed was consistently constant through the curve, constant through the circular curve, or followed an asymmetrical distribution."*

Typical speed distributions observed during the restricted path turn experiment are shown in Figure 2.14. It must be noted, however, that both these experiments were track-tests with a restricted number of test drivers, no sight restriction and mainly no opposing traffic. Results from the second track-test were calibrated by a later field test of driver/vehicle behaviour on intersection curves[57] where only four test drivers were used. In general, the same vehicle-driver behaviour was observed as in the restricted path turn track-test. All Good's test curves had spiral transition but details of the speed distributions around intersection curves were not presented.

No evidence was found for the British conditions which could be directly compared with the American and Australian studies already discussed.

The overall evidence thus indicates that Taragin's initial assumption that vehicle speeds are adjusted before a road curve is not valid in all cases and that there is some confusion about the form of the speed distribution adopted by drivers around road curves.

2.3.3 Relationships Between Speed, Road Geometry, Flow and Environment

Current horizontal alignment design practices, inherent in the design speed concept, suggest a relationship between side-friction factor and speed to be used for the determination of design elements. It has been suggested[19,22,40,41] that this relationship is not strong enough to be considered as a primary relationship in the design process and researchers have attempted to relate these two behavioural parameters, i.e. speed and side-friction factor, to geometric characteristics, mainly road curvature.

During the second phase on his work, Taragin[50] presented speed measurements at the minimum sight distance location on 35 two-lane rural highway curves with radii ranging from 200 feet to 2080 feet. Using least square analysis he fitted a straight line, a parabola and a hyperbola to the speed data for all individual locations. The linear relation between speed and curvature was found to give the best fit. He calculated the following equations for the mean, 90th percentile and the 95th speed percentile.

Speed (m.p.h.)		Equation*	Standard Error	r^2
Mean	=	46.26-0.749C	3.15	0.67
90th Percentile	=	55.22-0.909C	3.29	0.74
95th Percentile	=	58.46-1.000C	3.51	0.74

*C - Curvature

Taragin also found that sight distance had a slight effect, i.e. 1/3 of the curvature effect, on vehicle speeds on road curves and that superelevation had no effect at all.

In Britain, Charlesworth and Coburn[58] studied the effect of road curvature on vehicle speeds by recording space-mean speeds along 34 sections of relatively lightly trafficked roads in Buckinghamshire. They used average curvature (specified as the sum of the deflections of all the horizontal curves divided by the length of the section) instead of individual curvature, mainly because of its simplicity, accepting that it ignores the sharpness of individual curves. They concluded:

> *"After allowance had been made for the effect of other layout features, analysis showed that each 100 degrees of average curvature per mile accounted for 2.31 miles per hour reduction in mean speed. Further analysis showed that the effect on private cars was about twice as great as that on goods vehicles, the rates of proportion in mean speed being 3.07 and 1.67 miles per hour respectively for each 100 degrees of average curvature per mile."*

Oppenlander[59] developed a multivariate model to explain vehicular spot-speeds on two-lane American rural highways and considered a total of 49 independent variables as possibly affecting vehicle speeds. He concluded that the following multivariate equation best described the variation.

$$\begin{aligned} \text{Mean Spot Speed} = {} & 39.34+0.0267 \text{ (out of state car)} + \\ & + 0.1936 \text{ (truck combination)} - \\ & - 0.8125 \text{ (degrees of curve)} - 0.1126 \text{ (gradient)} + \\ & + 0.0007 \text{ (minimum sight distance)} + \\ & + 0.6444 \text{ (land width)} - 0.5451 \text{ (road side} \\ & \text{establishment)} - 0.0082 \text{ (total volume)}. \end{aligned}$$

Curvature was again found to be a main determinant of vehicle speed, with superelevation having no discernible effect.

Wortman[60] extended Oppenlander's multivariate approach to 4-lane rural highways. He analysed speed measurements obtained at 83 different study locations in Illinois, considering a total of 38 independent variables which were expected to affect vehicle speeds. Multivariate regression and factor analyses were used and the models derived for the prediction of mean spot-speeds were found to include eight independent variables other than road curvature. He recommended the following speed prediction model.

Mean Spot Speeds = 45.05+0.2046 (truck combination) + 0.009 (minimum sight distance) + 0.0930 (out of state passenger) +
+ 1.7419 (median type) - 1.4728 (presence of access control) -
- 0.4449 (number of roadside establishments) -
- 0.0511 (number of access points).

Curvature was not found to be significant, perhaps because of the small range of values for this variable.

Wahlgreen[61] developed a series of prediction models for running (space-mean) and spot (time-mean) speeds on two-lane highways in Finland. Contrary to other investigators, he found that sight distance was almost as powerful a speed determinant as average curvature. It is interesting to note here that, with the exception of one curve with a radius of 850m, the smallest curve radius considered was 1100m.

Mullin[19], reported on experiments conducted by the Department of Main Roads in New South Wales, in which speeds were measured at the centre of 21 curves with radii ranging from 250 feet to 1500 feet. The predominance of the curvature was taken as being the main criterion for site selection. Good[4] fitted the following linear regression model on the D.M.R.'s 85th percentile speed data which again shows curve radius to be the predominant speed determinant.

Speed (85th Percentile) = 1.767R/100 + 33.7 (r^2=0.83)

Superelevation was not found to have any significant effect on vehicle speeds.

Emmerson[62] conducted a 'controlled' experiment on cars on road curves by measuring car speeds at the centre of 12 road curves carefully selected so that curvature was the only factor expected to effect driving behaviour. By means of least squares regression analysis he fitted the following exponential relationship, shown in Figure 2.15, on the observed mean speed data.

Mean Speed (k.p.h.) = 74(1-exp(-0.017R)) (r^2=0.98)

Emmerson found that for curves of radii greater than 200m, curvature had little influence on speeds, whereas with radii less than 100m there were substantial reductions in speed. Concerning the choice of the exponential model Emmerson said:

"...has the advantages that the speed is zero when the radius is zero and that the speed tends to a constant value at large radii."

The first of these comments can be criticized as, in practice, no radii can be achieved which are tighter than that allowed by a vehicle's steering system. Zero speed should therefore ideally correspond to a finite, if small radius. The second comment concerning the tendency of speeds to 'level off'at large radii is clearly valid, as, the larger the radii the nearer the alignment becomes to a straight. Reflecting on the lack of studies of speeds on road curves in Britain, Emmerson made the further comment:

> *"...the predicted speed refers to the centre of the curve, but it is felt that until further research evidence is available it can be assumed that this speed is constant between tangent points."*

Homlquist[54] reported a 'close' relation between the maximum of travel time rate, 1/V, the reciprocal of speed, and the degree of curvature C, which was based on speed measurements obtained at 12 two-lane rural roads in Sweden. His formula was given as:

$$1/V = 1.5C+36$$

The curvature range and the 'goodness of fit' relationship were not specified.

O'Flaherty and Coombe[63,64,65,66] produced a series of spot-speed prediction models by applying 'stepdown' multivariate regression and factor analysis methods to speed data obtained at 85 different locations on two-lane rural roads in Britain. Four different vehicle groups were considered separately: free-moving cars, all free-moving vehicles, all cars and all vehicles in the traffic stream. A total of 45 independent variables were used in the analysis models. Road curvature varied from 0.0 to 14.91 degrees. Multiple regression and factor models were produced for the mean, standard deviation, 85th percentile and 95th percentile speed for each of the four vehicle groups, all of them indicating that the most important independent variables were those related to horizontal curvature and in particular the degree of curvature.

Neuhardt, Herrin and Rockwell[55] conducted a controlled study in the United States to investigate factors affecting driver/ behaviour on two-lane road curves and tangents. During the first stage of the study 11 test drivers made 10 runs on an 8-mile road section with varying geometry, and behavioural data was collected under the following driving scenarios:

Scenario A: Late for an important appointment;

Scenario B: No instructions;

Scenario C: Sunday drive.

In the second stage of the experiment, another 10 drivers made runs on a different route, 14 miles long, under scenarios A and C. Also 'low familiarity' and 'high familiarity' conditions with the test routes for scenarios A and C were tested. Simple linear regression models were fitted to the measured speeds. 'Effective curvature', C_E, which was defined as being the curvature of the actual vehicle path calculated from the measured maximum sprung-mass lateral body force per unit weight, vehicle speed and curve superelevation, was found to be a better vehicular speed determinant than the roadway curvature C_R, Table 2.5. In general vehicle speeds were found to be relatively unaffected by road curves with radii in excess of 700 feet. The variation of the minimum curve speed with the effective curvature is shown in Figure 2.16.

Despite the high correlation values shown in Table 2.5 it seems that a curvilinear model might have fitted the data better than the applied linear models.

McLean(56) applied simple bivariate regression models on Taragin's(50), DMR's(36) and Emmerson's(62) speed data in an attempt to find the most appropriate form for the vehicle speed/curvature relationship. The following four different models were tested:

(a) Linear regression between speed and curve radius;

(b) Curvilinear regression between speed and the square root of curve radius;

(c) Linear regression between speed and curvature;

(d) Exponential relationship between speed and curve radius of the form suggested by Emmerson.

The empirical relationships developed by McLean are listed in Table 2.6 and plotted in Figure 2.17.

It should be noted here that a meaningful comparison between the relationships developed cannot be made since they were conducted under different road, traffic and environmental conditions. Restricted sight distance was the common geometric feature in Taragin's study, whereas, in the other two studies, road curves were carefully selected to make curvature the main geometric factor affecting vehicle speeds.

Good(4) commenting on McLean's attempt to provide a single form for the speed/curvature relationship stated:

> *"It is likely that no single relationship will properly represent driver behaviour over the whole range of curvatures encountered on roads. Taragin's and Emmerson's models are attractive in that they directly account for the free speed on tangent sections of the road. However, the criteria which determine the speeds adopted on tangents and large radius curves may well be quite different from those applying at low speeds on curves of smaller radii. The 'appropriate' forms of relationship between speed and radius would correspondingly differ."*

In a comprehensive study in Australia, McLean(22,67) investigated the relationship between vehicle operating speeds and geometric parameters of road curves on two-lane rural roads in an attempt to produce various models that would predict driving behaviour on road curves as a function of curve geometry.

McLean carried out his study in two phases in keeping with Good's[4] assertion that a simple linear speed/curvature or radius relationship is unlikely to represent driving behaviour over the entire curvature range. Phase One concentrated on high standard curves (design speed standard 80 k.p.h. to 120 k.p.h. - NAASRA 1973), while Phase Two covered lower standard curves (design speed standard 40 k.p.h. to 80 k.p.h. - NAASRA 1973). Free-moving vehicle spot-speed measurements were taken at the middle of 120 directional road curves with curve radii ranging from 45m to 875m. Some speed measurements were also taken on level sections of the particular roads to identify desired speeds. Cars and goods vehicles were considered separately. Figure 2.18 shows percentile speed values of each vehicle class plotted against curve radius. It is obvious that speeds for both cars and goods vehicles become almost constant for curve radius in excess of 300m indicating that flatter curves do not affect driving behaviour in the same way as sharper curves.

Multivariate regression analysis was applied on the speed data in order to determine the variables that significantly influence vehicle speeds on curves. Desired speed of travel, being defined as the free-flowing speed on tangents, pertaining to the road section and curvature were found to primarily affect vehicle speeds on curves, whereas sight distance appeared to have only a marginal effect. Superelevation, verge width, pavement width and gradient were not found to significantly influence car speeds on road curves. Gradient had an effect on truck speeds.

As shown, Figure 2.9, the 85th percentile car speeds on low radius curves, design speeds less than 90 k.p.h., were found to exceed the standard curve speeds ($E + f = V^2/127R$ - NAASRA 1973), indicating that drivers accepted high side-friction values on the low radius curves.

Having shown the inadequacy of the design speed concept to represent actual driving behaviour over the entire curvature range, McLean developed a series of simplified linear regression models between the 85th percentile speed and the horizontal curve radius from which appropriate and more realistic design speed values could be calculated for a particular road environment. These simplified design speed / curve radius relationships for a range of desired speeds are listed in Table 2.7 and plotted in Figure 2.19. He none-the-less calculated maximum side-friction values, to be applied with the proposed low standard curve design method (curve speeds less than 90 k.p.h.) from a relationship obtained between 85th percentile side-friction and speed values.

For curve speeds above 90 k.p.h. McLean suggested that:

> *"...the concept of designing for a predicted 85th percentile speed is not in keeping with the purpose of high standard alignments. Here the objective is to provide high level of safety, comfort and convenience for a wide range of road users"*

Dietrich and Lindenmann[68] compared 'free travelling automobile' speeds on road curves measured on two-lane rural roads in Switzerland in 1965 and 1977 with the design speed V_p recommended by the Swiss Design Policy (SNV). They considered the 85th percentile speed for the speed comparison, shown in Figure 2.20.

Commenting on the differences between the measured speeds and the assumed design speeds they stated:

> *"The comparison of the 85% speeds 1965/1977 and the comparison, in turn, of these with the valid standards shows some of the problems in the development of speed behaviour in curves. For, instance, for a given radius of 120m the differences between design speed according to standards (SNV) and the one based on 1977 data (85% speeds) is 20 k.p.h. = a deviation of approximately 30% from today's valid standards."*

They found (Figure 2.20) that contrary to the 1965 results, in 1977 no direct connection between drivers speed and curve radius was found for radii greater than 100m. These findings were not substantiated by presenting the actual data points and the differences could be accounted for by different interpretation of two samples from the same population. Also, they did not specify whether the same site sample size was considered in 1965 and 1977.

Walawski[69] fitted simple linear regression models on mean, 85th and 98th percentile actual speed and curvature data obtained on two-lane rural roads in Poland. All the road curves considered were circular and distinction was made for upgrade and downgrade curves. The following models were obtained.

- horizontal curves on upgrades	- horizontal curves on downgrades
$V(50) = -0.90C + 61.48$	$V(50) = -0.75C + 60.71$
$V(85) = -1.32C + 74.44$	$V(85) = -1.21C + 73.56$
$V(98) = -2.19C + 90.12$	$V(98) = -2.11C + 89.70$

Figure 2.21 shows speed data plotted against curvature on upgrades and the fitted linear models. Correlation measures were not presented but, as the author stated, their comparison showed that the influence of the curvature of a horizontal curve on the variation of speed was greater for curves on upgrades than downgrades. This difference can be partially attributed to the hidden effects of positive gradient caused by the superior explanatory power of curvature.

The recommended Polish design relationships for f = 0.15 and f = 0.30 and an average superelevation of 0.035 are superimposed on Figure 2.21. These indicate that for a side-friction factor of 0.30, drivers were found not to exceed the assumed design speed. Where f = 0.15 the equality between the 85th percentile effective speed and the theoretical speed occurs at a radius of about 350 metres. This indicates once more the inadequacy of the design speed concept in the design of low radius curves.

In Britain, the Department of Transport[70,71] carried out an extensive study of speed/flow/geometry relationships on rural single, all purpose dual carriageways and rural motorways. In a similar manner to the earlier Charlesworth and Coburn[58] study, they considered curvature in average terms of bendiness, ignoring the sharpness of individual curves. Bendiness ranged between 0.0 and 216 degrees/km for single carriageways and between 0.0 and 120.0 degrees/km for all purpose dual carriageway sites. Gradient was expressed in terms of hilliness, being the sum of rises and falls divided by the length of the section, and ranged between 0 and 18 m/km for the single and 0 and 40m/km for the all purpose dual carriageway sites. The following multiple regression models were developed with light and heavy vehicles being treated separately.

	Single Carriageways	All Purpose Dual Carriageways
Light Vehicles	$V = 66+1.21W-0.04B-0.03H$	$V = 94-0.12B+0.28H_F$
Heavy Vehicles	$V = 65+1.18W-0.05B-0.21H$	$V = 79-0.10B-0.47H_R$

where
B = Bendiness (degrees/km)
H = Overall Hilliness (m/km)
H_R = Upgrade Hilliness (m/km)
H_F = Downgrade Hilliness (m/km)
W = Road Width (m)

Adjustments were recommended for verge width, wet weather, presence of intersection lay-bys and for motorways. It must be noted that the speeds considered in the study were journey speeds. Mean speeds of light and heavy vehicles plotted against bendiness for both single and dual carriageways are shown in Figures 2.22 and 2.23 and Figures 2.24 and 2.25 respectively. The straight lines fitted refer to different road widths. Surprisingly, on 10m single carriageways mean vehicle speed is found to increase with bendiness. Since the bendiness factor for these road sections varies only between 0 and about 40 degrees/km it can be suggested that this finding indicates that, above a certain limit, curvature does not strongly influence vehicle speeds. Furthermore, observed speed adjustments may be caused by geometric elements other than curvature or a combination of a number of factors. However, it should be noted that the average curvature does not account for the sharpness of individual curves and so these relationships can be of little help in studying behaviour of individual drivers on road curves.

The same approach was adopted in the Department's revised horizontal alignment design Policy[17] where design speed, being a close estimate of the 85th percentile journey speed under wet road conditions, is determined from a number of factors. These include an alignment constraint, A_c, being a measure of the quality of the section alignment, and a lay-out constraint, L_c, being a measure of the road cross section, verge width, and the number of accesses and junctions. Figure 2.26 shows the recommended design speed selection models in terms of A_c and L_c.

2.3.4 Relationships Between Side-Friction Factor and Radius or Speed

The inadequacy of the basic side-friction factor/speed design equation has been shown by various researchers in the past, some of whom have suggested that behavioural parameters such as side-friction factor should be determined from standard geometric elements such as radius or curvature.

McLean(22) produced f - V relationships, Figure 2.27, for Taragin's(50) 90th percentile and for the Department of Main Roads(36) mean speed data. He also presented the relationship between the 85th percentile side-friction factor and the 85th percentile car speed, Figure 2.28, from measurements obtained during the two phases of his work(22).

The weakness of these relationships is well demonstrated in these figures both visually by the data scatter and statistically by means of the coefficient of determination, r^2, given by McLean.

Several researchers have tried to overcome the deficiency described above by using test drivers in instrumented vehicles. This ensures better measurements of driving behaviour around road curves, but suffers from not being able to adequately represent the real population of drivers.

Ritchie, McCoy and Welde(72) conducted a series of tests in the United States to measure lateral accelerations and speeds on curves, adopted by 51 subjects who drove an instrumented vehicle over a 110 mile section of rural highway with instructions to drive normally. Ritchie et al. argued for an inverse relationship between side-friction factor and speed, Figure 2.29, as indicated by the data, to explain individual driver behaviour. In the analysis process drivers were grouped into five, 5 m.p.h. groups following a priority order of decreasing speed. The inadequacy of this method was pointed out by Good and Sweatman(73) who stated:

> *"There is a fundamental weakness in interpreting data averaged in this way as representative of individual behaviour, because the sample of drivers within each speed cell is likely to be different. The subdivision in 5 driver groups would reduce but not eliminate, this difficulty."*

Ritchie(74) using the same data and after testing three different f - V models proposed the following equation:

$$g = P - 0.168*(V/200-1)$$

where g = lateral acceleration in g's for V between 20 and 60 m.p.h.

P = 'personal variable constant' expressing g-tolerance

About 90 per cent of the P-values were stated as lying between 0.33g and 0.19g but no further explanation about the nature of P and the way it was calculated was given. Also Ritchie did not present the goodness of fit of the proposed f - V relationship.

In a subsequent article, Ritchie[75], considering what could be a valid criterion for driver speed selection on road curves said:

> *"It appears likely that the speed choice is a complex interrelation between personal, vehicle and roadway variables which provide the driver with a subjective estimate of safety or stability. Lateral acceler-tion appears to be a key variable in this judgement along with an increase in safety margin as speed increases."*

The latter was substantiated by McLean's[67] comparison, Figure 2.30, between observed and design (NAASRA - 1973) side-friction values and side-friction coefficients (CRB) plotted against a standard curve speeds calculated from the point-mass design equation $(E + f = V^2/127R)$.

Herrin and Neuhardt[73] proposed the following speed/lateral-acceleration trade-off model which, they believed, 'would encompass past observed relations'.

$$A/A_T = 1 - \exp[\beta(V_A - V)]$$

where A = Lateral Acceleration

A_T = Lateral Acceleration Tolerance

V_A = Aspiration Velocity

β = Constant, reflecting degree of driver expedience

When β takes large negative values the model indicates an unwillingness to trade speed for acceleration. For $\beta = 0$ a linear model similar to Ritchie[74] is obtained. The consistency of the model was examined by applying data collected from two groups of 10 drivers using an instrumented vehicle on different road sections and under different driving scenarios. Contrary to the definition of β, its highest value (-0.272) was found for relaxed drivers, travelling along a familiar route, whereas the lowest negative value (-0.084) was observed for fast drivers who were generally unfamiliar with the route. Although this inconsistency was not explained by the authors the overall results for 'relaxed' drivers unfamiliar with the particular route were very similar to those reported earlier by Taragin[50] and Ritchie et al.[72]. It must be noted again that averaged data was used to assess individual driver behaviour.

Good, Rolls and Joubert[40] examining the criteria which govern the selection of vehicle free-turning paths, conducted a series of steering tests where six drivers made free, easy and smooth turns on an airstrip with two intersecting runways of varying width. Different combinations of entry speed and deviation angles were tested. A single test car was used and its calibrated instrumentation produced continuous records of lateral acceleration, longitudinal acceleration, yaw rate (i.e. the rate of turn), steering wheel force and angle, distance travelled and vehicle forward speed. Four different longitudinal acceleration strategies, i.e. acceleration throughout turn, entering deceleration, constant speed throughout turn and deceleration throughout the turn were tested. The data analysis was directed towards providing answers to the following fundamental questions:

(a) *"Does the behaviour of the car/driver system in free turns at constant speed correspond with the assumptions of current design practice?"*

(b) *"If so, are the levels of lateral acceleration and jerk (rate of change of lateral acceleration) adopted by individual drivers the same for all vehicle speeds and deviation angles, thereby indicating that lateral acceleration and jerk have preferred values and are the factors determining the trajectory selected by the driver?"* and

(c) *"Alternatively, do the data suggest some other criteria by which drivers select their paths in free turns?"*

In the analysis process, lateral acceleration and yaw rate measurements were explained in terms of curvature, deviation angle and entry speed by means of regression techniques. Also, mean and 95th percentile side-friction factor data plotted against speed was compared with values recommended by current design policies. Drivers were found to develop higher f values than those recommended by design standards, when making free turns, Figure 2.31. This was partly attributed to the absence of lateral movement restriction imposed during the tests.

Lateral acceleration was not found to be a major determinant of the turning behaviour, whereas maximum yaw rate, which remained constant and independent of speed and deviation angle, was thought to affect the way in which free turns were made. No significant differences between right and left turns were observed, but entry jerks were found to be greater than exit contrary to Leeming and Black's[53] findings on the behaviour of drivers on transition curves. Good et al. concluded:

"...the results, if shown to be relevant to restricted path driving, have implications for the geometric design of highway loops and ramps, provision of visual information for the detection of yaw rate for night-

time driving and the design of vehicle lateral dynamics."

To evaluate the findings of the free-turn test Good and Joubert[41] carried out a similar experiment, but including lateral movement restrictions. Sixteen subjects drove an instrumented vehicle around a series of non-superelevated transitional curves, carefully set out on a runway and its associated taxiways, with varying curvature and deviation angles. Behavioural data was collected as in 1969, by means of calibrated instrumentation for two different driving scenarios, i.e. relaxing and fast driving. Contrary to previous findings no 'preferred yaw rate' was observed and the maximum yaw rate was found to increase with curvature and so remain constant with deviation angle. All the same no 'preferred lateral acceleration' was observed and in general maximum lateral acceleration was found to decrease with speed, Figure 2.32, for all individual trials.

When individual f data was aggregated and average values were plotted against speed an increasing f - V relationship was obtained, Figure 2.33, which as Good explained was mainly due to the fact that a different population of drivers was sampled for each speed level.

It was suggested by the authors that lateral acceleration values developed by drivers on road curves could be better related to the fixed independent geometric elements with which drivers are confronted. Percentile levels of side-friction demand derived from these relationships could be used in the design process in order to better represent driving behaviour. Figure 2.34 shows the f - R relationship obtained for relaxed and fast drivers respectively.

Entry transitions were found to be longer than exit transitions, which contradicted earlier findings. For tight radii curves with transitional curves, drivers 'cut the corner' so as to reduce the maximum curvature of the vehicle path. Thus the levelling-off of lateral accelerations for both high radii and high curvatures could be explained. Looking at the distribution of lateral acceleration around individual curves, the author observed dual peaks at critical points around those curves which had their circular section occupying 50 to 70 per cent of their total length. He associated that with the requirement to remain within restricted lateral boundaries. Comparing driver behaviour for the two different test scenarios Good found 'a remarkable repeatability' in behaviour with the only difference being the adoption of an overall higher speed and lateral acceleration level for the 'stressed' driving conditions (Figure 2 .34).

Good and Joubert's[40,41] elaborate tests were conducted with a limited number of subjects and may not, therefore have reflected 'real' driving conditions on the road. Drivers were aware that no opposing flow existed. Lateral movement was simply restricted by means of ordinary road marks used for curve setting out.

In an effort to validate their track-test findings Good and Joubert[57] carried out field tests of vehicle/driver behaviour on intersection curves. The vehicle/driver behaviour observed on intersection and interchange curves was generally consistent with that found in the restricted-path experiment, and a clear distinction was observed between the behaviour when lateral boundaries were present or absent. It should be noted, that in the later test radii ranged from 50 feet to 297 feet and speeds of less than 25 m.p.h. were achieved. The validity of the findings of the above experiments for the entire curvature range of open road curves therefore, remains questionable.

Good and Sweatman(73) reviewing strategies on road curves criticised the importance that had been given to lateral acceleration as the determinant of driver behaviour or comfort on road curves. Based on the observed 'preferred yaw rate' in free turns(40) and on the fact that different levels of side-friction factors are developed by drivers at different speeds, they suggested "*...perhaps they (drivers) are responding to a different motion variable, or combination of variables*". They proposed a behavioural model where drivers willing to limit their sideslip velocity, being equal to sideslip angle (angle between the vehicle heading and its direction of motion) multiplied by its forward speed, would have to adopt lateral acceleration values decreasing with increasing speed. However, they concluded:

> "*It seems reasonable that no single relationship will properly represent driver behaviour over the whole range of curvatures encountered on roads.*"

Dietrich and Lindenmann(68) reporting on speeds on road curves in Switzerland, compared, Figure 2.35, the observed 85th percentile f values, plotted against curve radius, with those recommended by the Swiss Standards (SNV). A decreasing f - R relationship was obtained indicating that below 400 metres radius drivers adopted f values considerably higher than those given in the design Policy. Unfortunately the goodness of fit of this relationship was not presented to substantiate Good's suggestion of relating f to a fixed geometry parameter instead of speed.

2.3.5 Vehicle Path

In his first speed study on sharp horizontal curves, Emmerson(39), assessing the possibility of an error existing between the measured curvature of the road centre-line and the vehicle path at the centre of the curve stated:

> "*It was found that many cars on curves of radius less than 500 feet sought to increase the curvature of their path by cutting the curve corner, and although those vehicles crossing the road centre-line were not recorded many other cars had shifts of 2 and 3 feet in lateral placement between the beginning of the curve and its centre...*"

Assuming circular curves and an average shift of 3 feet he found that the error between the actual and the geometric curvature ranged between 8 per cent and 58 per cent. Emmerson did not test the hypothesis that those shift were due to the absence, if any, of transitions.

Neuhardt, Herrin and Rockwell[55], whose work has already been detailed, found that the effective curvature of vehicle paths explained driving behaviour on horizontal curves better than roadway curvature. Effective curvature was also found to decrease with increased lane width and to increase with increased curve length.

Glennon and Weaver[77] recorded free-flowing vehicle paths around five non-spiral road curves ranging in curvature from 2 to 7 degrees and with superelevation varying from 0.04 to 0.08. Car-following techniques and cine photography were used for data collection. Forward speed and lateral location measurements were analysed by means of a special purpose analysis projector. It was found that at the point of maximum lateral acceleration, which in almost all cases was found to coincide with the point of maximum speed or the point of minimum path radius or both, vehicle path curvature exceeded the centre line curvature of the road. The following regression equations between the roadway curvature (D) and the vehicle path curvature (D_V) were determined.

Vehicle Path Degree Greater than D_V (Per cent)	Equation	Coefficient of Determination
0	$D_V = 2.427+1.057D$	0.930
5	$D_V = 0.984+1.165D$	0.985
10	$D_V = 1.014+1.128D$	0.984
15	$D_V = 0.984+1.124D$	0.983
50	$D_V = 0.796+1.030D$	0.991
100	$D_V = 0.474+0.919D$	0.986

Based on these findings, the authors proposed a new approach to curve design depending on the selection of *"(i) an appropriate vehicle path percentile relation, (ii) a reasonable safety margin to account for unexplained variables achieved by either raising the lateral force demand or lowering the available skid resistance, and (iii) a minimum skid resistance versus speed relationship that the highway department will provide on all pavements"*.

Substituting percentile vehicle path radius (R_V) with the roadway radius (R) in the conventional point-mass equation they derived the following formula which was used in their new approach:

$$E + f = 7.86R + 4.030$$

Assuming a superelevation rate at the beginning and end of a road curve equal to 0.7E and substituting f with the skid number SN_V divided by 100 minus a safety margin (M_S) they derived the following formula for the calculation of R:

$$R = -514 + \frac{V^2}{5.48E + 7.86(0.015N_V - M_S)}$$

However, the authors considered the application of the new approach difficult because it required a safety margin and a typical skid resistance/speed relationship. Glennon and Weaver also found that in many cases, the highest side-friction factor demands were made in the first or last quarter of the curve, which was then attributed to the absence of transitions.

Lyford[78] conducted a study *"to determine the feasibility of transition curves in horizontal alignment, as measured by changes in vehicle placement on a curve"*. Using cine-photography Lyford recorded vehicle tragectories on rather flat horizontal curves, ranging in curvature between 0.5 to 5 degrees and with almost identical geometric characteristics.

Curves were classified into four different groups according to their degree of curvature and pavement width. Vehicle path and speed were recorded for each curve at four different positions, identified as A, B, C and D, Figure 2.36, and at 11 stations at every individual position.

Only free-flowing vehicles were considered, selected with criteria similar to Taragin[50], i.e. 6 seconds or more separation from the following vehicle and 10 seconds before and 5 seconds after a vehicle travelling in the opposite direction. A complicated split-plot statistical model was used for the analysis of the data and after an extremely elaborate analysis the author concluded:

> *"The study showed that the paths of vehicles are affected by the use of spirals on horizontal curves. Vehicles were found to traverse a non-spiral curve with more constant lateral placement from the centre-line than they did a spiralled curve .... truck combinations travel further from the centre-line on a horizontal curve than do automobiles or single unit trucks. The paths of vehicles relative to the roadway centre-line are different for entering and leaving a curve and for the inside and outside of the curve, and the degree of curve affects the lateral placement of vehicles."*

Good[4] strongly criticised Lyford's work on the basis that (a) for the positions A and C, station 1 to 11 are numbered during the transition from tangent to curve, whereas for the positions B and D, the station numbers increase during the transition from curve to tangent; and (b) completely contradictory results were obtained when vehicle placement data was averaged for all groups and positions and plotted against the station sequences without regard to the direction of movement, Figure 2.37 , compared to those taken from less comprehensive plots where lateral placement data was plotted against station of measurement with reference to different groups, Figure 2.38, and to the direction of travel, Figure 2.39.

Vehicles seemed to move towards the centre of curvature when entering a curve and to move away from it during the exit transitions. This is a phenomenon similar to the 'corner cutting'[41] or to shifting laterally[39], usually generated by the transition. Lyford did not consider the effects of transition curves. He also stated that the paths of vehicles were different for each curve type and group for horizontal curves of three to five degrees but this was not justified. Lyford also did not examine the possibility that vehicle path could vary according to vehicle entry speed.

2.4 CONCLUSIONS

The objective of this review was to identify the extent to which vehicle/driver behaviour around road curves has been investigated in the past. It is apparent that although most of the design concepts were defined in the first half of the century, experimental work on the dynamic interaction between vehicle/driver and road geometry did not start until the early 1950's. Overall, the following main conclusions were drawn:

a. The design speed concept has been found to be a poor representation of actual speeds adopted by drivers on road curves[4,22,40,41,57,73]. The intention of most current design policies has been to provide a road that is safe and comfortable for travel at a uniform speed, by co-ordinating various elements such as curvature, superelevation, and sight distance[15,18,35,37]. However, there has been evidence[4,22,40,41,57,73] that designs determined in this way do not necessarily ensure consistency, especially for low geometric standards[22,41,68]. Operating speeds vary along road links and have been found to be considerably in excess of the assumed design speeds on low radius curves[22,41,67,68,69]. This problem, that design criteria derived from a design speed may not always be adequate for the actual speeds experienced, has been recognised by various road authorities such as AASHO[15]. The lower f values have been adopted by AASHO for low speeds because 'drivers tend to over-drive low design speed highways'. It has been suggested[22,41,73] that a comprehensive model which would allow prediction of speeds from the geometric characteristics, road class, surface properties and environmental data could lead to a more realistic design of low speed roads in particular.

b. The current approach to 'safe speeds' on road curves is to assume a 'safe and comfortable' relationship between side-friction factor and design speed. The concept of a safe f value was first introduced by Barnett[12] who proposed a constant maximum f value over a range of design speeds. That approach was later modified by other investigators and road authorities[15,28,30], but the resulted relationships were found to be based on unreliable or irrelevant information[4,22,41]. The existence and validity of the assumed relationships have been widely criticised in the past[4,22,41,57,67] particularly for the higher curvature situations where vehicle speeds and lateral accelerations have been found to exceed design values. Recent studies[22,36,67] have indicated that drivers adopt their own safety margins at each particular road curve and that design practices should be altered to account more for the actual interactions between the vehicle/driver combination and road geometry.

c. There have been relatively few observations of the way in which vehicle speeds vary around road curves, especially in the U.K., and the results have not been consistent. Taragin[50] suggested that drivers adjusted their speed before a curve entry although subsequent reports indicated a varying performance depending on curve radius, with minimum speed values occurring before, at, or after the mid point of the curve[40,41,51,54,57]. Others[52,54] showed that speeds remained constant over a specified portion of the curve length (i.e. 20 or 25 per cent). There have been no recent major studies to investigate speed variation around road curves over a wide range of geometric, traffic and environmental conditions.

d. The standard design centripetal force equation ($E+f = V^2/127R$) assumes that vehicle speed remains constant throughout a curve, that actual lateral acceleration is always lower than the design 'safe' value, and that the actual vehicle path coincides with the centre-line of the road curve. Deficiencies in the first two assumptions have been discussed above. The validity of the third assumption has not been adequately investigated mainly because of technical difficulties in the collection and analysis of appropriate information. Glennon and Weaver[77] suggested that this assumption is valid only for large radius curves (i.e. $C < 4.0$ degrees). There is also some evidence to suggest that drivers adopt a 'cut the corner' driving behaviour around low radius curves to reduce the maximum curvature of the vehicle path, and reduce lateral forces (see (i) below). However, the importance and the extent of the differences between vehicle path and the geometry of the centre-line of the curve has not been examined in much detail over a wider range of road curvature.

e. Curvature has been shown to be a major determinant of speed at the mid point of curves on single carriageway curves[4,22,40,41,50,54,55,59,62,63,68]. Its predominance has however been questioned by a recent Australian study[22,67] in which desired speed was found to explain more of the speed variation at the centre of road curves than curvature. The influence of other geometric, traffic and environmental parameters on curve mid point speeds have also been studied in the past by means of multiple regression and factor analysis techniques[50,58,59,60,61,64,65,66,70,71]. Elements such as sight distance, gradient, traffic flow and verge or road width have been found to explain only small proportions of speed variability, with curvature being the major speed determinant. Superelevation appeared not to have a significant effect.

f. There have been a number of relationships proposed to describe the variation in speed with curve radius(50,56,62), but none seems to be wholly satisfactory. All have suggested that mid-point speeds vary significantly with curve radius up to a certain radius level becoming more constant for larger radii. For that reason it has been suggested (4,22,73) that no single relationship is likely to properly represent driving behaviour over the whole curvature range encountered and that drivers use different criteria for selecting speed on short and large radius curves.

g. The correlation obtained for the basic design relationship f-V(4,9,15,22,41) has generally been found to be poor. Additionally, in most studies, investigators have attempted to draw conclusions concerning invididual driver behaviour from f-V relationships obtained after using averaged data over a large sample of drivers. The inadequacy of the above relationship has led to suggestions that the side-friction factor should be related to fixed geometric parameters and not to speed. However, the f-V relationship can be useful to designers for comparison of the variation of the road surface capabilities with speed.

h. The review of literature has shown that road surface friction capability reduces as speed increases particularly for low speeds. The exact form of the relationship is mainly dependent on the road surface conditions and varies with pavement materials(22,46,47,48,49).

i. Studies of lateral placement of vehicles(39,41,55,57,77,78) have shown that path radius and the radius of the centreline of the carriageway do not necessarily coincide. On short radius curves drivers tend to 'cut the corner' reducing maximum path curvature, and consequently the lateral forces that apply. A more consistent behaviour has been observed on larger radius curves with maximum vehicle path curvatures frequently exceeding the roadway curvature. A study(78) comparing vehicle lateral placement on transition and unspiralled curves concluded that more consistent behaviour was achieved on the latter although the conclusions did not seem justified.

j. Studies of behaviour on low radius curves have shown asymmetrical lateral acceleration distributions around road curves(40,41,53,57), with higher lateral jerk (rate of change of lateral acceleration) observed on the exits.

k. There appears to be a lack of uniformity in some of the main areas in the curve design practice between the various current policies examined. The most outstanding differences observed are those of the definition of Design Speed and of the form of the f-V relationship. In the American Policy[15] design speed is still used as a 'design procedure' directed at providing consistent and co-ordinated alignment. They have also adopted a linearly decreasing f-V relationship for the determination of minimum curvature. The current NAASRA[18] and CRB[35] policies for rural road design are largely modelled on the American policy with some differences of detail. The DMR's policy does not use the design speed approach but utilises a speed/radius relationship to relate design values of speed dependent parameters to horizontal radius. DMR's approach is basically similar to Barnett's original approach[12]. The main difference is that the validity of Barnett's concept was dependent upon drivers adopting an approximately uniform speed, whereas the DMR approach allows speeds to vary along the road according to the standard of horizontal alignment. The new British Design Policy[17] has adopted Barnett's original design speed approach with the determination of design speed being based on 85th percentile car speeds under wet conditions predicted from the geometric properties of the road, road class and roadside characteristics. Minimum curvatures and safe speeds, however, are calculated by means of a constant f-V relationship over the entire speed range considered. This is similar to the old Royal-Dawson[27,44,45] practice which is in contradiction to the findings of recent studies. However, as the Departmental Standard states:

> *"The various values quoted in this Standard are not, therefore, to be regarded as inviolable, but departures should be assessed in terms of their effects on economic performance, the environment, and the road user."*

Finally, the German Policy[37] uses the same design speed approach as the new British Standard with a decreasing f-V relationship for the determination of minimum curvatures.

Summarising the available literature on vehicle/driver behaviour on road curves it becomes obvious that a considerable amount of work is required to fill in gaps in our existing knowledge. The key areas where information is lacking are briefly listed below:-

a. The effects of road curve geometry, traffic and environment characteristics on vehicle/driver behaviour on dual carriageways.

b. The behavioural characteristics of goods vehicles around road curves.

c. The effects of combined geometric elements on vehicle/driver behaviour.

d. The effects of curve geometry on entry speed on both single and dual carriageway curves.

e. Finally, most of the relevant studies reviewed have been conducted in either the U.S.A. or Australia. Driving behaviour in Britain is not necessarily identical to that of the countries mentioned above. There has been no major study in this country on the effects of curve geometry traffic and environmental characteristics on vehicle speeds around road curves.

TABLE 2.1: SPEED MEASUREMENTS BY THE DEPARTMENT OF MAIN ROADS (36)

Radius (ft)	Number of Curves	85th Percentile Speed (mile/h)	Mean Friction Factor
250	2	37.0	0.32
300-325	3	38.0	0.24
370	1	39.0	0.21
600	1	45.5	0.18
700	2	48.0	0.14
800	3	50.0	0.18
1000	3	54.0	0.16
1100	1	48.5	0.12
1200	2	55.0	0.11
1400	1	58.0	0.13
1500	2	60.5	0.11

TABLE 2.2: MINIMUM VALUES OF ROAD ALIGNMENT DESIGN ELEMENTS (17)

DESIGN SPEED kph.	120	100	85	70	60	50	V^2/R
A. STOPPING SIGHT DISTANCE m.							
A1 Desirable Minimum	300	225	165	125	95	70	
A2 Absolute Minimum	225	165	125	95	70	50	
B. HORIZONTAL CURVATURE m.							
B1 Minimum R * without elimination of Adverse Camber and Transitions	2880	2040	1440	1020	720	510	5
B2 Minimum R * with Superelevation of 2.5%	2040	1440	1020	720	510	360	7.07
B3 " " " " " 3.5%	1440	1020	720	510	360	255	10
B4 Desirable Minimum R " " 5%	1020	720	510	360	255	180	14.14
B5 Absolute Minimum R " " 7%	720	510	360	255	180	127	20
B6 Limiting Radius " " 7% at sites of special difficulty (Category B Design Speeds only)	510	360	255	180	127	90	28.28
C. VERTICAL CURVATURE							
C1 FOSD Overtaking Crest K Value	*	400	285	200	142	100	
C2 Desirable Minimum * Crest K Value	185	105	59	33	19	11	
C3 Absolute Minimum " " "	105	59	33	19	11	6.5	
C4 Absolute Minimum Sag K Value	37	26	20	20	20	13.5	
D. OVERTAKING SIGHT DISTANCE							
D1 Full Overtaking Sight Distance FOSD m.	*	580	490	410	345	290	

TABLE 2.3: LIMITING RADIUS AND SIDE-FRICTION FACTOR VALUES (37)

SPEED (k.p.h.)	RADIUS (m)	f^1 (g)	f^2 (g)
40	60	0.15	0.14
60	160	0.12	0.11
80	350	0.08	0.07
100	600	0.07	0.06
120	1000	0.05	0.04
140	1400	0.05	0.04

^{1}E=0.06 ^{2}E=0.07

TABLE 2.4: SUGGESTED TARGET VALUES FOR SIDEWAY FORCE COEFFICIENT PROPOSED BY THE MARSHALL COMMITTEE (48)

Category of site	Type of site	Sideway Force Coefficient	
		Test speed km/h (mile/h)	SFC
A	Most difficult sites: (i) roundabouts (ii) bends with radius less than 150 m (500 ft) on unrestricted roads (iii) gradients of 5% (1 in 20) or steeper or longer than 100 m (330 ft) (iv) approaches to traffic signals on unrestricted roads	50 (30)	0.55
B	Average sites: (i) Motorways and other high-speed roads, i.e. speeds in excess of 95 km/h (60 mile/h) (ii) trunk and principal roads, and other roads with more than 200 vehicles per day in urban areas (sum in both directions)	50 (30) 80 (50) 50 (30)	0.50 0.45 0.50
C	Other sites: Straight roads with easy gradients and curves without junctions and free from any feature such as mixed traffic especially liable to create conditions of emergency	50 (30)	0.40

TABLE 2.5: SPEED/CURVATURE REGRESSION EQUATIONS (55)

Scenario-Familiarity	Correlation Improvements with C_E on Route 315 Roadway Curvature	r^2	Effective Curvature	r^2
A—High	$V = 70.4 - 1.41\ C_R$	.66	$V = 70.3 - 1.29\ C_E$	.90
A—Low	$V = 64.0 - 1.19\ C_R$	.52	$V = 64.6 - 1.19\ C_E$	.87
B—Average	$V = 58.2 - 0.98\ C_R$	.57	$V = 58.4 - 0.94\ C_E$	.86
C—High	$V = 51.6 - 0.55\ C_R$	.43	$V = 52.1 - 0.58\ C_E$	.84
C—Low	$V = 50.7 - 0.80\ C_R$	.52	$V = 50.8 - 0.76\ C_E$	.77

Set	Correlation Improvements with C_E on Route 257 With Roadway Curvature	r^2	With Effective Curvature	r^2
A—Low	$V = 69.1 - 1.62\ C_R$	.82	$V = 66.7 - 1.36\ C_E$	.89
C—Low	$V = 46.4 - 0.65\ C_R$	.62	$V = 45.7 - 0.58\ C_E$	.75

TABLE 2.6: EMPIRICAL SPEED/CURVATURE RELATIONSHIPS (56)

Independent variable	Taragin, 90th percentile speed (km/h)	Dependent variable DMR, 85th percentile speed (km/h)	Emmerson median speed (km/h)
Curve radius R (m)	$59.1 + 0.065R$ $r^2 = 0.59$	$52.3 + 0.098R$ $r^2 = 0.91$	$40.8 + 0.097R$ $r^2 = 0.77$
$\sqrt{R}$	$43.2 + 2.10\sqrt{R}$ $r^2 = 0.67$	$31.7 + 2.95\sqrt{R}$ $r^2 = 0.90$	$25.9 + 2.62\sqrt{R}$ $r^2 = 0.88$
Curvature C (deg/100 m)	$89.4 - 0.45C$ $r^2 = 0.74$	$93.1 - 0.55C$ $r^2 = 0.73$	$73.7 - 0.19C$ $r^2 = 0.87$
Exponential $Vo(1 - \exp - BR)$	$83(1 - \exp - 0.014R)$ $r^2 = 0.73$	$89(1 - \exp - 0.01R)$ $r^2 = 0.71$	$74(1 - \exp - 0.017R)$ $r^2 = 0.95$

TABLE 2.7: 85TH PERCENTILE SPEED PREDICTION RELATIONSHIPS FOR A RANGE OF DESIRED SPEEDS[22]

Desired speed	Speed Prediction Relationship
60	60 - .380C
70	69 - .715C
80	77 - 1.05C
90	85 - 1.41C
100	95 - 1.96C
110	105 - 2.82C
120	115 - 3.94C

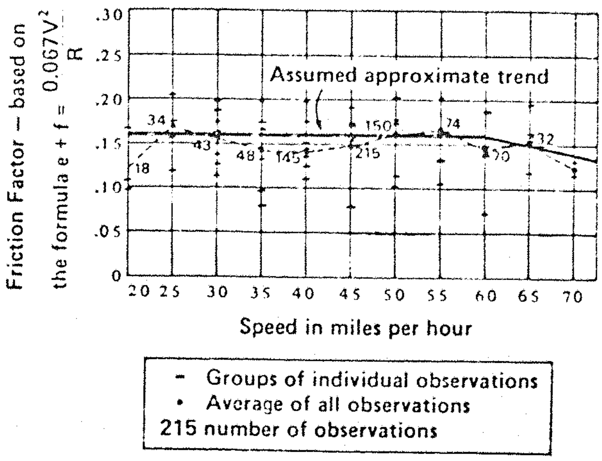


Figure 2.1: Average Side-Friction Factor when Side Pitch is noticed(12)

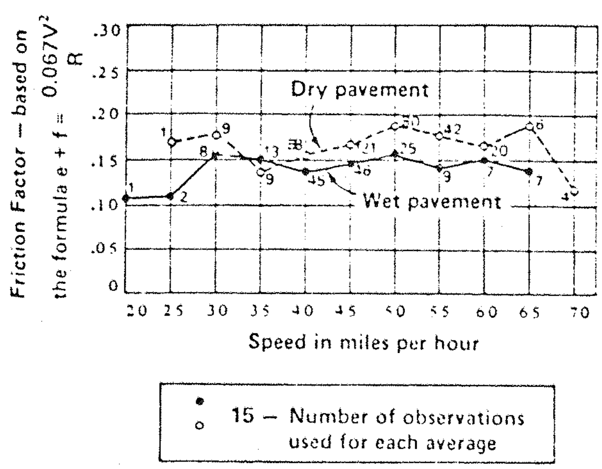
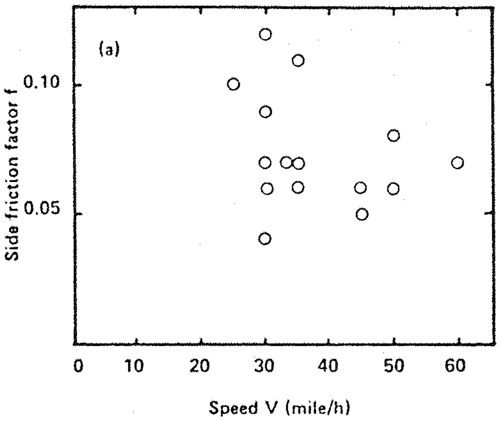


Figure 2.2: Average Side-Friction Factor when Side Pitch is noticed. Dry versus Wet Pavements(12)



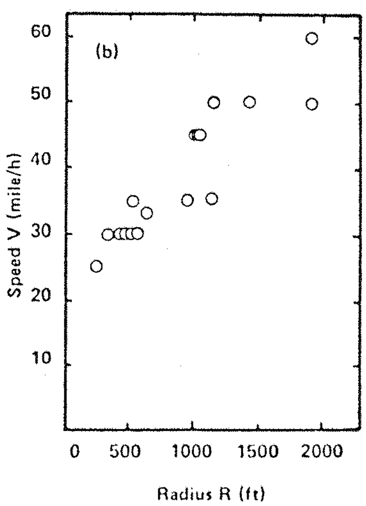


Figure 2.3: Safe Speeds; (a) Side-Friction Factor at which Side Pitch is noticed (b) Speed at which Side Pitch is noticed(29)

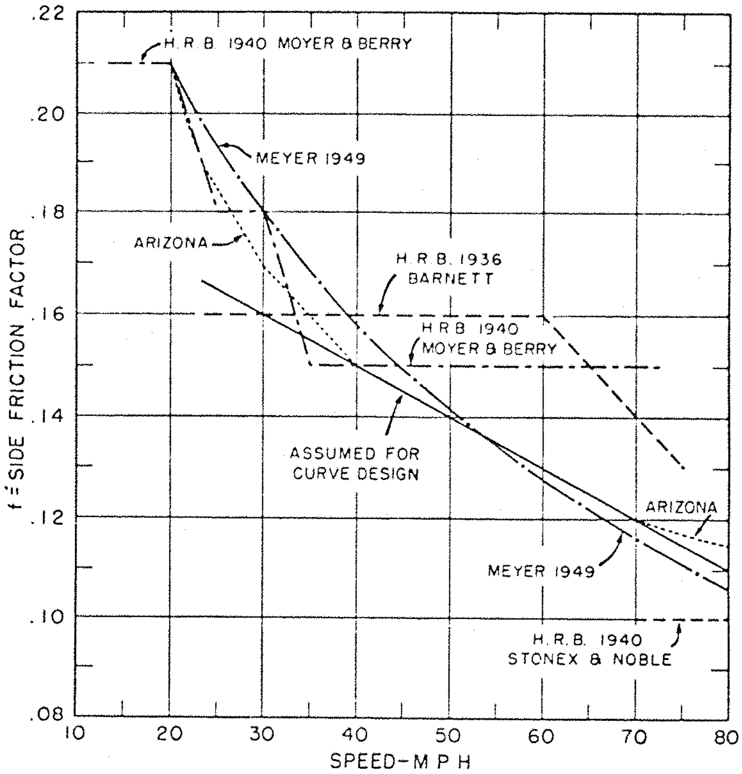


Figure 2.4: Maximum Safe Side Friction-Factor Values(15)

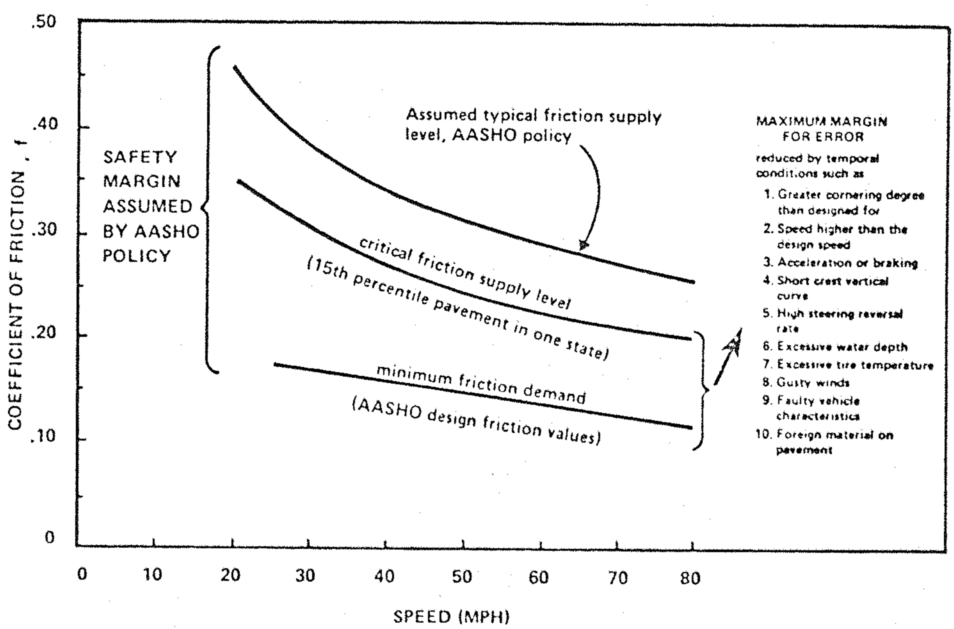


Figure 2.5: Evaluation of the Factor of Safety Employed in Horizontal Curve Design(21)

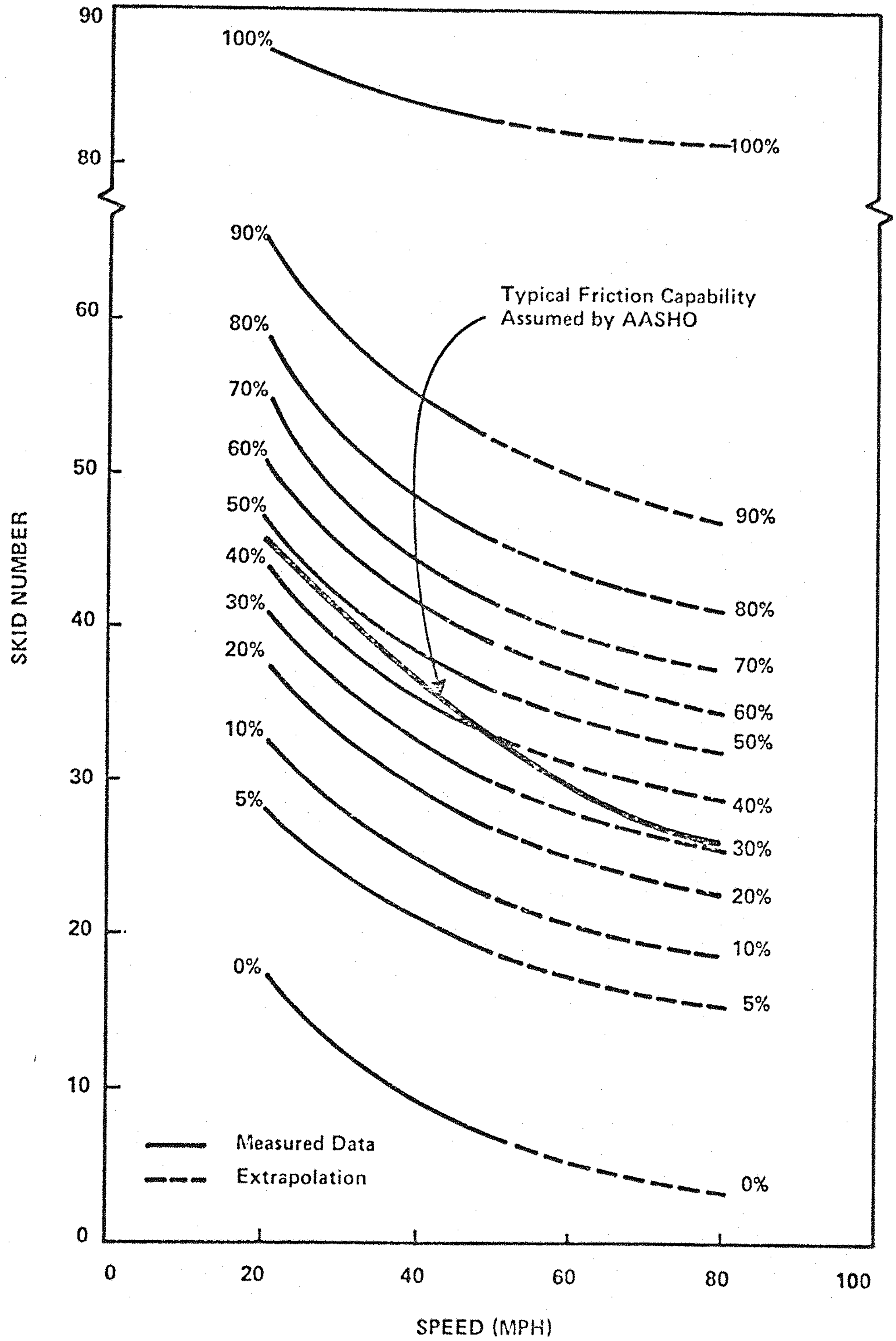


Figure 2.6: Percentile Distribution of Relation between Friction Capability and Vehicle Speed for 500 Pavements in One State[21].

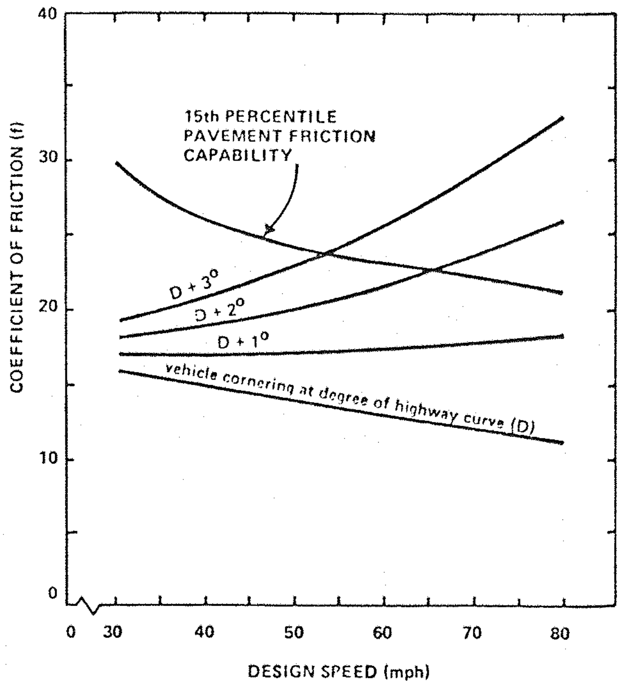


Figure 2.7: Friction Demand Related to Degree of Cornering for Various Design Speed Highway Curves (E=0.08)[21]

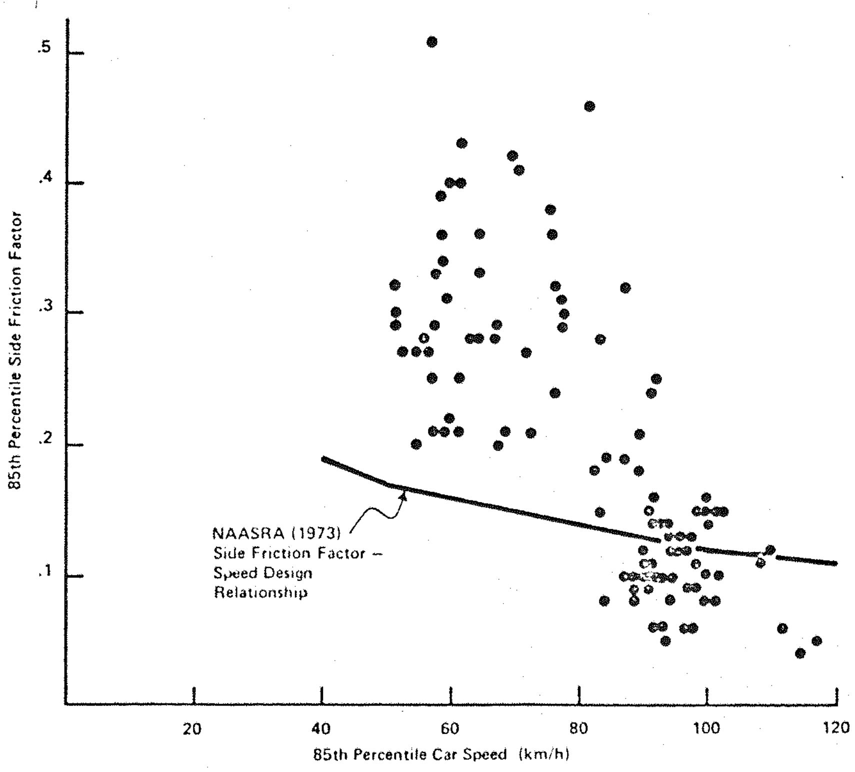


Figure 2.8: Percentile Car Side-Friction Factor against 85th Percentile Car Speed[22]

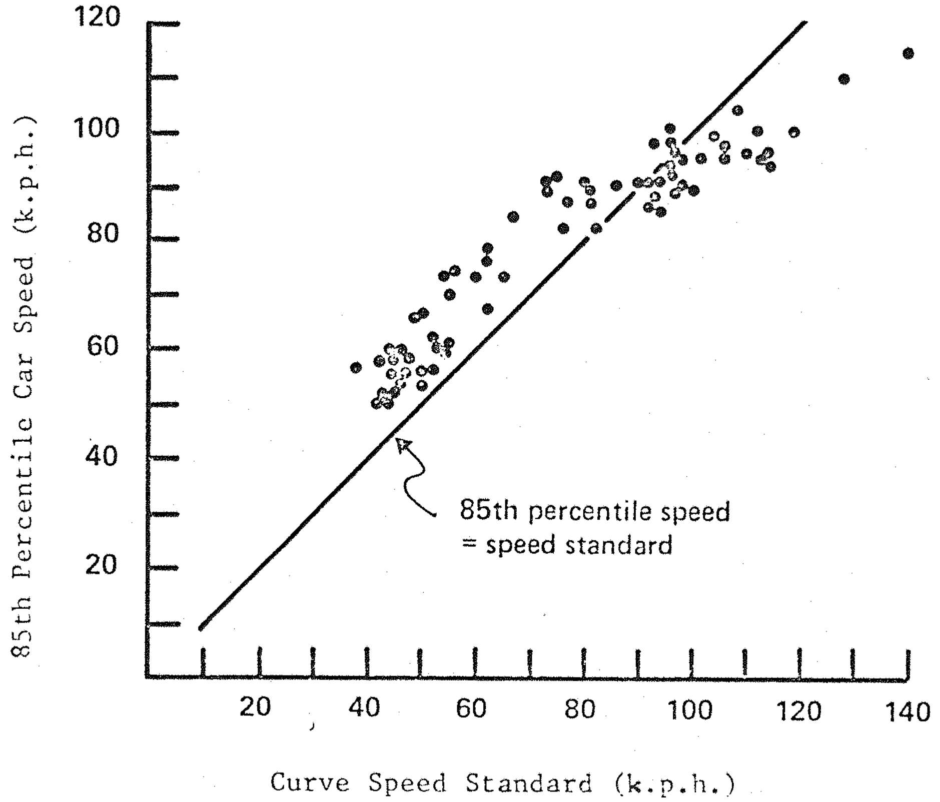


Figure 2.9: 85th Percentile Car Curve Speed against Curve Speed Standard(22)

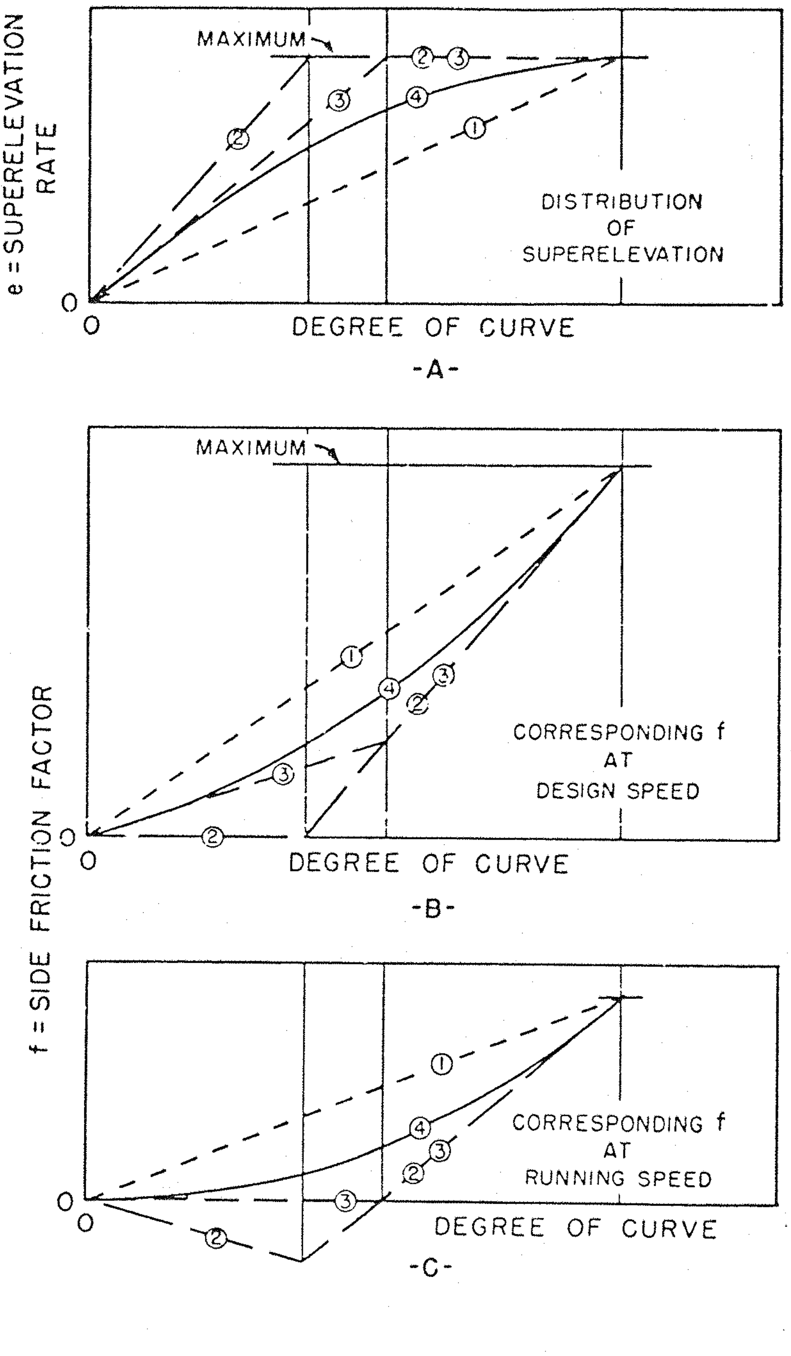


Figure 2.10: Methods of Distributing Superelevation[15]

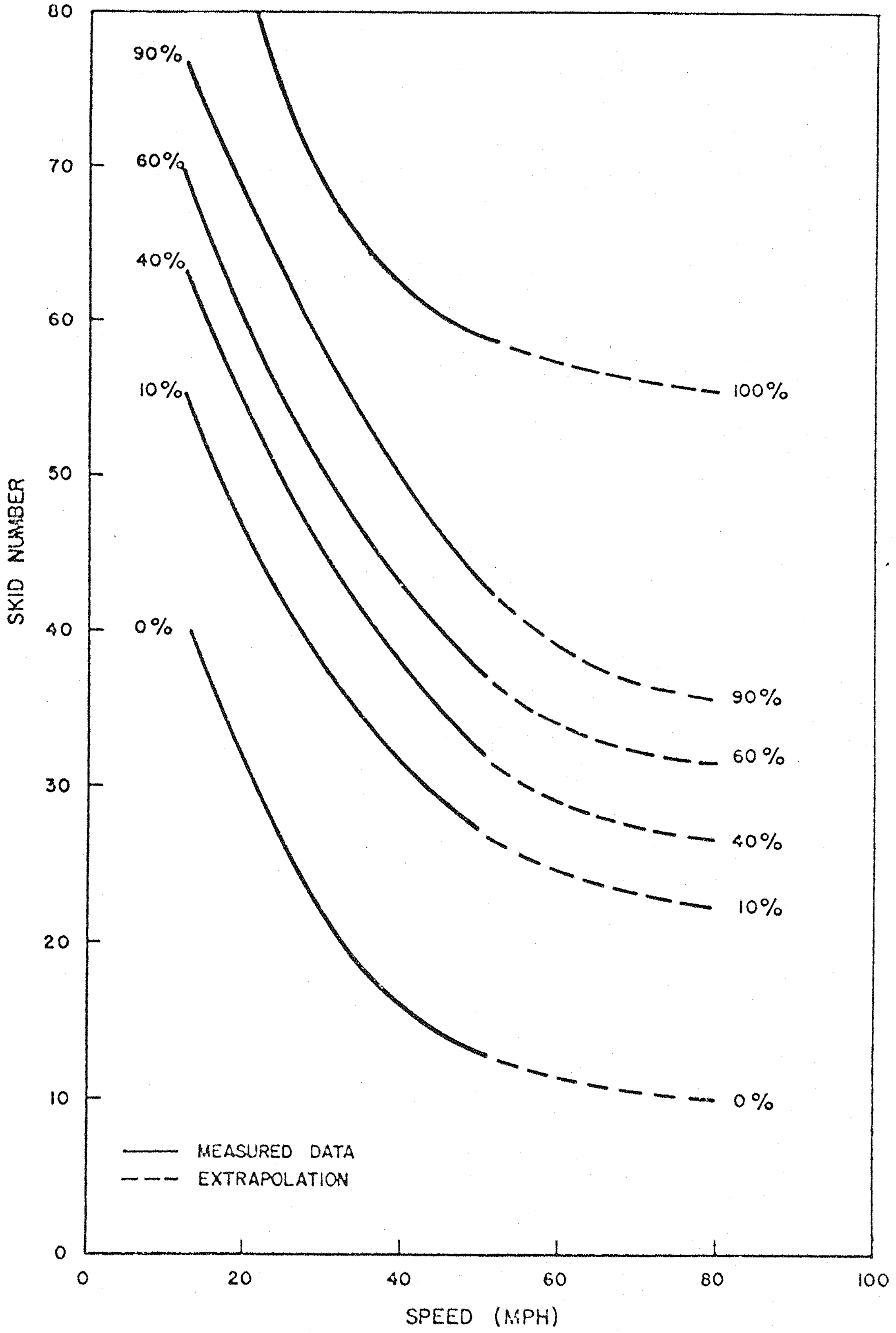


Figure 2.11: Percentile Distribution of Relationship Between Friction Capability and Speed for 600 Pavements in Germany(21)

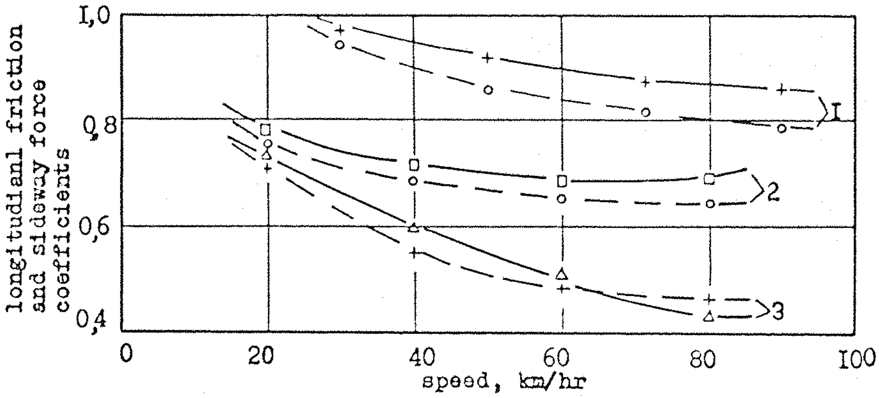


Figure 2.12: Longitudinal and Sideway Force Coefficients (16^{o} turning angle: 1-Wet Rough Concrete Surface; 2-Coarse Texture Wet Surface; 3-Smooth Wet Concrete Surface[49]

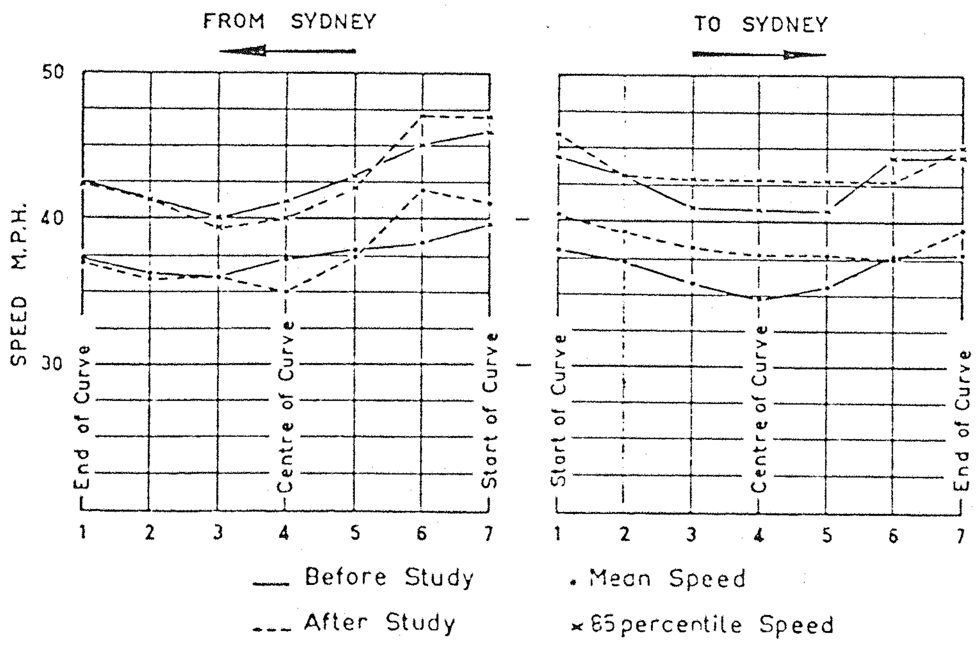
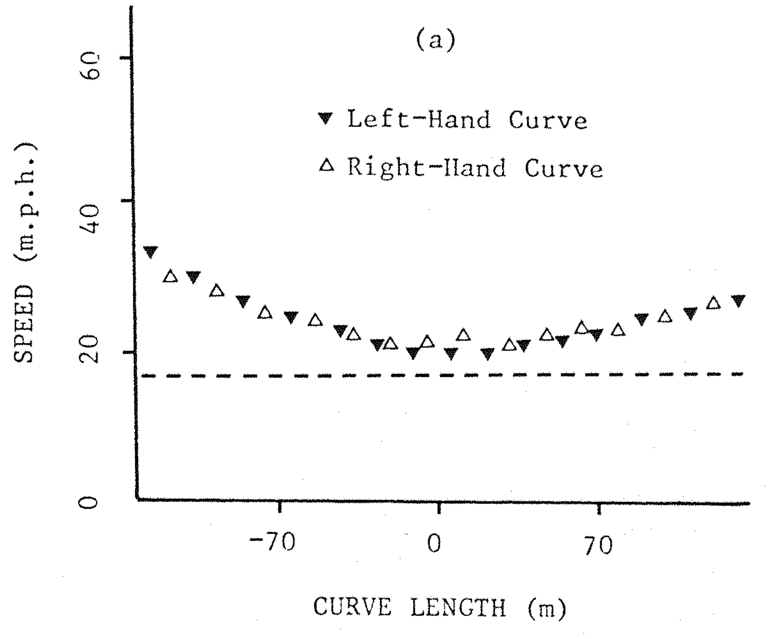


Figure 2.13: Variation of Speeds on a Curve[51]



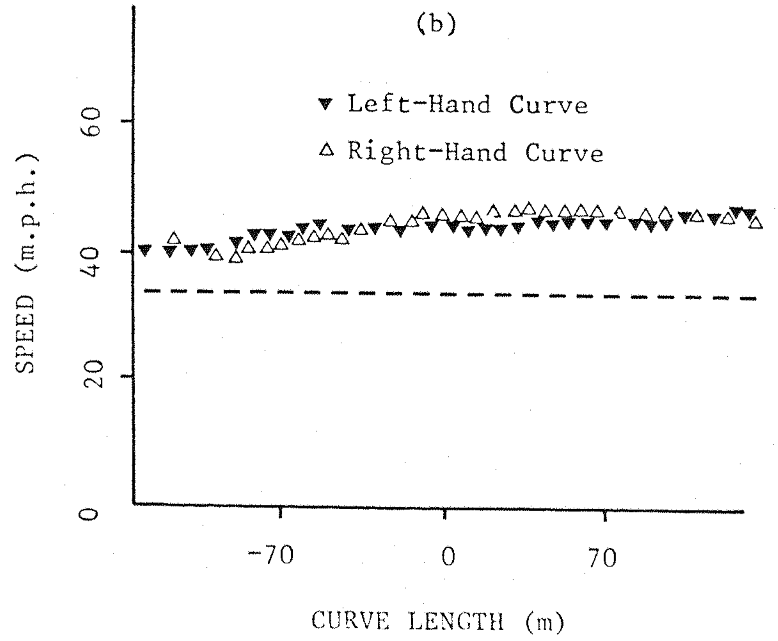


Figure 2.14: Variation of Speeds around Road Curves. (a) Curve Radius of 60 feet; (b) Curve Radius of 380 feet[41]

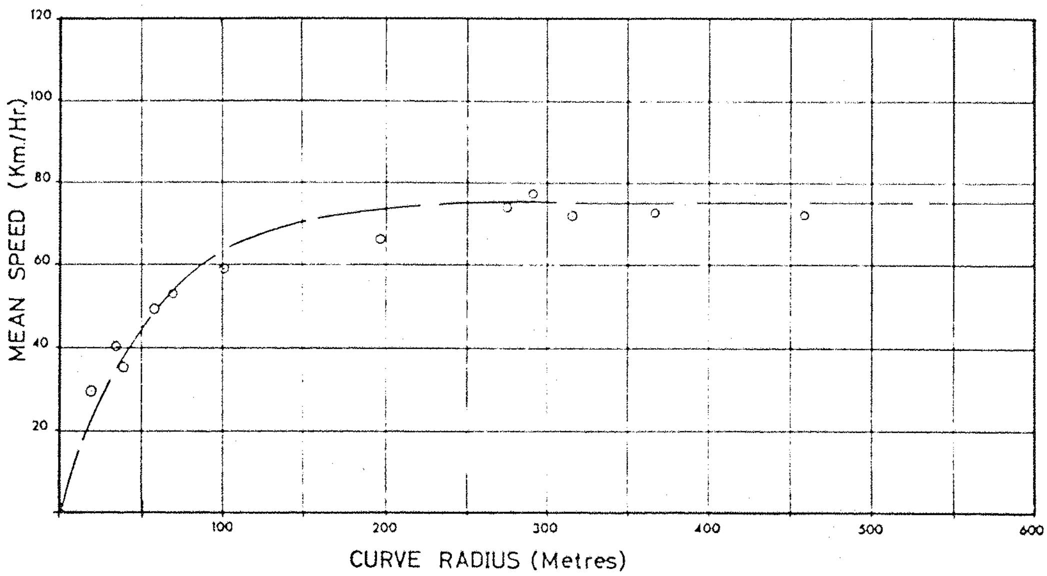


Figure 2.15: Speed and Curve Radius Relationship(62)

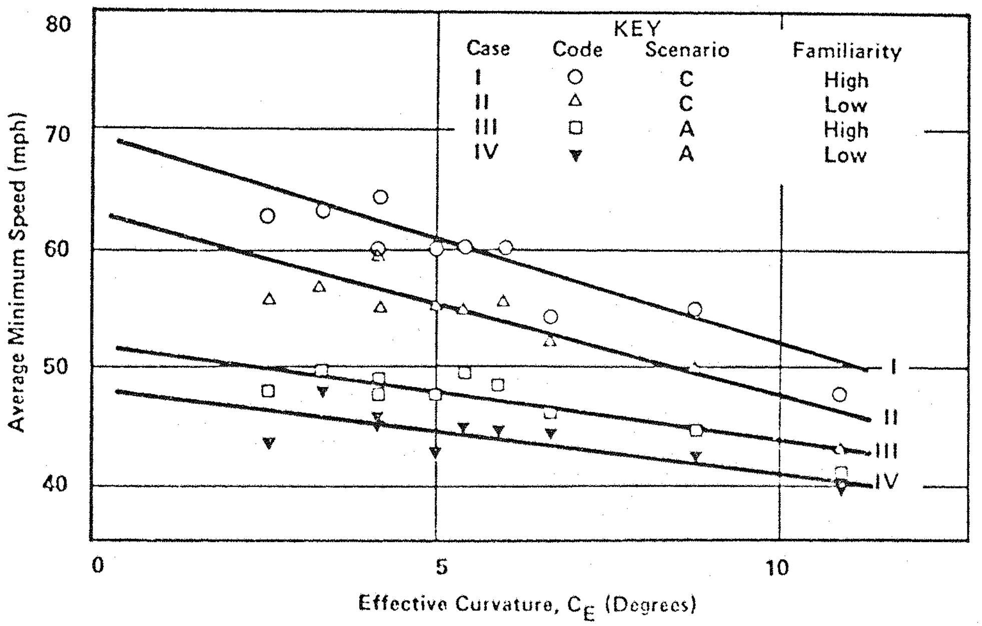


Figure 2.16: Variation of Speed with Vehicle Path Curvature(55)

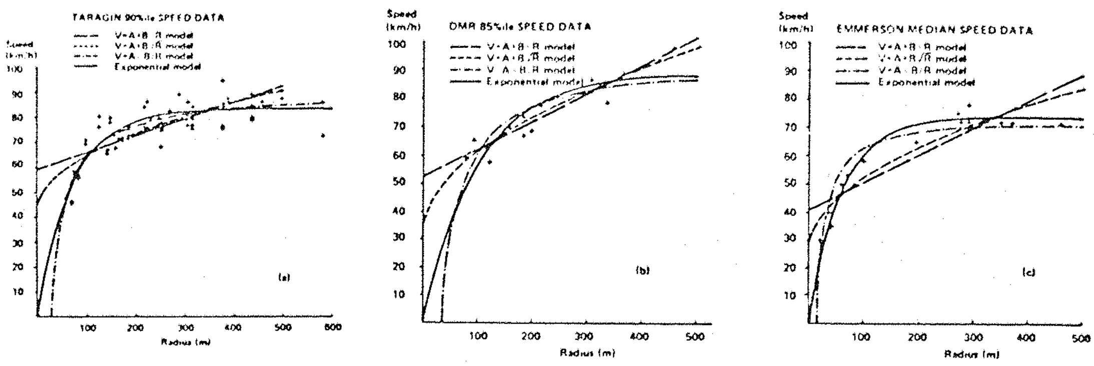


Figure 2.17: Empirical Speed/Radius Relationships(22) for Data of (a) Taragin(50), (b) DMR(36); (c) Emmerson(62)

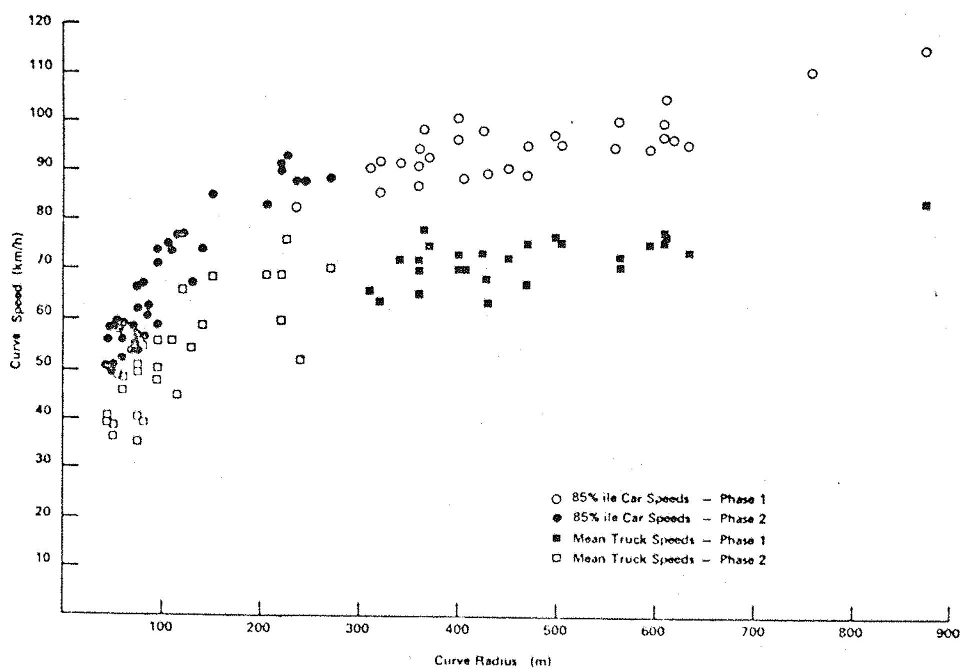


Figure 2.18: 85th Percentile Car and Mean Heavy Vehicle Speeds against Radius (22)

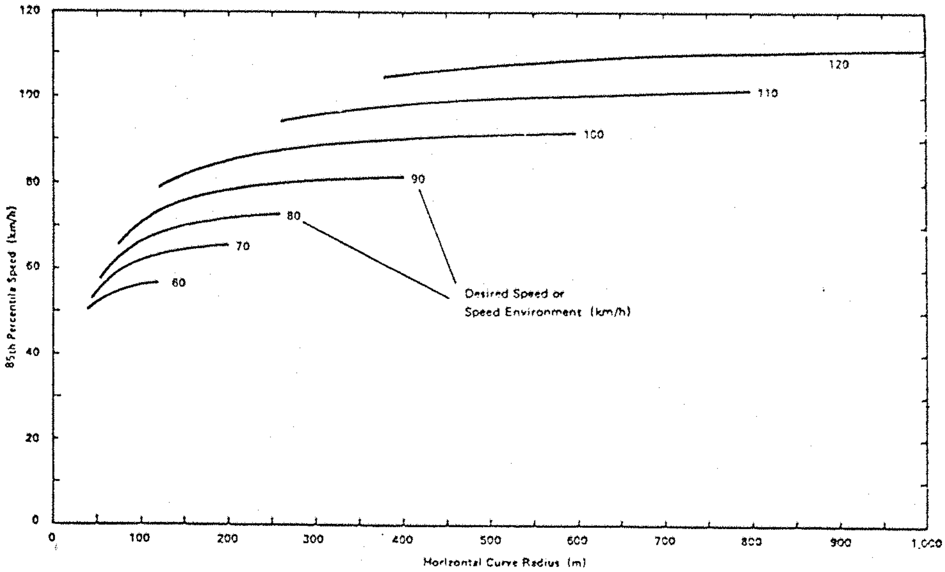


Figure 2.19: Curve Speed Prediction Relationships(22)

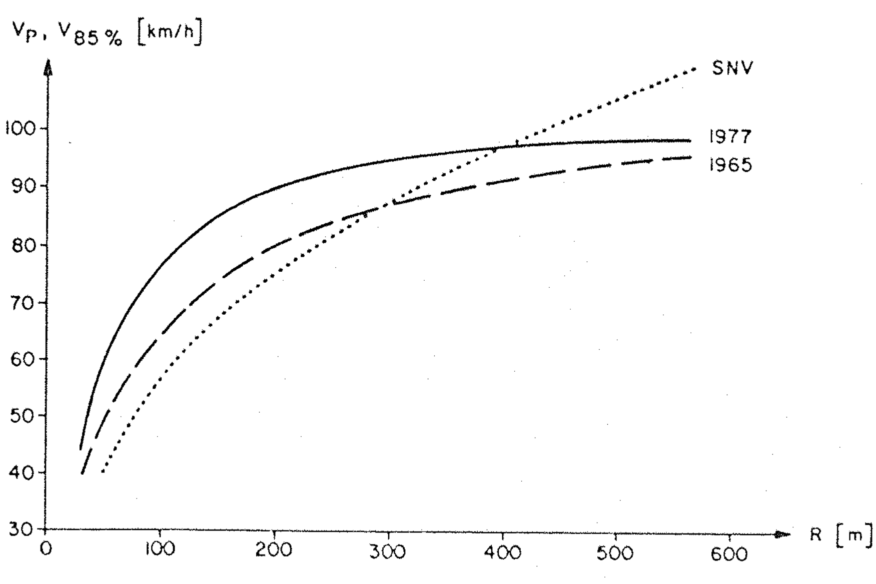


Figure 2.20: Comparison of the 85th Percentile Speeds 1965 and 1977 with the Design Speed V_p according to the Valid Standards SNV(68)

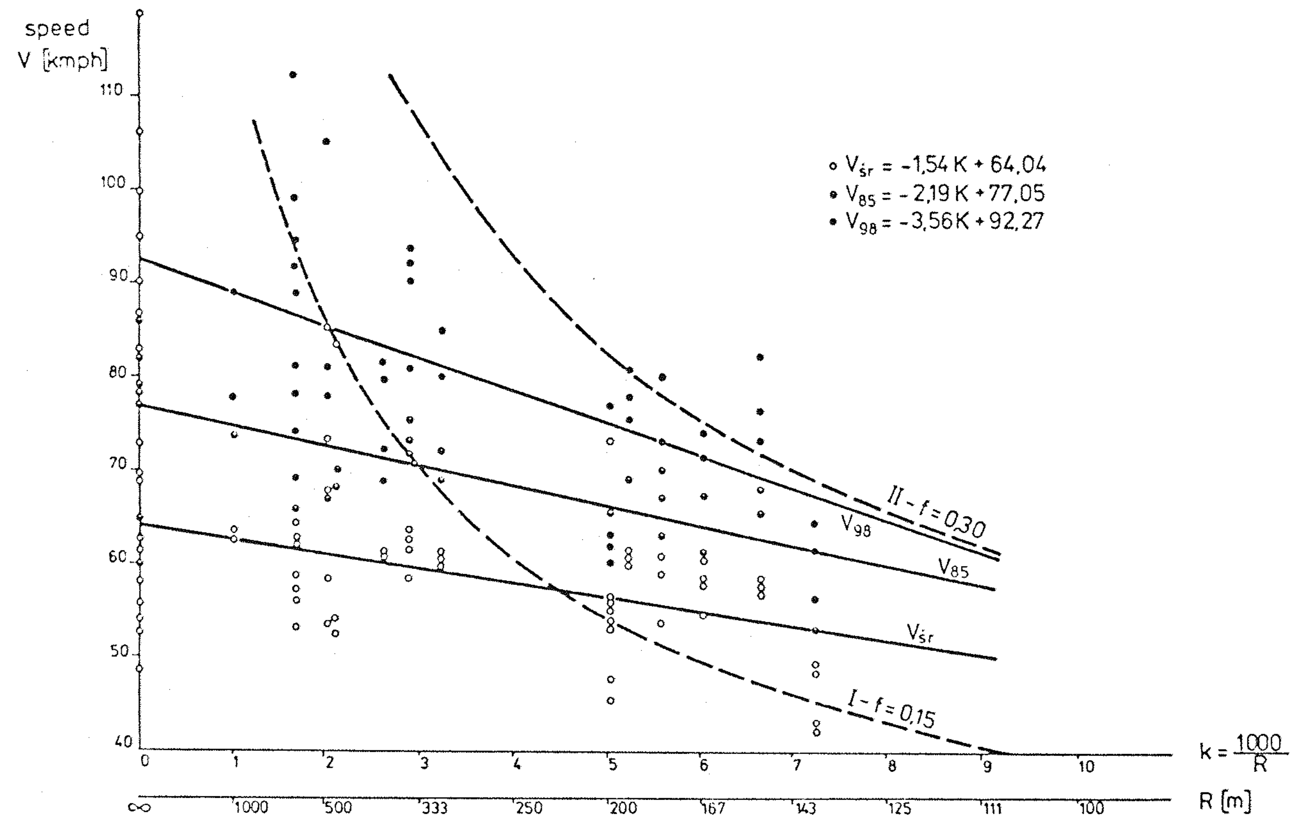


Figure 2.21: Relationship between Spot-Speed and Radius of Horizontal Curve (69)

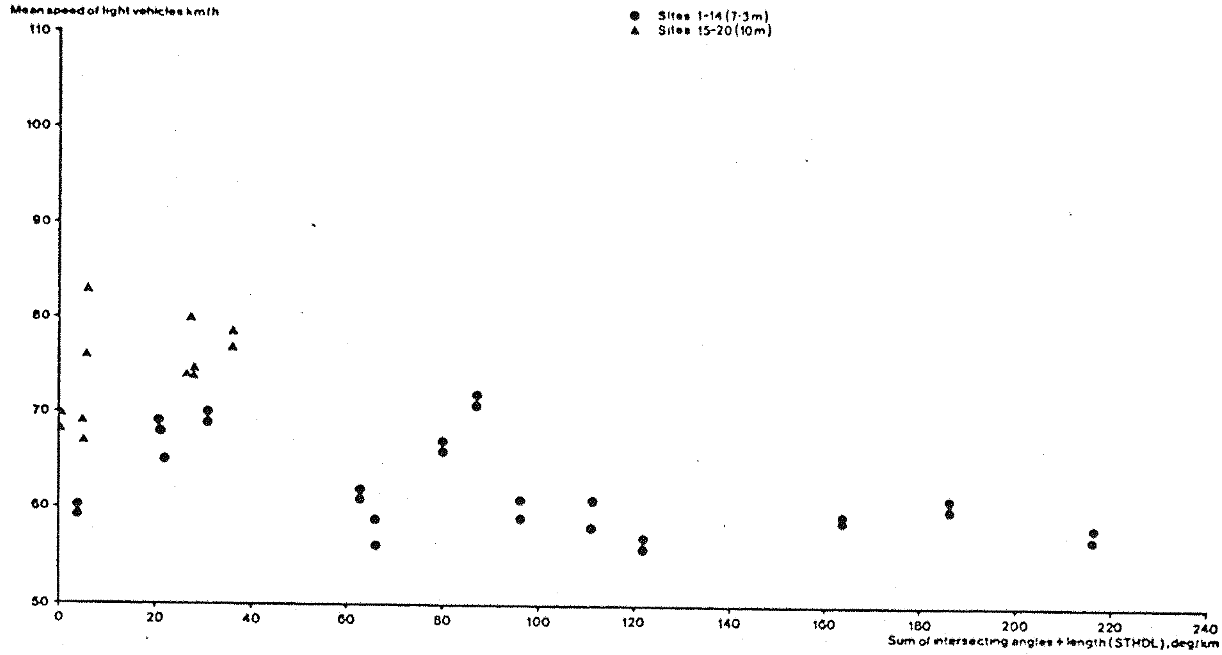


Figure 2.22(a): Mean Speed of Light Vehicles against Bendiness(70)

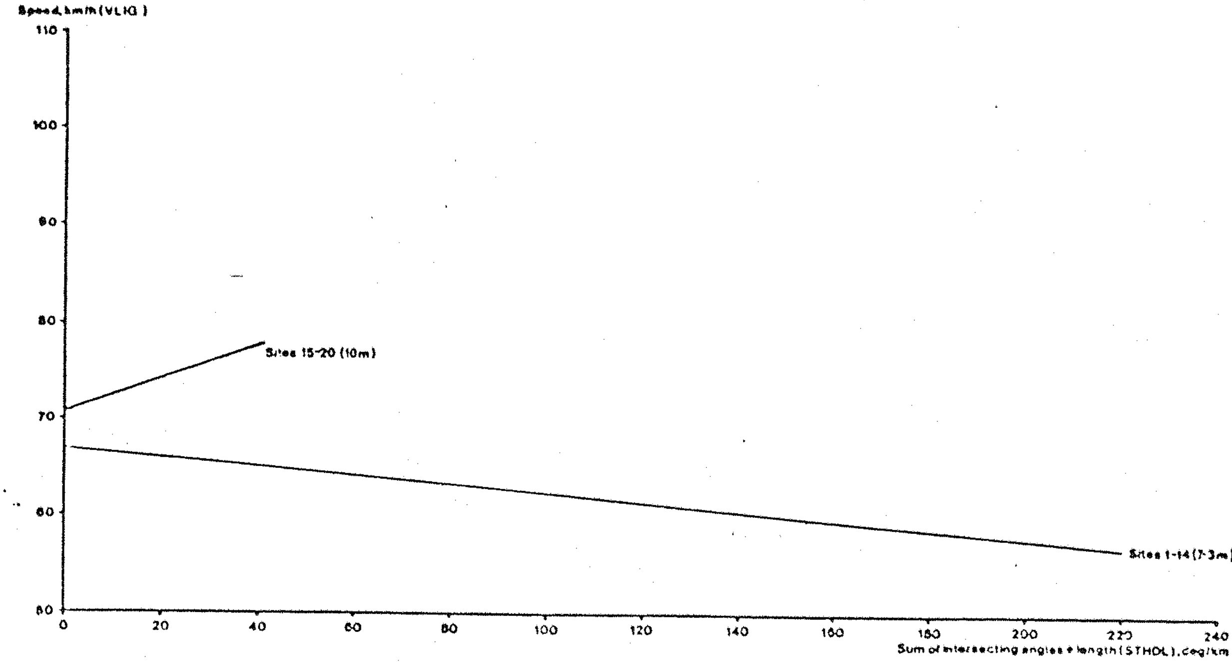


Figure 2.22(b): Mean Speed of Light Vehicles against Bendiness by Road Type(70)

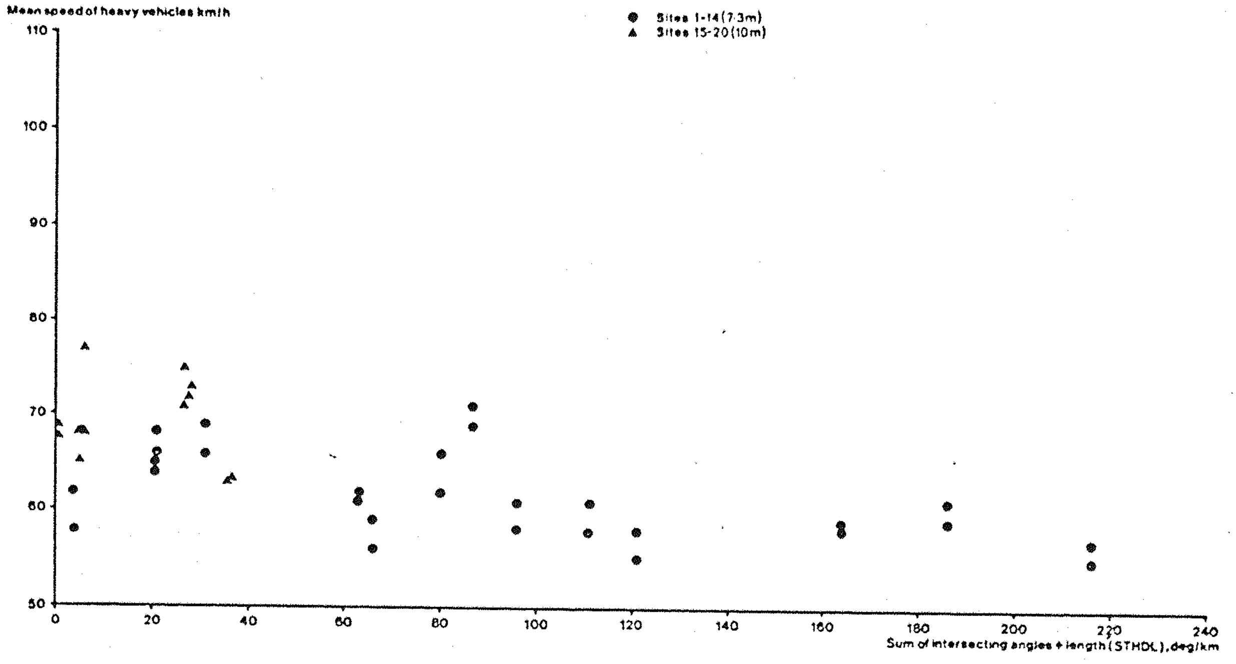


Figure 2.23(a): Mean Speed of Heavy Vehicles against Bendiness(70)

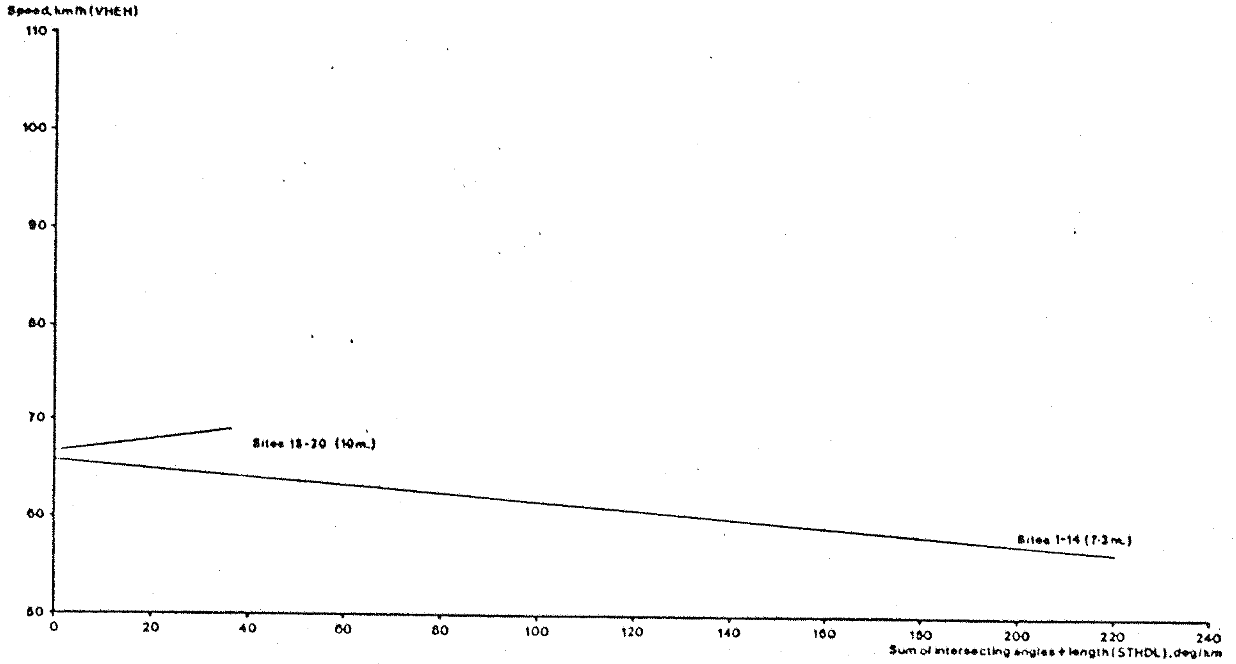


Figure 2.23(b): Mean Speed of Heavy Vehicles against Bendiness by Road Type(70)

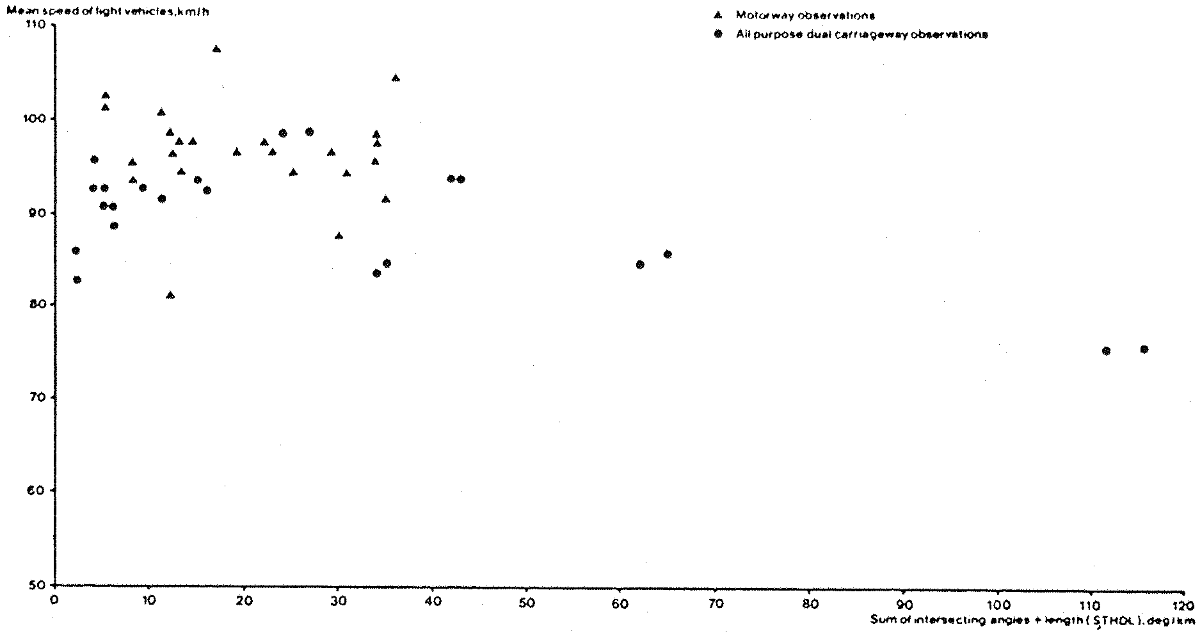


Figure 2.24(a): Mean Speed of Light Vehicles against Bendiness(71)

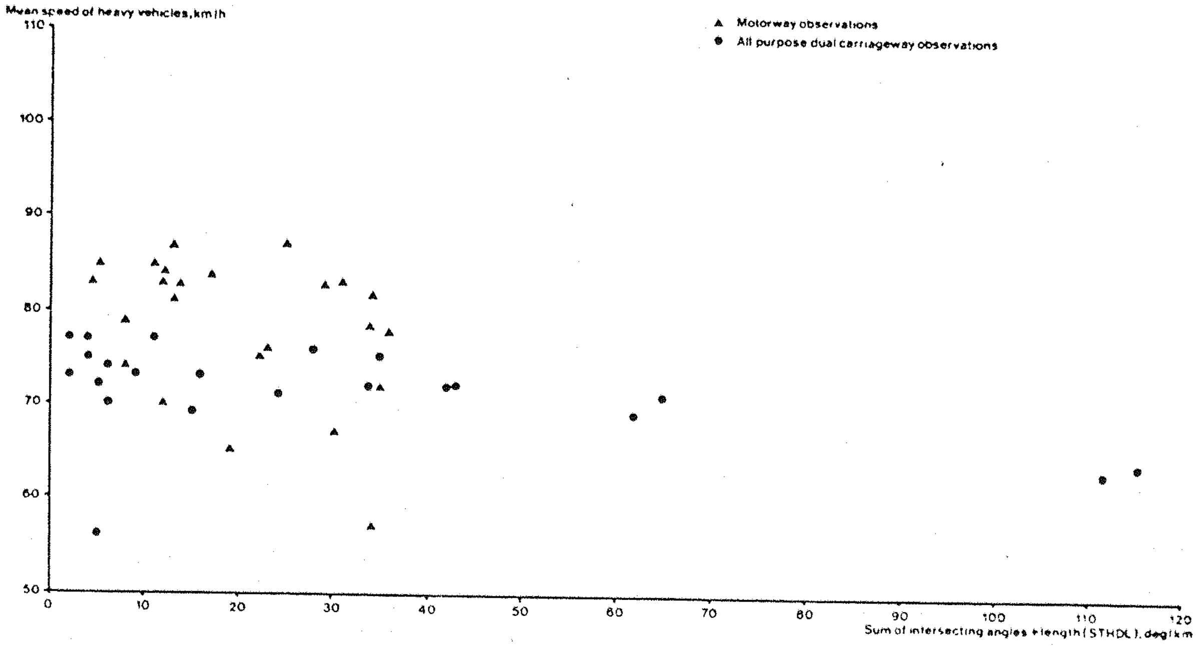


Figure 2.25(a): Mean Speed of Heavy Vehicles against Bendiness by Road Type(71)

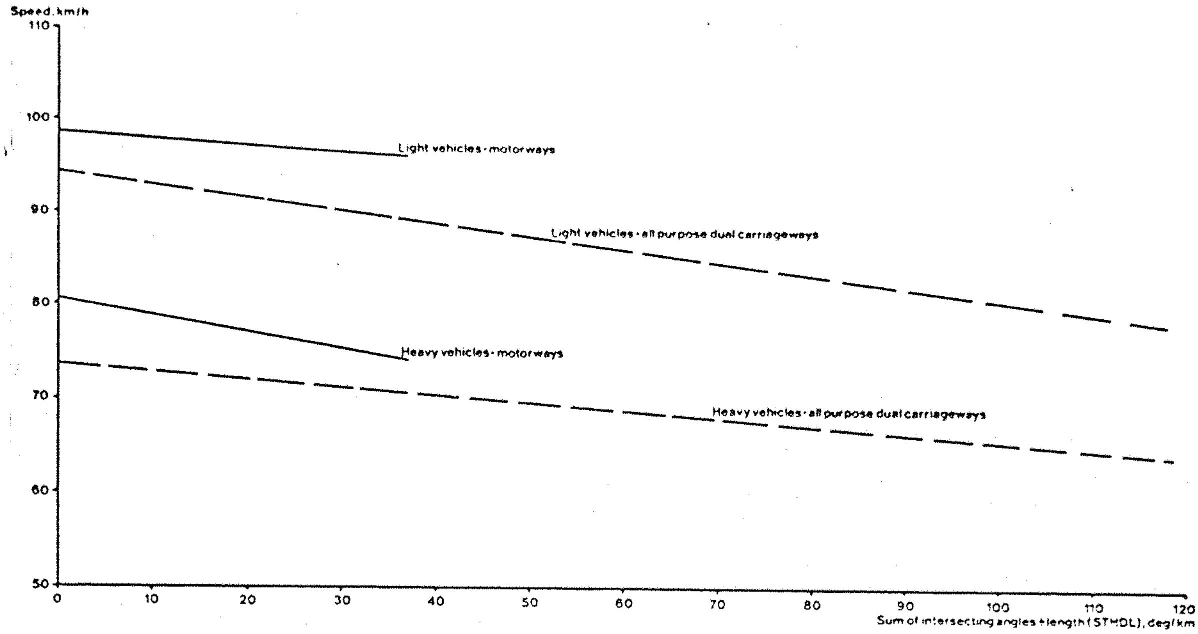


Figure 2.24(b) and 2.25(b): Mean Speed of Light and Heavy Vehicles against Bendiness by Road Type(71)

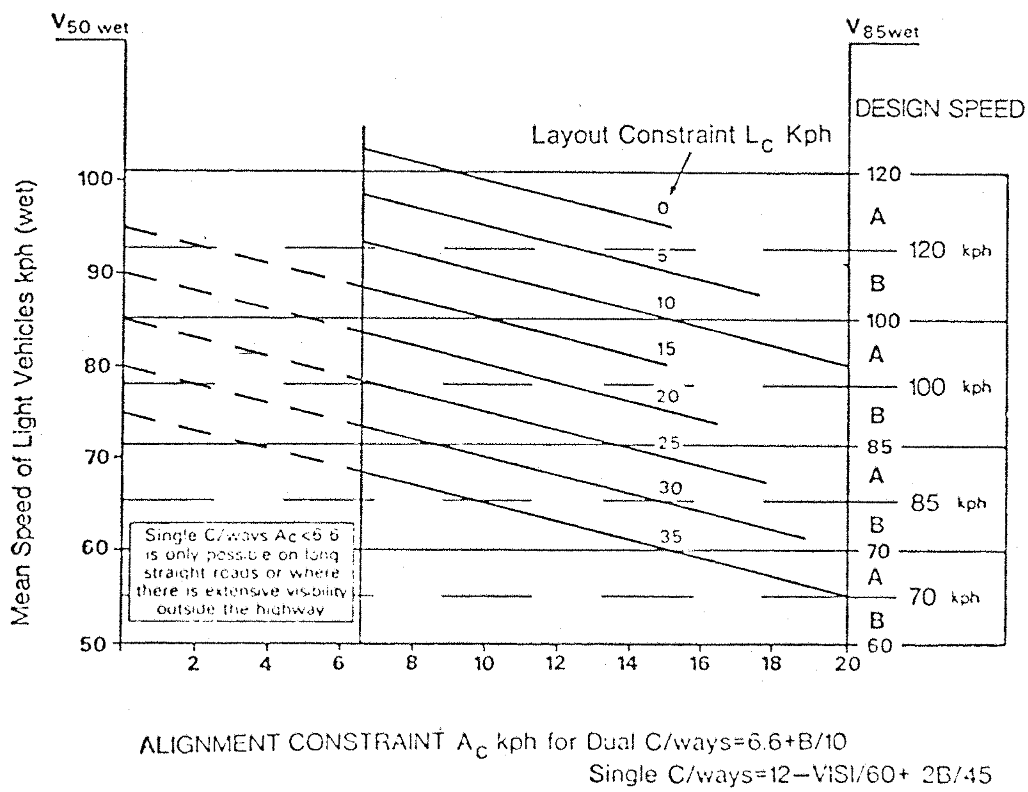


Figure 2.26: Selection of Design Speed(17)

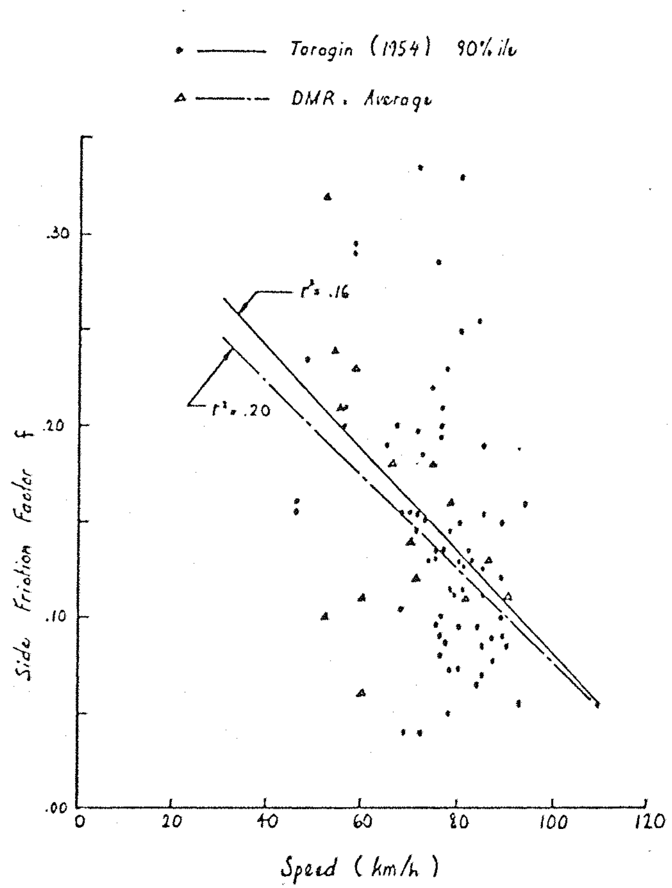


Figure 2.27: Plots of Side-Friction Factors against the Speeds from which they derived[22]

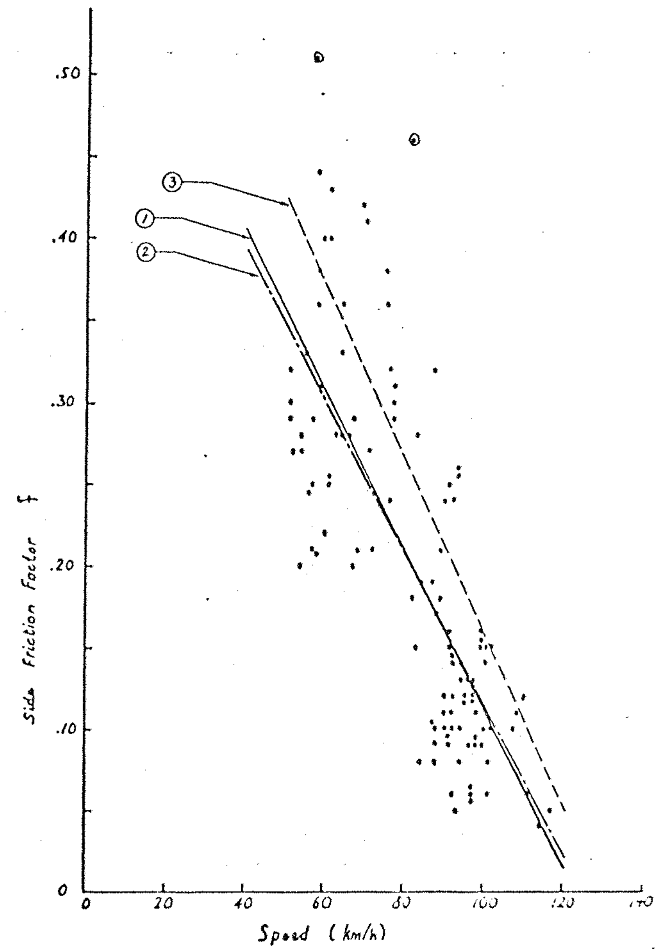


Figure 2.28: Plot of the 85th Percentile f Values against the corresponding 85th Percentile Curve Speed Values[22]

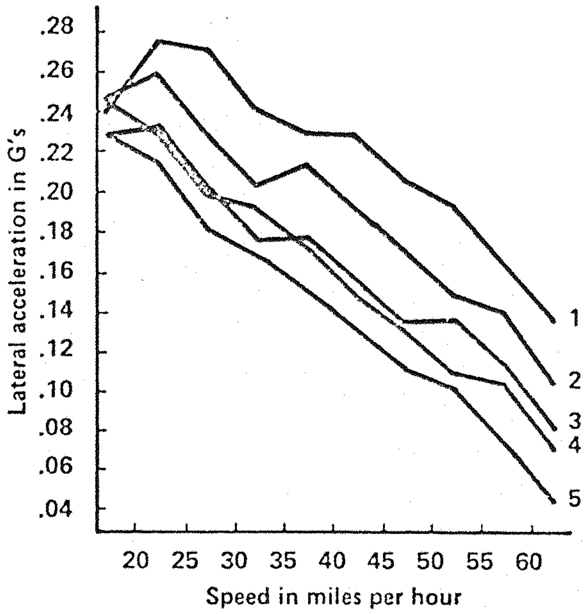


Figure 2.29: Mean Lateral Acceleration as a Function of Cell-Mean Speed. Each Curve is based on Ten Subjects grouped by Mean Speed (74)

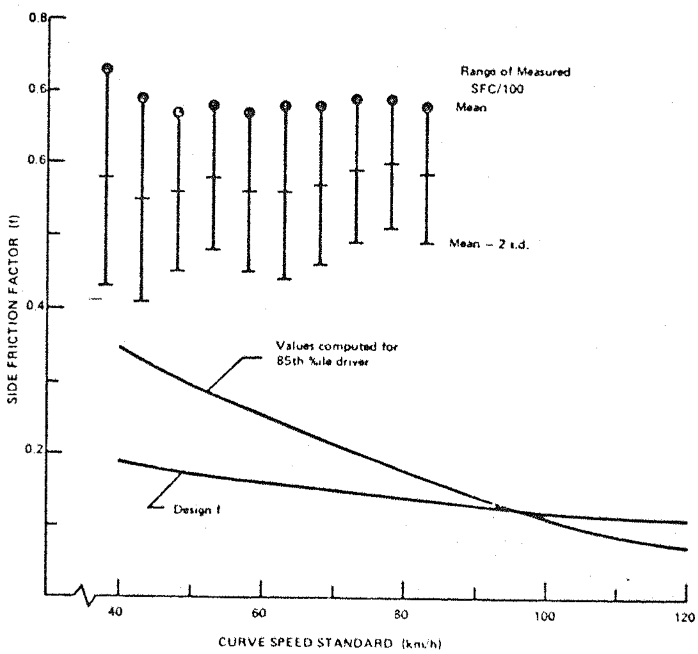


Figure 2.30: Side-Friction Factors and Side Force Coefficient Survey Values (67)

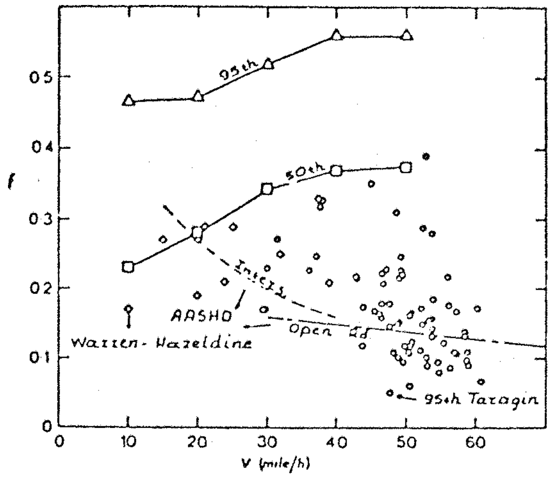


Figure 2.31: Comparison of AASHO[15] Side-Friction Factor Values with Results of Previous Studies[42]

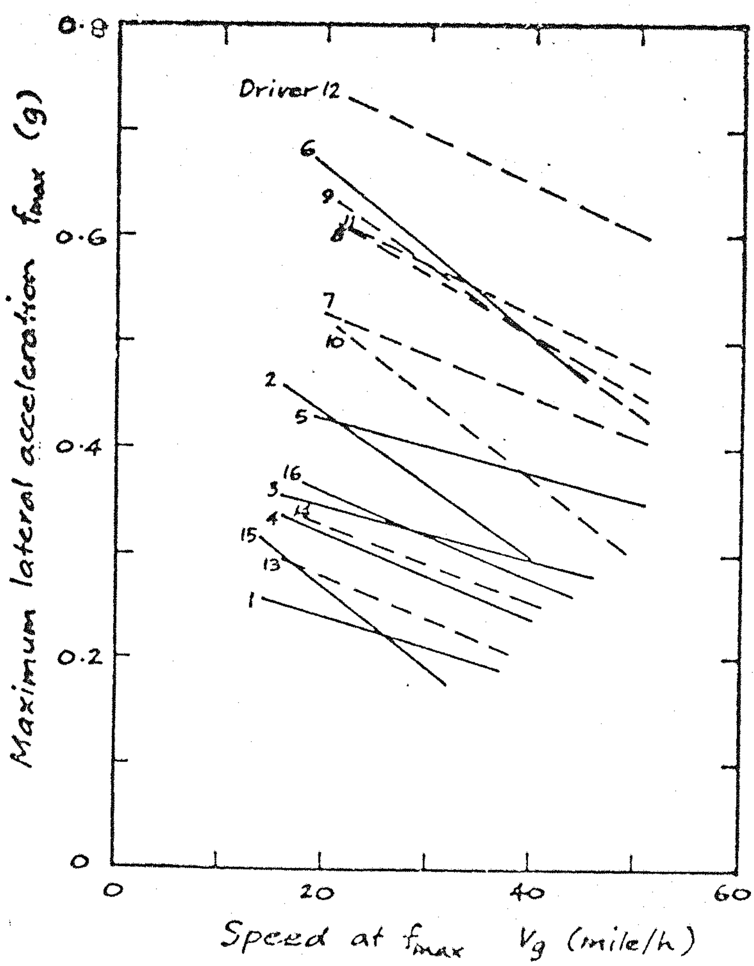


Figure 2.32: Regression of Maximum Lateral Acceleration and Speed at which it occurred for Individual Subjects[41]

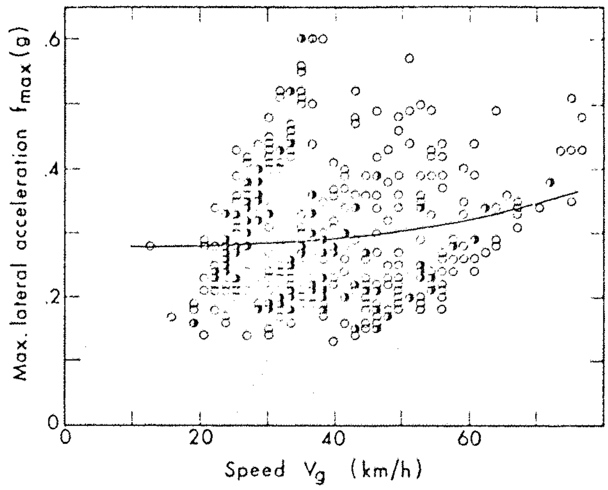


Figure 2.33: Relationship between Maximum Lateral Acceleration and Speed at which it occurred(41)

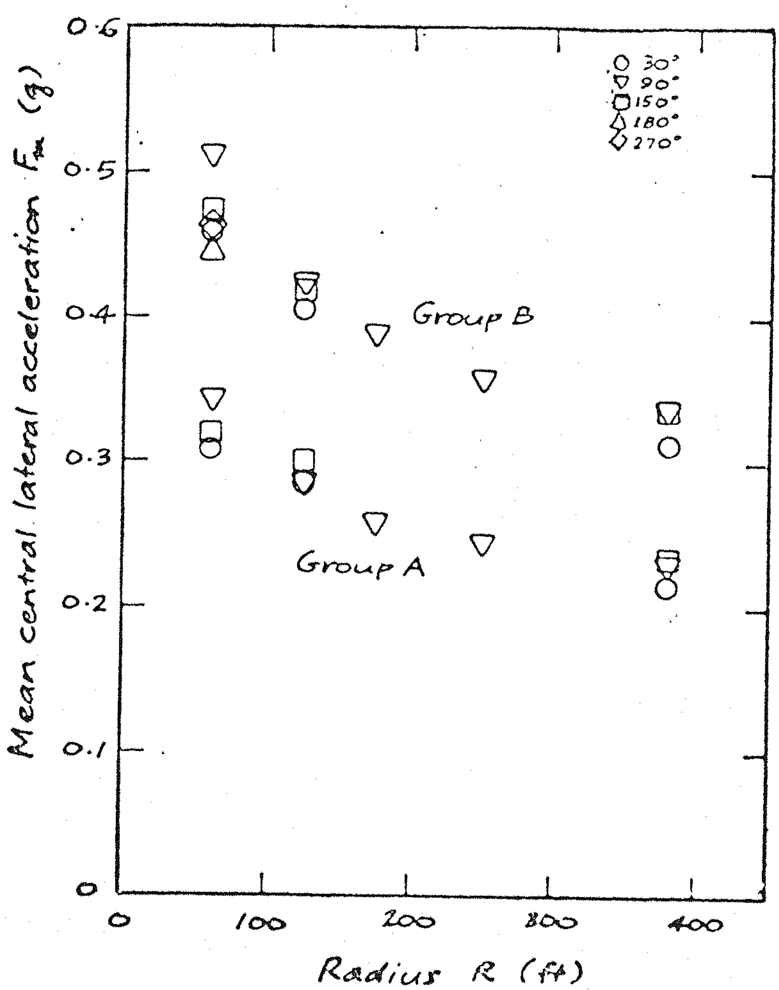


Figure 2.34: Variation with Curve Radius of Mean Central Lateral Acceleration for Second Trials of Groups A and B(41)

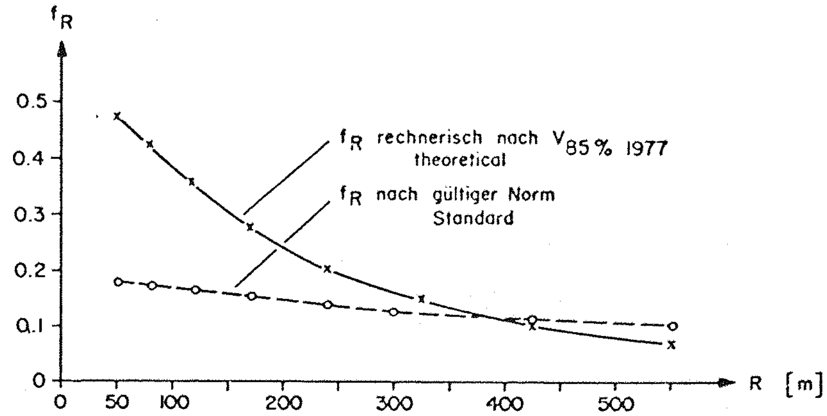


Figure 2.35: Comparison of the Necessary Radial Skid Friction Coefficients: f_R(Standard): and f_R(1977, Theoretical)(68)

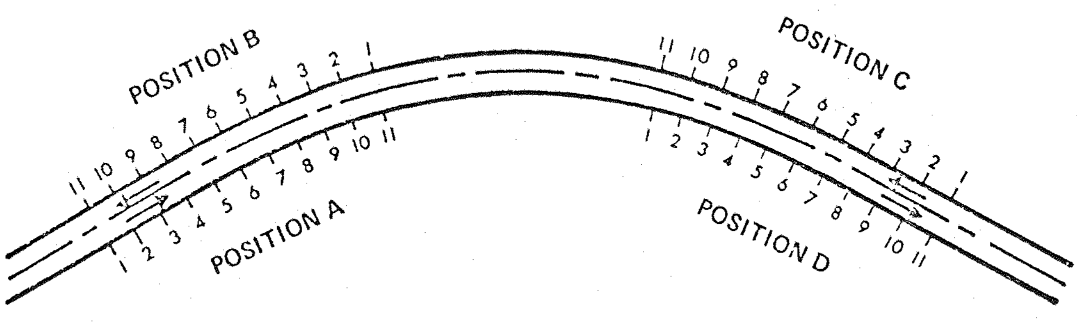


Figure 2.36: Curve Positions and Stations for Measurement of Vehicle Lateral Placement(78)

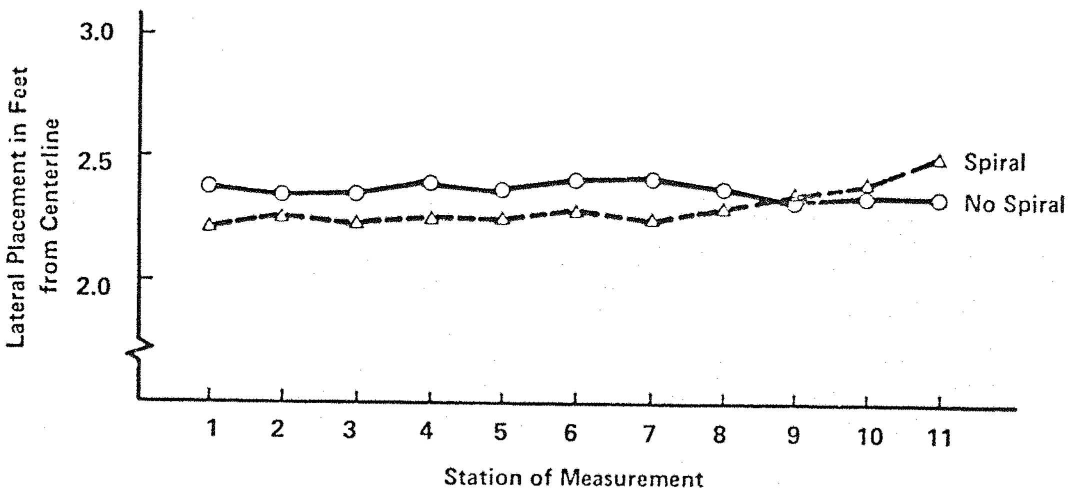


Figure 2.37: Effect of the Interaction of Station of Measurement with Curve Type on Lateral Placement (78)

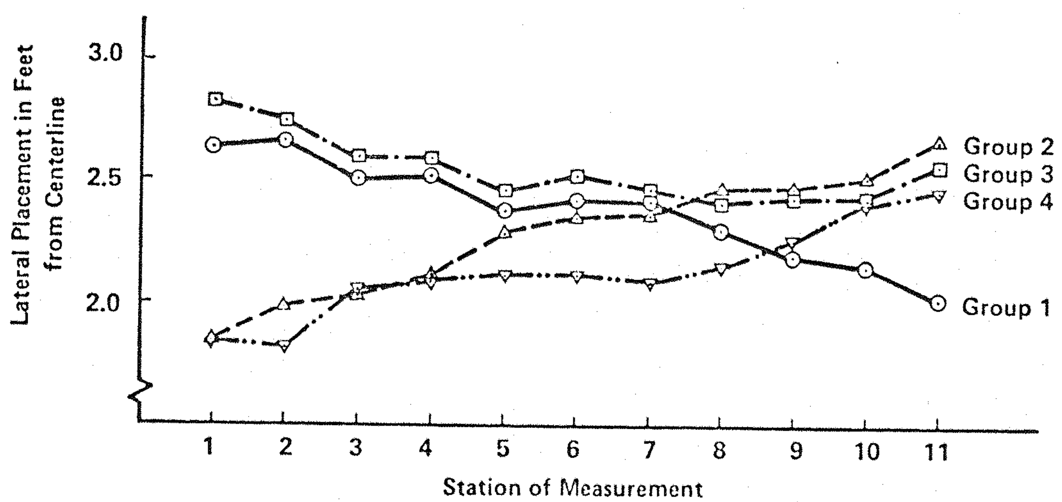


Figure 2.38: Effect of the Interaction of Station of Measurement with Curve Group on Lateral Placement (78)

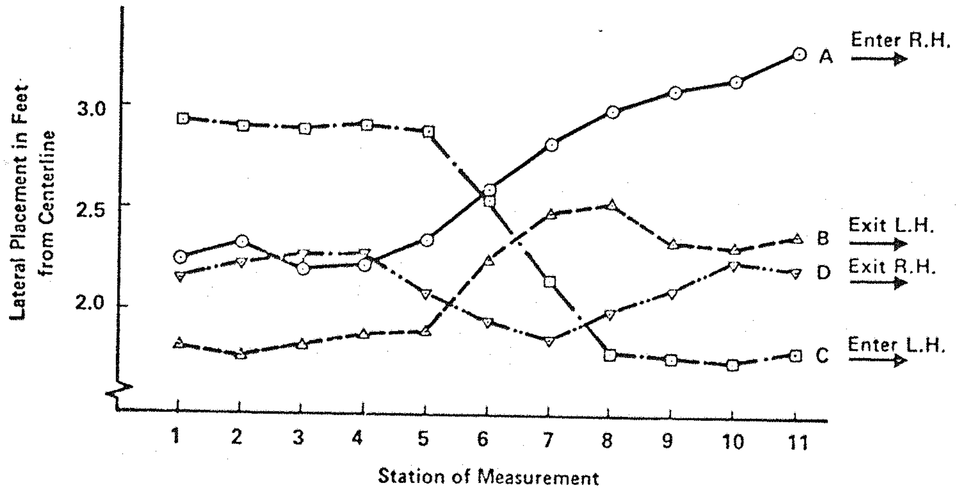


Figure 2.39: Effect of the Interaction of Station of Measurement with Curve Position on Lateral Placement (78)

CHAPTER THREE

DESIGN OF THE STUDY AND DATA COLLECTION

3.1 INTRODUCTION

A study of this nature involves a complex set of interactions between a number of factors and this must be reflected in the method of approach and data collection procedure. However, for clarity, each of these factors is considered separately below.

It should be noted that the objectives of this work required that information should be collected at public road sites. At each site it has been necessary to collect a sample of vehicle speed and lateral placement data from which a range of behavioural parameters could be determined. These parameters were subsequently used in the modelling processes described in Chapter 5, but are also defined below.

3.2 VEHICLE CLASSIFICATION

The basic vehicle classification is by type. Interactions with other vehicles may result in apparent behavioural changes and it is thus also necessary to define the vehicle sampled in terms of level of impedence.

3.2.1 Vehicle Type

Vehicles were classified by type as follows:

a. Cars: All light vehicles with four wheels and an unladen weight less than 1.5 tonne. They normally have limited seating capacity of not more than eleven occupants and are not usually subject to any speed limit other than the prevailing speed limit on the roadway.

b. Goods Vehicles, which were divided into:

   (i) Rigid Goods Vehicles which included all rigid vehicles on the roadway which were not cars or buses or coaches.

   (ii) Articulated Vehicles.

   (iii) Buses and Coaches with seating capacity for more than eleven.

3.2.2 Level of Impedence

A vehicle travelling along a road can be regarded as being either completely free-moving or its speed can be influenced by the presence of other vehicles on the road. A vehicle is considered to be free-moving when it travels along the road at the speed and lateral placement desired by its driver subject only to the road geometry and environmental conditions:

a. Free-flowing vehicles.

b. Vehicles leading a platoon (Platoon Leaders).

c. Vehicles in a platoon.

d. Impeded vehicles.

The following criteria were adopted to identify levels of impedence:

(i) Headways between successive vehicles of at least nine seconds[50], for single carriageways, and of at least six seconds for dual carriageways, indicated free-flowing conditions. (The time headway criterion for identifying free-flowing vehicles was reduced for dual carriageways on the basis that the additional freedom in lateral movement and the absence of opposing traffic would result in driving behaviour being less responsive to the presence of other vehicles.

(ii) Drivers were assumed not to be affected by the presence of vehicles in the opposing lane on curves of radii larger than 200m[31,39].

(iii) A vehicle met by an opposing vehicle while travelling around a curve with a radius less than 200m was considered to be impeded by the opposing vehicle.

(iv) Vehicles travelling in platoons were distinguished from platoon leaders, as they represent two entirely different driving modes.

3.3 SAMPLING PROCEDURES

The objectives and methods of analysis were the most important considerations when constructing a sampling frame. It was necessary however to balance the number of sites studied against the level of information collected at each site, with the time and budgetry constraints applied.

Sites can be selected either on the basis of predetermined values of curve geometry, traffic and environment, or on a completely random basis. The first of these procedures was chosen so as to provide as fair and uniform a distribution of data points for the subsequent multiple regression and correlation analyses as possible. The detailed procedure is described later.

Oppenlander[79] derived a theoretical, and subsequently a graphical solution, of a formula from which the required minimum sample size for the estimation of various percentiles of a normally distributed population can be determined. The formula is:

$$n=\frac{V^2 S^2 (2+u^2)}{2h^2} \qquad (3.1)$$

where n = minimum sample size,

V = the deviate of the normal distribution which corresponds to a desired confidence limit (e.g. for a 95 per cent confidence level, V = 1.960),

S = standard deviation of the sample,

u = the deviate of the normal distribution which corresponds to the percentile being estimated (e.g. for the 15 and 85 percentiles, u = 1.037),

and h = permitted error in the estimate of the population percentile from the sample statistic.

Alternatively, the minimum sample size required for the 50th percentile (mean) of a normally distributed population may be estimated by considering confidence intervals. The confidence intervals of a sample mean are given by:

$$\text{confidence intervals} = \pm Z * \frac{\sigma}{\sqrt{n}} \qquad (3.2)$$

where Z = Z-statistics, depending upon the confidence level selected,

σ = population variance,

and n = sample size.

If in equation 3.2, the sample standard deviation is substituted for the population variance, and the absolute tolerance limit, h, is set equal to the above confidence interval, the minimum sample size, n, which is required to estimate the population mean is given by:

$$n=\frac{Z^2 . S^2}{h^2} \qquad (3.3)$$

The values of the allowable absolute tolerance limit, h, and the Z-statistic can be pre-set and the sample standard deviation determined. In this study the minimum site sample size statistically acceptable was related to the lateral acceleration as it is generally accepted as the main behavioural parameter influencing driving behaviour around curves as well as including both speed and road curvature effects. Preliminary studies[3] had shown that lateral acceleration distributions at the centre of curves can be approximated by normal distributions, with sample standard deviations of approximately 0.50 m/sec^2. A minimum acceptable site sample size of 24 sites was determined with the tolerance limit set to 0.20 m/sec^2. This value was adopted as the statistical criterion for the determination of the study site sample size on both single and dual carriageways.

The value of the standard deviation of a speed distribution depends upon the location at which the sample has been collected and is higher on long, straight and level road sections than on curves where the geometry limits vehicle speeds. For that reason a representative value of standard deviation had to be found from recent speed studies on unrestricted road sections. Bennett(80) recommended 13.0 k.p.h. for cars, a figure in close agreement with the value of 11.97 k.p.h. found in our preliminary study(3). Bennett's value of 13.0 k.p.h. was accepted as a good approximation of the standard deviation of the car sample to be collected. At a confidence level of 95 per cent and for an allowable absolute tolerance limit of 3.0 k.p.h. the minimum sample sizes, statistically required, for the estimation of the mean, the 85th percentile and the 99th percentile speed of cars were calculated from equations 3.1 and 3.2.

Minimum sample size required for the estimation of the same percentile speeds were also calculated for goods vehicles. A value of 8.0 k.p.h. was adopted(3) as representative of the standard deviation of the samples. A confidence level of 95 per cent and a tolerance error of 3.5 k.p.h. were again applied.

The sample sizes thus required are given in Table 3.1 for both cars and goods vehicles. The normality assumption implied in this method of calculating sample sizes for certain parameters was taken to be valid for the case of vehicle speed distributions(3,22).

Although the minimum sample sizes given in Table 3.1 are statistically acceptable they should be treated with some scepticism since they do not account for the changes in vehicle speeds which occur through time and because of different flow and environmental conditions.

It was decided to collect public road data on more than one occasion (phases) at each site to allow for the variation in driving performance which may occur through time. To account also for possible flow effects, public road data was recorded on a fixed time and not on a fixed sample size basis using a random sampling procedure.

3.4 SITE SELECTION

3.4.1 Selection Procedure

Most study sites were selected from a total of about 200 directional road curves (Tables A1 and A2 - Appendix A) on both single and dual carriageways, used by Halcrow Fox and Associates in their recent study for the Department of Transport 'Effects on

Safety of Marginal Design Elements'[2]. That the initial sample of sites had to be drawn from a specific group of road curves presented restriction on the range of the values of the geometric and flow parameters. It was therefore necessary to devise a selection system which would result in the production of a set of sites displaying a wide and varying range of characteristics, within which any regional difference in behaviour would be contained. The final selection was thus made on the following basis:

(a) Road curves specified by the Department of Transport[2] prior to the study should form the basis of the sample.

(b) The main geometric features, should vary over an acceptable range.

(c) All curves should have radii not greater than 500 metres. This formed part of the 'Terms of Reference' and, was identified from the results of earlier work[62].

(d) Curves should be isolated.

(e) Geometric, flow and environmental variables should be compatible with the data collection process (sampling procedure).

(f) Reverse and continuous road curves should be excluded, as well as those at locations where factors other than road geometry could clearly be of overriding importance to driving behaviour.

(g) All sites had to have low to moderate traffic flows during the survey periods to avoid excessive vehicle interactions and too low a sampling rate.

(h) All sites had to be on unrestricted sections of road.

3.4.2 Sample Selection

Preliminary site selection was undertaken using ordnance survey maps and construction plans. This was followed by helpful discussions with members of staff of the Department of Transport and of Halcrow Fox and Associates. Despite the critical evaluation of the study sites at this initial stage, it was considered that the sample should be re-evaluated after the end of Phase I, when all the directional road curves selected would have been visited and more detailed geometric information would be available.

Initially, a total number of 64 directional road curves on both single and dual carriageways were obtained from the sample already available covering a range of geometric and flow characteristics. Radius and then gradient were the main variables considered in selection, as short radii and steep grades were hard to find. Short sight distances independent of radius was incorporated where possible, but this was rather rare.

An important feature of the initial sample of sites from the Halcrow Fox and Association data base was the lack of low radius curves, particularly for single carriageways. For that reason, our sample was supplemented with 12 additional directional single carriageway curves covering the lower end of the curvature range. These 12 supplementary directional road curves were carefully selected from a sample of 44 which had been considered in a preliminary study carried out in early 1980 in the Hampshire area(3).

After the completion of Phase I, two directional single carriageway sites were removed from the initial sample of 76 directional road curves because of the existence of a speed restriction and high levels of suburban traffic flow controlling vehicle speeds. A further examination of the samples for both single and dual carriageways revealed that they should be supplemented by two more low radius directional single carriageway curves and two more moderate radius directional dual carriageway curves. These sites were incorporated into the sample for the second round of data collection (Phase 2).

In total 56 single and 22 dual carriageway curves were surveyed. These sites are listed in Tables 3.2 and 3.3.

3.4.3 Location of Sample

Figures 3.1 to 3.4 show the roads on which the study sites have been selected. Dual carriageway sites were generally located in the southern part of the country. This was unavoidable because only those preselected dual carriageway sites in the south met our criteria, and provided a reasonable range of geometric and flow characteristics.

3.5 SITE GEOMETRY AND DESCRIPTION

The geometric parameters considered in this study are listed in Table 3.4. Detailed measurements for most of these parameters were initially available from the Halcrow Fox(2) data base and our preliminary study(3). Some additional site surveys were, however, undertaken to supplement and check the existing data base. The same survey techniques used in the Halcrow Fox(2) study were applied to the 16 supplementary directional road curves to ensure consistency.

In the Halcrow Fox study(2) long sections of road had been considered and were divided into 100 metres long 'survey units'. Identification of the sections and the survey units was achieved by means of OS maps, road construction plans and aerial photography. Extensive surveys were then carried out to obtain the exact geometric characteristics of the sections. Additional surveys were carried out to obtain measurements of superelevation and width, as well as to provide the necessary geometric information for the new sites introduced after the completion of Phase I.

The ranges of the geometric parameters encountered at all the study sites are given in Tables 3.5 and 3.6 for single and dual carriageways respectively. A detailed geometric base is also given in Tables A3, A4 and A5 - Appendix A.

3.5.1 Horizontal Alignment

Horizontal curves were regarded as being circular arcs. This assumption was considered necessary since the identification of transition curves was difficult due to the lack of detailed construction plans for all of the sites. Where horizontal alignment plans were available, the end points of the road curves were taken either as the mid-points of the transition curves, if supplied, or as the tangent points identified on the ground during the surveys. A comparison between some of those estimates and construction plans showed small differences, but there was no apparent bias in the sample with respect to the location of the estimated point relative to the actual end point of the curve.

Curve radius based on the centre line of the carriageway was either read off the plans, where available, or measured on the ground by means of the simple technique followed by Halcrow Fox(2). In this technique, start and end bearings were measured with respect to grid North on OS plans. The radius was then calculated as the rate of change of bearing expressed in radians per metre, and the curve length measured along the centre-line of the carriageway.

3.5.2 Vertical Alignment

Gradient was taken from vertical alignment plans, where available. Where such plans were not available, gradient was initially measured by Halcrow Fox(2) with an Abney level and taken as the average of two 50 metre sections. This gradient information therefore referred only to the 100 metres 'survey units' and no specific values of gradient between the curve end-points were given. Additional measurements were taken during our surveys with an automatic level. Accurate values were thus obtained for the gradient of specific portions on each curve, i.e. entry, middle and exit.

3.5.3 Road and Verge Width

A complete record of lane width at various locations on the approach and within a curve was obtained for each directional road curve on both single and dual carriageways. Measurements were carried out by means of a metallic measuring tape.

Verge width was measured at the centre of each curve. Measurements were accurate to ±0.2 metres. On dual carriageways the verge width of the fast lanes was taken to be equal to the width of the central reservation.

3.5.4 Superelevation

Superelevation was measured by an automatic level at the entry, middle and exit point of each curve. On dual carriageways super-elevation was measured separately for each carriageway.

3.5.5 Sight Distance

Sight distances had been measured by Halcrow Fox[2] from the mid-point of 'survey units' between points 1.05 metres above the carriageway as specified in 'Layout of Roads in Rural Areas'[16]. The overtaking sight distance was measured along the centre line on single carriageways. For dual carriageways the stopping sight distance was measured along the centre of the inside lane. The sight distance of a 'survey unit' was defined as:

> *"...the longest distance from which a driver could see the mid-point of the section continuously as he approached, rather than the furthest a driver at the mid-point of the section (survey unit) could see ahead."*

The precise determination of sight distances required viewing within the carriageway which, especially for dual carriageways, was extremely hazardous. For that reason a simple method for estimating sight distances from the carriageway edge was developed (Halcrow Fox 1981 - see Appendix A). An adequate correlation was found when estimates of sight distances, produced by this method, were compared with sight distance measurements from within the carriageway.

It should be noted that the sight distance measurements given for the 62 directional sites, finally selected from the sample of about 200 directional sites provided by the Department of Transport, referred to the mid-point of a 'survey unit' 100 metres long. The 'survey unit' did not necessarily coincide with individual curves and, therefore, measured sight distances were not necessarily representative of the minimum sight distances of these curves. Close estimates of the minimum values were obtained by considering the minimum sight distance of the 'survey unit' which had its mid-point close to the centre of the curve. To retain the consistency of the data a similar approach was taken for the rest of the site sample with sight distances measured at a point close to the centre of the curve.

3.6 CURVE LOCATION AND SETTING OUT

The majority of the study sites were located in the field by means of the information given by the Halcrow Fox and Associates Study[2]. Local sites had already been located during our preliminary study[3]. For the additional six directional sites which were included after the completion of Phase I, location and setting out were carried out at the same time these curves were surveyed.

A reference grid was set out to enable consistent measurements of the forward and lateral movement of each vehicle to be made. The reference grid used consisted of a series of lateral marks placed on the road surface at predetermined positions. At these positions, for each lane, a set of two lateral marks was placed at the two ends of a pre-selected distance of about 20 metres dividing the lane into three parts of equal width. The locations are illustrated in Figure 3.5.

Initially, lateral marks were placed near the entry, the middle and the exit points of each directional curve. The exact positions were pre-determined from a speed/distance profile produced by means of an instrumented vehicle, driven by the same driver at a consistent driving mode. This allowed for a 'normal' driving pattern to be derived for each directional curve, and lateral marks to be placed at positions around the curve where considerable speed changes, if any, had been observed. The main shortcoming of this approach was the assumption that the speed/distance profile produced for the test driver would not be representative of the entire population from which the sample was to be drawn. The first trials revealed that on road curves with short radii, vehicle/driver behaviour was inconsistent. It was thus decided that lateral marks should be placed at the entry, middle and the exit points of each curve for consistency. This also allowed for accurate comparisons of vehicle speed changes at specific positions around a road curve to be made between different sites and for driver behaviour to be analysed at fixed critical alignment locations. A typical example of lateral road markings for one carriageway is shown in Figure 3.5.

3.7 COLLECTION OF PUBLIC ROAD DATA

Public road data was collected in two separate stages, Phase I and Phase II. Phase I started in November 1980, after the initial sample of sites had been selected, and was completed in February 1981, despite the difficult working conditions of the winter. Phase II began in June 1981, after the public road data collected during the first stage of the study had been analysed, and the surveys were completed in August 1981.

A comparison between the basic statistics of the two phases revealed that public road data collected during the winter and the summer periods was very similar. It was therefore considered that additional data would not improve the relationships already obtained between the dependent variables (driver behaviour), and the independent variables (road geometry, flow environment), and that a third data collection stage would not be required. The sample sizes in Phase II had been increased to account for this possibility.

Public road data collected during Phases I and II of the study were classified into four main categories as follows:

a. Public road vehicle speeds at the predetermined locations at each study site. (Public road vehicles were defined as those vehicle/driver combinations sampled from the users of the road during the course of their normal journeys.)

b. The lateral locations of public road vehicles at the predetermined positions.

c. General vehicle and driver characteristics.

d. Environmental data.

In the first category, public road vehicle speeds were recorded at four different locations, one before and three within each directional curve for both single and dual carriageways.

On the approach to the curve, vehicle speeds were measured by means of a Gatso digital mini radar speed-meter. Approach speeds were collected at positions from which, in most of the cases, the actual curve was not visible since they were used to represent free (desired) vehicle speeds on that particular section of the road, Care was taken to ensure that the radar speed-meter was well hidden from drivers' view.

Vehicle speeds were measured within the curve by timing vehicles over a fixed distance of about 20 metres at the entry, middle and the exit of each directional road curve (see section 3.6). Timing was performed manually by observers well hidden from the drivers' view. The manual timing of vehicles over a specified distance requires good reactions, experience and reliability. However, it was thought to be the most appropriate method for this study as radar speed-meters do not give accurate readings when on bends, and four would have been difficult to conceal from the drivers' view. The alternative use of pneumatic tubes was earlier abandoned since they are visible to drivers and have been shown to influence their behaviour[81]. The use of photo-electric detectors had also been rejected as they are difficult to set, unreliable and expensive.

A series of preliminary tests were carried out by all the study observers over sections of different lengths, i.e. 15, 20, 25 and 30 metres. It was found that a distance of about 15 metres was very short for timing fast moving vehicles whereas 30 metres was an unnecessarily long distance. From the remaining two, a disance of 20 metres was finally adopted on the grounds that driver behaviour would be more homogeneous over a shorter distance than a longer distance especially around road curves where a rather changeable driving pattern was expected.

The lateral placement of public road vehicles was also recorded by the same observers at the six pre-selected locations, as shown in Figure 3.5. Each observer recorded the position of the nearside front wheel of every vehicle sampled at the two end-points of the fixed distance over which vehicles were timed, at the entry, middle and the exit of every directional study site. Reference was made to the two lateral marks temporarily placed on to the road surface which divided each lane into three parts of equal width. Each of these three parts was then subdivided into another two subjectively by the observer. Thus, a possible total number of six lateral placements was created and the actual lateral placement of each vehicle was taken as the nearest of these six locations.

The following additional data was collected for each vehicle/driver combination sampled:

a. Vehicle Class.

b. Flowing Mode.

c. Sex of Driver.

d. Number of Passengers.

e. Vehicle Make.

f. Vehicle Registration Number.

g. Lane of the Carriageway (only for dual carriageways).

Vehicle class and flowing mode definitions have been described in Section 3.2. It was considered that the supplementary information on vehicle occupants could be useful in establishing possible trends among different groups of the driver population to identify otherwise unaccounted for variability in the subsequent analysis.

The following environmental and flow information was also collected:

i. Weather Condition (Wet or Dry).

ii. Road Surface Condition (Wet or Dry).

iii. Time of Measurement.

iv. Traffic Flow.

Data at all the study sites was recorded for a fixed sampling period of one hour (see Section 3.3). This was considered to be an economically justified sampling period, and was also long enough to provide the required sample sizes over the two study phases.

Initially it was decided that all vehicles on the road during the fixed sampling period should be considered, no matter whether they were free flowing or impeded by other slower vehicles. Each observer, therefore, was to record as many vehicles as possible within the sampling period and the final sample size was to be produced by matching up the data from the four different survey locations. This sampling procedure was tested at few local sites and it was found that the collection of an acceptable sample within the time allocated was difficult especially at sites with moderate to high flows. In some cases after matching up the data from the four observers, sample sizes of between 9 and 14 vehicles per hour were produced. It was, therefore, decided to link the observers using two-way radios and information on each vehicle identified by the first observer at the approach location was supplemented by the other three observers as the vehicle passed round the curve. The same sampling period of one hour was retained. The sampled vehicles were randomly chosen, on the 'next up' basis.

The only shortcoming of this random sampling procedure was that it resulted in low sample sizes of goods vehicles especially at those sites where the proportion of commercial vehicles was low. Whenever it was considered that the sample of goods vehicles had to be increased, the sampling period was extended as necessary. Goods vehicle data was not recorded at sites where gradient obviously affected their speed and no goods vehicle data was collected at sites with long uphill approaches and gradients greater than 3 per cent(63,82,83). Goods vehicle speed data was collected on all the downhill grades. This decision was made on the grounds that speeds of commercial vehicles on downhill grades were found by Charlesworth and Coburn(58) to be much the same as on level roads. The same conclusion was also reached by Willey(84) in the United States.

Public road data was recorded manually on survey forms (Figures A1 to A3 - Appendix A) in dry weather and on tape recorders in wet weather. At the end of a sampling period the total flow was also recorded. On single carriageways the traffic flow for both directions was considered whereas only directional flows were recorded on dual carriageways.

Sample sizes produced for cars, during the first phase of the study, varied between 28 and 70 cars at the single carriageway sites and between 29 and 81 cars at the dual carriageway sites. On average, 45 cars were sampled at each single carrriageway site and 56 at each dual carriageway site. Sample sizes for goods vehicles were much lower and ranged from between 1 and 22 vehicles at single carriageways and between 1 and 12 vehicles at dual carriageways.

During the second phase of the study the survey procedures remained the same but additional care was taken to ensure the collection of larger sample sizes at all the study sites. Better weather conditions, higher traffic flows, and experience gained from the previous surveys allowed the recording of more vehicles within the fixed sampling period of one hour used in Phase I. Where larger goods vehicle samples were required the sampling period was extended accordingly. Samples collected during the second phase of the study, for cars, varied in size from 39 to 77 cars (59 on average) at single carriageway sites, and from 67 to 98 cars (85 in average) at dual carriageway sites. Goods vehicle samples also varied in size between 1 and 33 vehicles at single carriageways and between 2 and 21 vehicles at dual carriageways. The variations in the sample sizes were caused mainly by different levels of traffic flow and the length of the road which comprised the sites.

In total, from both phases some 10,500 vehicle manoeuvres were recorded at the 56 directional single carriageway and 22 directional dual carriageway sites. Overall sample sizes for cars ranged from 79 to 134 cars (average of 104 cars) at single carriageway sites and from 87 to 173 (average of 138 cars) at dual carriageway sites.

Goods vehicle samples varied in size between 2 and 45 vehicles at single carriageway sites and between 1 and 30 vehicles at dual carriageway sites. The final sample sizes obtained are given in Tables 3.7 and 3.8. The operational, driver, vehicle, traffic and environmental parameters that were considered in this study are also listed in Table 3.9.

3.8 INSTRUMENTED VEHICLE

Speed information was recorded at all the sites considered in the Halcrow Fox Accident Study[2] with radii below 500 metres, by means of an instrumented vehicle. This was in addition to the public road data collected at the 78 directional road curves finally selected for both single and dual carriageways.

The main reason for the use of the test vehicle was that the expensive collection of public road data at all the Halcrow Fox sites would not be likely to be worthwhile because of the 'poor' site condition constraints on drivers. It was considered however that since the use of the test vehicle/driver combination was relatively inexpensive, the results could be used to identify site to site variabilities for accident evaluation. Clear relationships between test driver performance and accidents could make further public road data collection worthwhile.

The test vehicle was fitted with modified event recording equipment to enable distance measurements to be taken at set time intervals of about one second while the test vehicle, a 1.6 litre Ford Cortina, was driven through the study sites. The propshaft revolutions per second, which were later converted into speed, were counted and the information recorded on a magnetic data cartridge. This operation used one channel out of the available four of the event recorder, leaving three channels available for manual input of information. The information input by the observer related to the reference point marked on the road.

Constant speed runs were carried out over a section of road which was straight and level to calibrate the detection equipment. It can be seen from the results shown in Table A6 of Appendix A that the number of revolutions of the propshaft recorded was almost constant over the test road section regardless of vehicle speed. The small variations were probably caused by manual input errors in estimating the start and finish points of each test run. The trials were carried out using the recommended tyre pressure although tests indicated that the results were not sensitive to small changes of pressure.

Test vehicle data was always collected with the same driver, who was asked to drive around the study sites as normally as possible. Earlier tests made during a study on road intersections, carried out by the Transportation Research Group of the University of Southampton[86] for the Transport and Road Research Laboratory, had showed that the driving of the test driver, the same person used in this study, was consistent and reasonably representative of public road drivers. It was thus expected that consistency would be found between public road driver behaviour and the driving behaviour of the test driver at the study sites. During the earlier work[87] it was found that a maximum of 3 successful free runs per site with the test vehicle would produce statistically acceptable results. Since driving behaviour around rural road intersections and interchanges under low to moderate flow conditions was not expected to be considerably different from that of open road curves, especially with short radii, it was decided to follow the same practice in this study. Surveys with the test vehicle were carried out between April and August, 1981.

3.9 ACCURACY OF DATA COLLECTION PROCEDURES

Most of the geometric measurements were taken from the Halcrow Fox[2] data base. A reasonably high level of accuracy of these measurements is reported in that particular study. The same, if not a higher level, was achieved for the superelevation and additional width and gradient measurements obtained during the survey periods of the study.

Behavioural or operational parameters, such as speed, path and hence actual lateral acceleration are, however, far more difficult to measure accurately. They are highly dependent on the accuracy of the study instrumentation and the consistency of the observers.

The accuracy of the radar speed-meter used to measure approach speeds was highly dependent on the accurate setting of the device in relation to the road-line. For accurate speed measurements to be taken, the radar axis had to be set parallel to the road-line so that the beam could be transmitted at the required angle of 20 degrees to the line of travel of the vehicles. To check the accuracy and the sensitivity of the Gatso mini radar used, the radar beam was set at five different angles to a straight road alignment, including the normal setting of 20 degrees, and at angles of 15, 17, 23 and 25 degrees, and a series of runs at different preset speeds were made. The results of these tests are shown in Figures A4 and A5 - Appendix A. They clearly indicate, that for a normal setting of 20 degrees to the line of travel of vehicles, a high level of accuracy can be achieved which is only slightly reduced with a five degree error in setting.

Speeds were obtained within the study curves by timing vehicles over a fixed distance (see Section 3.7). The timing of the sampled vehicles was performed by means of digital electronic watches accurate to 1/100th of a second. The timing accuracy and consistency of the observers was assessed during preliminary tests when the same vehicles were timed by all the observers over a fixed distance. The resulting speed estimates were compared to those recorded by means of the radar speed-meter. The results are given in Table 3.10 and it can be seen from the consistency of the observed mean speeds that there are no systematic errors in the timing procedures.

It is important at this stage to examine the level of significance of the error term introduced by the survey method used. Actual vehicle path radius is the other measurement, apart from speed, which is required for the determination of behavioural parameters such as lateral acceleration. Average vehicle speed and geometric radius data from three sites considered in the preliminary study(3) was used to test the importance of errors. The percentage errors in lateral acceleration due to radius errors of 0.5, 1.0, 2.0, 5.0 and 10.0 metres were determined and the results are given in Table 3.11.

It can be seen from Table 3.11 that minor errors in the determination of the actual vehicle path geometry do not seriously affect the accuracy of the resulting values of various behavioural parameters, especially lateral accelerations, where vehicle speed is the predominant factor.

TABLE 3.1: MINIMUM SAMPLE SIZES REQUIRED FOR THE ESTIMATION OF PERCENTILE VEHICLE SPEEDS

Speed Statistics	Minimum Sample Size	
	Cars	Goods Vehicles
Mean	75	20
85th Percentile	115	32
99th Percentile	180	50

TABLE 3.2: SURVEYED STUDY SITE LIST - SINGLE CARRIAGEWAYS

Group	Curve No.	Radius	Road	County
100	1	34.0	B3054	Hampshire
101	1	39.0	B3055	"
102	1	290.0	B3056	"
103	1	40.0	A339	"
104	1	170.0	A272	"
104	2	161.0	"	"
130	2	349.4	A64	North Yorkshire
130	4	286.5	"	"
130	11	469.5	"	"
130	15	425.8	"	"
131	4	232.3	A61	"
131	6	355.6	"	"
131	18	361.1	"	"
133	2	406.8	"	"
140	2	237.4	A659	West Yorkshire
140	4	289.4	"	"
141	4	294.5	A660	"
142	1*	344.6	A6038	"
142	5	143.1	"	"
143	4	172.9	A62	"
143	9	250.9	"	"
144	2	139.1	A629	"
145	4	143.5	"	"
152	1	215.4	A417	Gloucester
171	4	499.0	A465	Gwent
172	3	374.0	"	"
183	3	194.4	A4059	Mid-Glamorgan
183	7	102.7	"	"
190	1	89.90	A285	West Sussex
190	1	89.90	"	"

56 Directional curves

*Excluded from the data analysis

TABLE 3.3: SURVEYED STUDY SITE LIST - DUAL CARRIAGEWAYS

Group	Curve No.	Direction	Radius	Road	County
1190	4	B	510.0	A38	Devon
1192	2	N	436.0	"	"
1192	3	P	169.3	"	"
1192	7	P	286.5	"	"
1192	9	P	447.5	"	"
1192	11	P	331.5	"	"
1192	14	P	420.9	"	"
1192	16	P	253.2	"	"
1192	20	P	297.1	"	"
1194	2	P	265.9	A380	"
1194	4	P	72.5	"	"
1195	2	P	134.7	"	"
1195	4	P	145.8	"	"
1195	2	N	311.4	"	"
1197	1	P	374.5	"	"
1200	3	B	260.2	A33	Hampshire
1202	1	B	383.7	"	"
1210	1	N	210.8	A24	Surrey
1211	1	N	208.0	"	"

20 Directional curves

TABLE 3.4: GEOMETRIC PARAMETERS CONSIDERED IN THE STUDY

1.	Horizontal Radius (m)
2.	Curvature (deg.)
3.	Curve length (m)
4.	Total curve angle (rad.)
5.	Rate of change of total angle (rad/m)
6.	Curve approach width (m)
7.	Curve entry width (m)
8.	Curve middle width (m)
9.	Curve exit width (m)
10.	Middle verge width (m)
11.	Curve entry superelavtion (m/m)
12.	Curve middle superelevation (m/m)
13.	Curve exit superelevation (m/m)
14.	Curve approach gradient (%)
15.	Curve entry gradient (%)
16.	Curve middle gradient (%)
17.	Curve exit gradient (%)
18.	Sight distance (m)

TABLE 3.5: SUMMARY OF GEOMETRY DATA - SINGLE CARRIAGEWAYS

PARAMETER	VALUE		
	Minimum	Maximum	Average
Curve Radius (m)	34.00	499.00	242.00
Curve Length (m)	47.90	303.00	154.17
Total Angle (rad.)	0.191	2.290	0.861
Middle Lane Width (m)	2.72	7.38	4.33
Verge Width (m)	0.10	19.00	2.88
Superelevation (m/m)	0.011	0.087	0.057
Middle Gradient Magnitude (%)	0.00	7.82	2.56
Sight Distance	70.00	1920.00	252.93
Flow (Veh/h)	110.00	831.00	476.00

TABLE 3.6: SUMMARY OF GEOMETRY DATA - DUAL CARRIAGEWAYS

PARAMETER	VALUE		
	Minimum	Maximum	Average
Curve Radius (m)	72.50	510.00	298.48
Curve Length (m)	71.00	555.00	226.66
Total Angle (rad.)	0.190	2.172	0.875
Middle Lane 1 Width (m)	2.80	4.22	3.56
Middle Lane 2 Width (m)	2.82	4.42	3.57
Verge Lane 1 Width (m)	0.20	12.00	3.35
Verge Lane 2 Width (m)	0.80	18.30	3.62
Superelevation (m/m)	0.031	0.104	0.061
Middle Gradient Magnitude (%)	0.05	8.55	2.80
Sight Distance	36.00	345.00	114.56
Flow (Veh/h)	393.00	1341.00	682.00

TABLE 3.7: SINGLE CARRIAGEWAYS - SAMPLE SIZES

SITE			SAMPLE			
Site Code	Group	Curve	All Cars	Free Cars	Goods Vehicles	Total
1	100	1	96	86	11	107
2	100	1	92	85	10	102
3	101	1	102	96	8	110
4	101	1	95	86	14	109
5	102	1	107	100	10	117
6	102	1	102	97	20	122
7	103	1	91	82	13	104
8	103	1	89	80	24	113
9	104	1	93	89	17	110
10	104	1	86	85	21	107
11	104	2	97	96	20	117
12	104	2	88	85	22	110
13	130	2	104	87	30	134
14	130	2	98	88	28	126
15	130	4	99	77	30	129
16	130	4	102	88	23	125
17	130	11	99	80	32	131
18	130	11	96	84	27	123
19	130	15	95	79	26	121
20	130	15	90	80	25	115
21	131	4	100	89	29	129
22	131	4	100	86	27	127
23	131	6	112	101	25	137
24	131	6	114	100	22	136
25	131	18	112	91	24	136
26	131	18	104	80	2	106
27	133	2	100	82	28	128
28	133	2	105	84	27	132
29	140	2	120	99	18	138
30	140	2	124	106	11	135
31	140	4	115	100	18	133
32	140	4	121	104	2	123

... continued

TABLE 3.7: ... continued

SITE			SAMPLE			
Site Code	Group	Curve	All Cars	Free Cars	Goods Vehicles	Total
33	141	4	128	110	7	135
34	141	4	124	111	8	132
35	142	5	109	80	0	109
36	142	5	109	79	6	115
37	143	4	89	84	10	99
38	143	4	79	74	30	109
39	143	9	89	75	13	102
40	143	9	91	83	22	113
41	144	2	110	88	13	123
42	144	2	116	84	13	129
43	145	4	110	88	16	126
44	145	4	126	103	9	135
45	152	1	100	88	30	130
46	152	1	101	93	30	131
47	171	4	129	106	0	129
48	171	4	134	114	30	164
49	172	3	118	92	40	158
50	172	3	114	73	33	147
51	183	3	87	72	45	132
52	183	3	98	83	31	129
53	183	7	104	82	28	132
54	183	7	96	72	33	129
55	190	1	115	112	7	122
56	190	1	111	110	11	122

TABLE 3.8: DUAL CARRIAGEWAYS - SAMPLE SIZES

SITE			SAMPLE			
Site Code	Group	Curve	All Cars	Free Cars	Goods Vehicles	Total
1	1190	4	152	139	16	168
2	1190	4	141	129	3	144
3	1192	2	141	131	29	170
4	1192	3	162	153	20	182
5	1192	7	164	153	20	184
6	1192	9	173	149	3	176
7	1192	11	165	152	1	166
8	1192	14	152	138	1	153
9	1192	16	132	119	0	132
10	1192	20	152	140	0	152
11	1194	2	127	111	30	157
12	1194	4	139	115	17	156
13	1195	2	155	134	13	169
14	1195	2	157	130	22	179
15	1195	4	151	126	16	167
16	1197	1	136	118	3	139
17	1200	3	101	78	26	127
18	1200	3	99	81	22	121
19	1202	1	127	99	23	150
20	1202	1	113	94	26	139
21	1210	1	87	76	28	115
22	1211	1	104	99	19	123

TABLE 3.9: OPERATIONAL/VEHICLE/TRAFFIC AND ENVIRONMENTAL PARAMETERS MEASURED IN THE STUDY

1.	Approach speed k.p.h.
2.	Curve entry speed k.p.h.
3.	Curve middle speed k.p.h.
4.	Curve exit speed k.p.h.
5	Entry lateral placement (m)
6.	Middle lateral placement (m)
7.	Exit lateral placement (m)
8.	Vehicle class
9.	Flowing mode
10.	Driver's sex
11.	Vehicle make
12.	Vehicle front track width
13.	Number of passenger
14.	Weather condition
15.	Pavement condition
16.	Date/Time
17.	Total flow (vehicles per hour)

TABLE 3.10: SUMMARY OF RESULTS OF TIMING ACCURACY TESTS

DESCRIPTION	MEAN SPEED VALUES (k.p.h.)			
	Observer A	Observer B	Observer C	Radar Speed-meter
Distance of 15 metres				
Test 1	56.52	57.23	56.29	56.54
Test 2	54.09	53.18	53.42	53.87
Distance of 20 metres				
Test 1	76.75	75.90	76.51	76.00
Test 2	79.96	80.50	79.34	79.47
Distance of 25 metres				
Test 1	74.51	75.00	74.90	74.51
Test 2	78.87	78.00	77.92	78.12

TABLE 3.11: TEST OF THE SIGNIFICANCE OF ERROR TERMS INTRODUCED BY THE LATERAL PLACEMENT DATA COLLECTION METHOD

Error in Radius (m)	Curve Radius=39m Speed=37.76 k.p.h. Lateral Acceler. (%)	Curve Radius=165m Speed=73.01 k.p.h. Lateral Acceler. (%)	Radius=300m Speed=80.96 k.p.h. Lateral Acceler. (%)
0.5	1.26	0.30	0.00
1.0	2.50	0.60	0.34
2.0	4.87	1.20	0.67
5.0	11.34	2.94	1.64
10.0	20.00	5.71	3.23

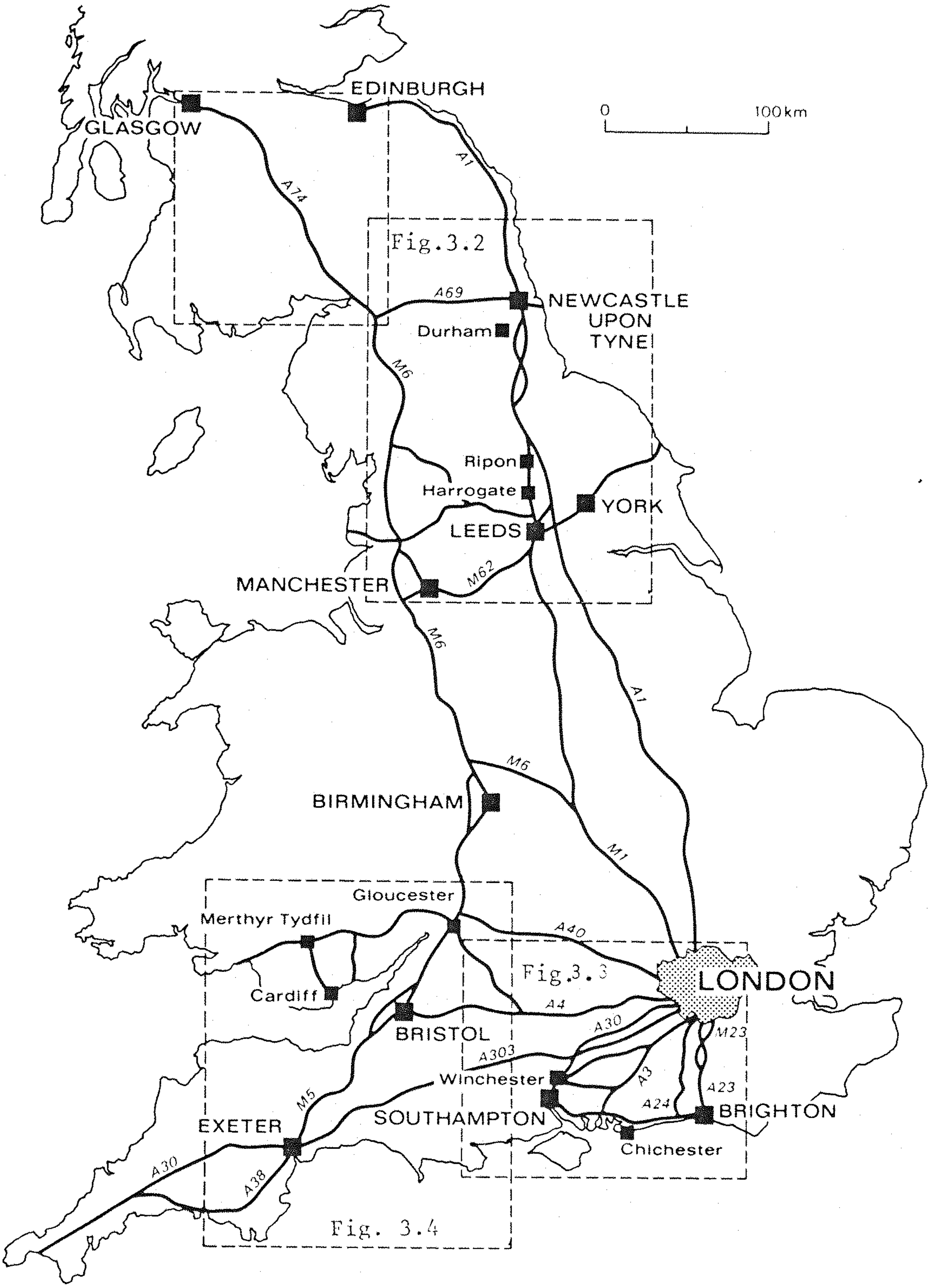


Figure 3.1: Location of All Study Sites

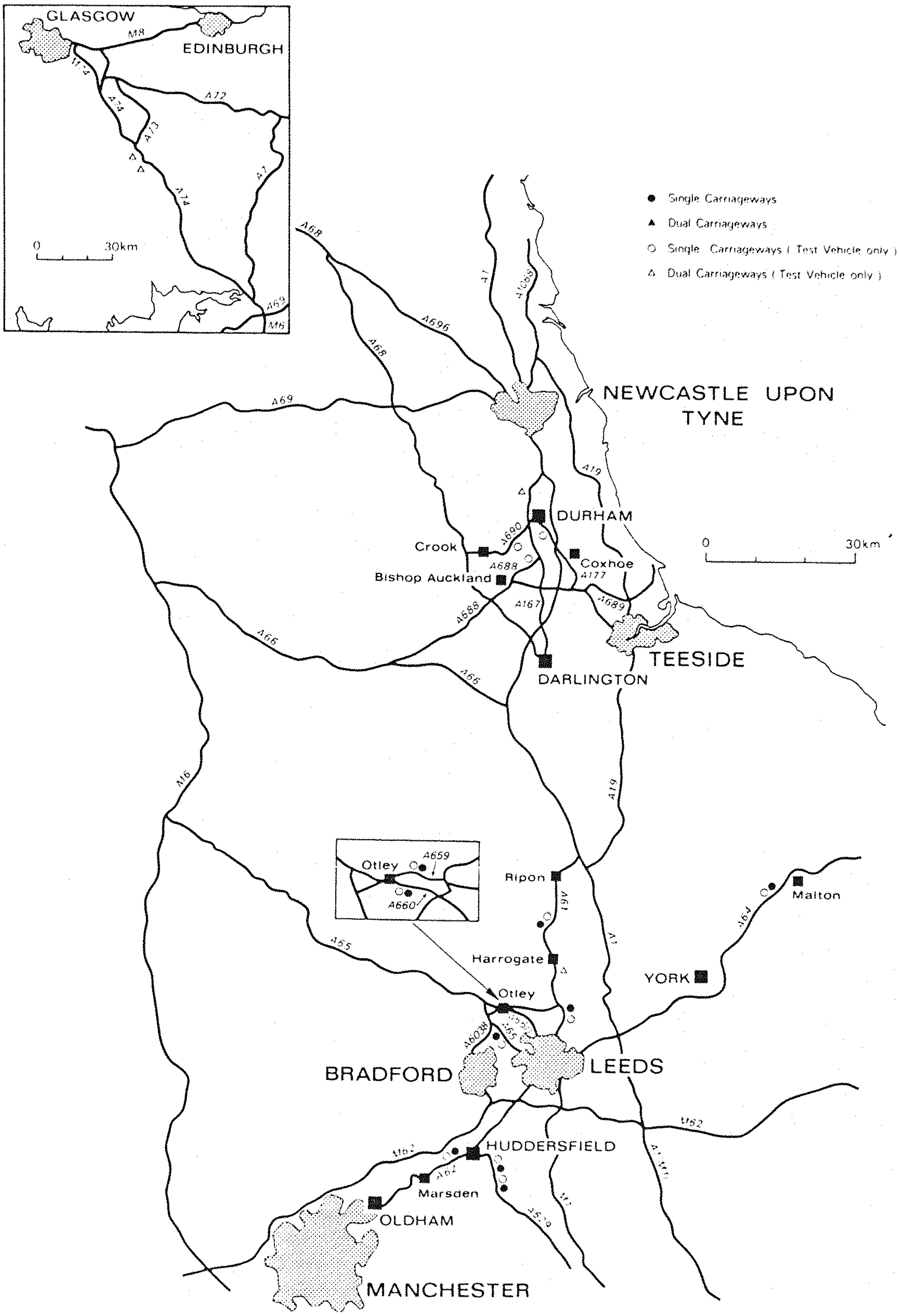
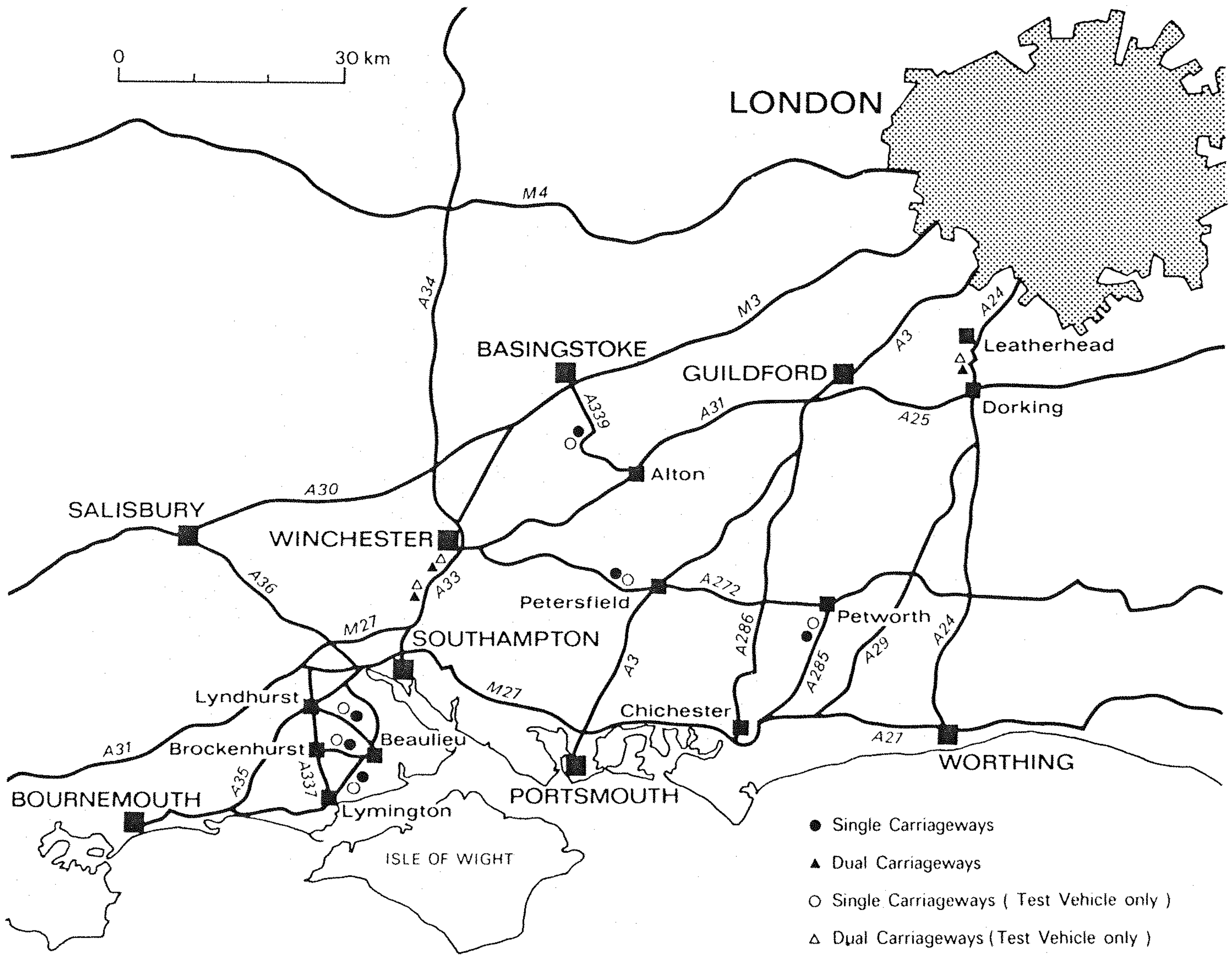


Figure 3.2: Location of Northern Study Sites

Figure 3.3: Location of Southern Study Sites



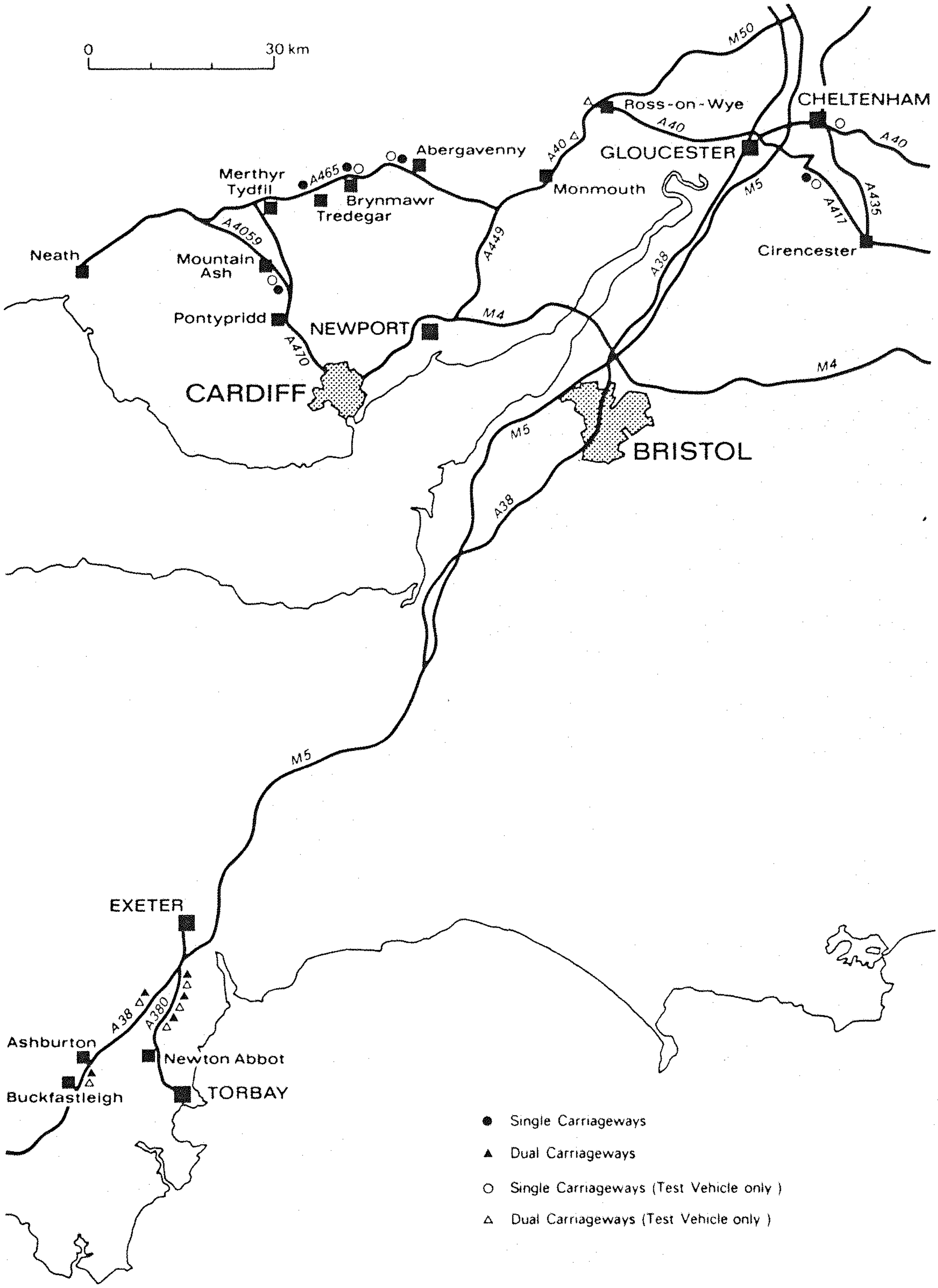
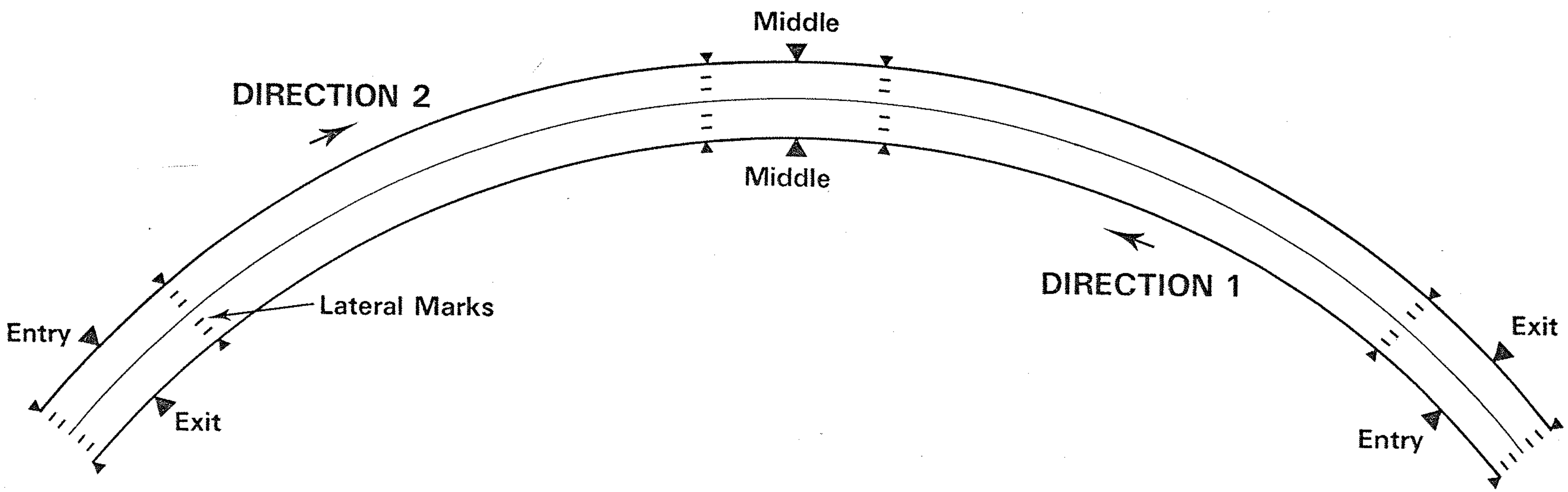


Figure 3.4. Location of South Western-Study Sites



SINGLE CARRIAGEWAY
GROUP 183
Curve 7
Sections 7-8
Hor. Rad. = 102.70m

Figure 3.5. Typical Example of Road Markings used for Public Road Data Collection

CHAPTER FOUR

DATA MANIPULATION

4.1 DATA MANIPULATION AND REDUCTION

Geometric, environmental and traffic flow data for each directional study curve was checked manually, before being coded and punched on to computer cards. Some basic calculations had to be carried out to obtain superelevation values and these were performed on a programmable pocket calculator. This data was then input into files on the University ICL 2970 computer.

Obvious errors were removed and corrections were made only when the error observed was simple and clearly identifiable, such as in the matching up of registration numbers of vehicles. Cases where the vehicle speed at a single survey location was substantially different from that at the other positions within the site, for no apparent reason, were excluded together with those cases where only partial information was available. The total number of such changes only amounted to an insignificant percentage of the total sample.

Vehicle timing and registration data were input in the form in which they had been recorded. Lateral location, vehicle class and driver information was coded appropriately. The information concerning the front track width of the vehicles sampled was also input, together with a code indicating the make of the vehicle. Front track width data, i.e. the distance between the middle points of the two front wheels, was taken from manufacturers specifications and used to accurately locate each vehicle. The relationship between overall width and front track width for all the sampled cars is shown in Figure B1 - Appendix B. In cases where no specific information about the front track width of a car was available, an estimate was made from that relationship. An average value of 1.632 metres was found for the front track width of the recorded sample of cars, and was used where both the overall and the front track widths were not available. The variation in front track width was much greater for rigid and articulated goods vehicles. Average values of 1.920 metres and 1.980 metres were adopted for rigid and articulated goods vehicles respectively, after information from the manufacturers and the British Road Federation(86) was analysed and compared with information available to the Transport and Road Research Laboratory(87). An average value of 2.05 metres was also adopted for buses and coaches.

The edit procedures were completed by a series of manual checks of the information on the computer files against the original data. Edit checks were carried out to identify possible punching or copying errors as well as coding and format inaccuracies. In cases where such errors were detected, data files were edited interactively. The resulting edited files have been used in all the subsequent analyses.

Previous experience[3,22] had shown that it would be very difficult to collect enough information for the different vehicle categories considered, classified according to vehicle type and prevailing ' flow conditions'. This was expected to be particularly the case for single carriageway sites where the existence of low flow conditions would result in data samples consisting almost entirely of free-moving vehicles.

As expected, sample sizes for some vehicle class/flowing mode combinations were found to be extremely low for either single or dual carriageway sites. Free-moving vehicles were always the predominant class on either road types, although in the case of dual carriageways platoon leaders and cars in platoons were found to represent a considerable proportion of the data, substantially higher than on single carriageways. The number of impeded cars on single carriageways was low mainly due to the prevailing conditions. Goods vehicle samples were generally considerably lower than those of cars and no separation according to different types and flowing conditions was possible. It was, therefore, decided that the analysis should be concentrated on those vehicle categories for which the available sample sizes could be statistically and conceptually justified. The following three categories were considered:

a. All Cars.

b. Free (Flowing) Cars.

c. Goods Vehicles.

The entire sample of cars recorded during the two survey periods was included in the first category. In the second category only free-moving cars and platoon leaders were included. In the third category all goods vehicles recorded during the surveys were included.

Goods vehicle data was not recorded at those sites where gradient severely restricted vehicle speeds. Information from other sites had to be excluded from the final analyses where the sample of goods vehicles was unacceptably low in either statistical or conceptual terms. The sample sizes obtained for goods vehicles on both single and dual carriageway sites is shown in Figure 4.1. An examination of the distribution reveals that, if the desirable minimum of 20 vehicles is adopted, a considerable number of study sites would be excluded from subsequent analyses whereas a minimum sample size of 18 vehicles for single and 17 vehicles for dual carriageway sites would ensure the inclusion of a substantial number of sites in the final analysis. Such a relaxation would also provide an acceptable range of curvature values for both single and dual carriageways, a main requirement of the regression analysis. These slightly reduced sample sizes were thus adopted, providing final samples for analysis of 31 single carriageway and 12 dual carriageway sites. The sample sizes are detailed in Table 4.1.

Test vehicle speed data, originally stored on magnetic data cartridges, was also input to computer files after it had been transferred to paper tape. At the same time complete lists of these data were produced in order to carry out manual tests of consistency. In one case, the detecting device which was attached to the vehicle's propshaft was found to have produced erratic results due to misplacement, and additional runs had to be made at three study sites.

The entire site sample of 56 directional single carriageway and 22 directional carriageway sites was considered for both car classifications in the final data analysis.

4.2 DETERMINATION OF DESIGN SPEEDS

The design speeds of all the road sections selected for this study were calculated according to Departmental Standard TD 9/81[17].

According to the Departmental Standard, the Design Speed of a homogeneous road section, longer than 2.0 kilometers, can be derived *"from Figure 1* (see Figure 2.26)*, which shows the variation in speeds for a given L_C against A_C".* L_C and A_C are defined as alignment and layout constraints. L_C can be determined when the road type, carriageway width, verge width and the degree of access and number of junctions are known. A_C is derived by the following formulae:

Single Carriageways $\quad A_C = 12 - VISI/60 + 2B/45$

Dual Carriageways $\quad A_C = 6.6 + B/10$

where B is the bendiness of the section, degrees/km and

VISI is the harmonic mean visibility of the section, metres.

In this study, bendiness and visibility parameters were calculated for each road section, which included particular study sites, longer than the required limit of 2.0 kilometers. However some use of the following visibility prediction equation recommended for use by the Standard was also made in cases where actual visibility (sight distance) measurements were not available.

$$\text{Log}_{10}\,VISI = 2.46 + VW + 25 - B/400$$

where VW is the average verge width of the section, metres.

Design speeds derived for the road sections considered in this study are listed in Tables B1 and B2 of Appendix B, for single and dual carriageways respectively.

TABLE 4.1: AVERAGE SAMPLE SIZES FOR DIFFERENT VEHICLE CLASSIFICATIONS

VEHICLE TYPE	SINGLE CARRIAGEWAYS			DUAL CARRIAGEWAYS		
	Minimum	Maximum	Average	Minimum	Maximum	Average
All Cars	79	134	104	87	173	138
Free Cars	72	114	89	76	153	121
Goods Vehicles	2	45	21	1	30	17

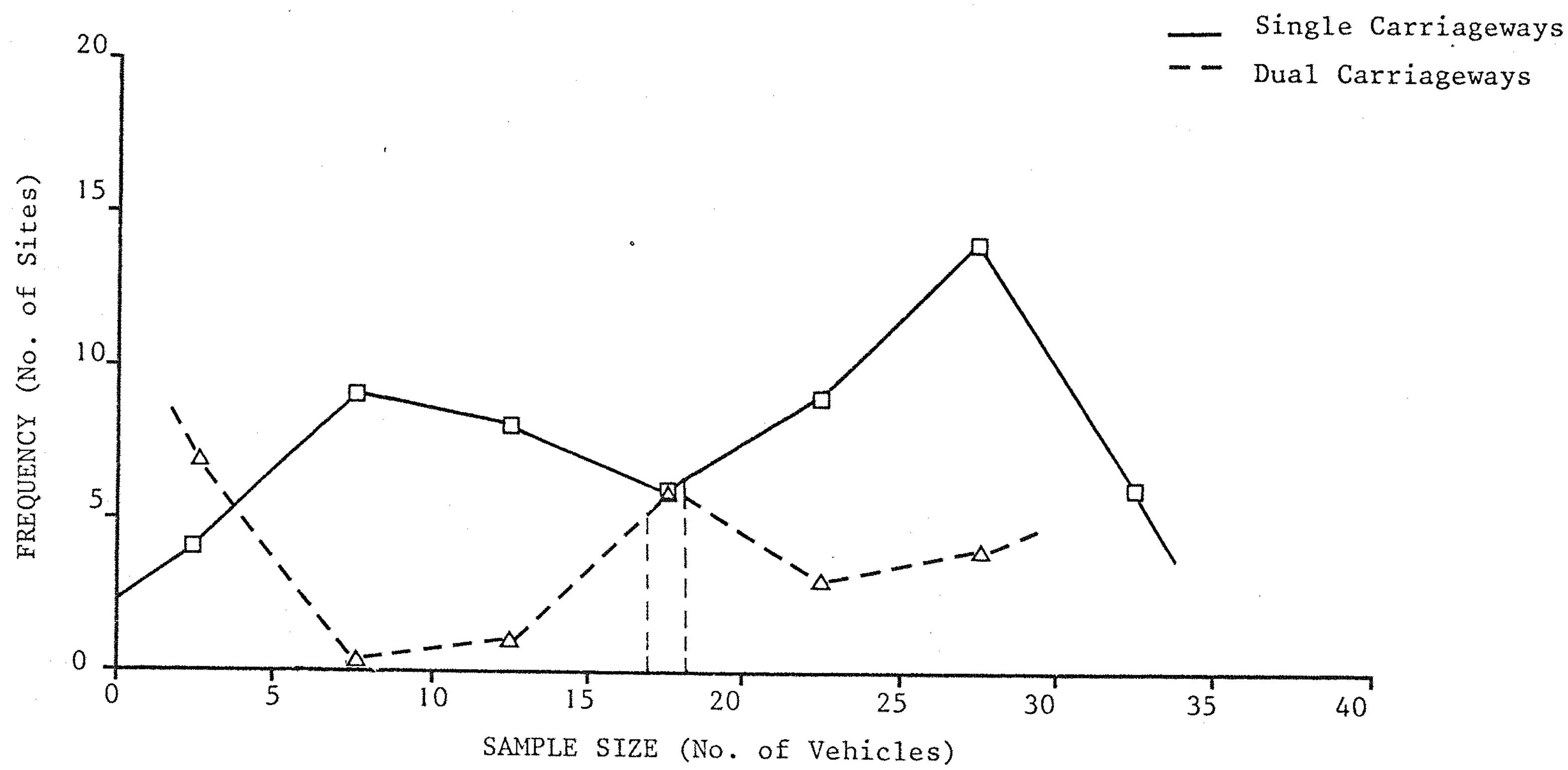


Figure 4.1: Frequency Distribution of Sample Sizes
(Single and Dual Carriageways - Goods Vehicles)

CHAPTER FIVE

METHOD OF ANALYSIS

5.1 INTRODUCTION

The main objective of the analyses was to determine the relationships found in the data between vehicle/driver behaviour and curve geometry, traffic flow, and environmental parameters prevailing at the study sites during the course of the surveys.

The methods of analyses described in this chapter follow a number of sequential stages:

a. An examination of the distributions of speeds and lateral accelerations.

b. Tests to compare speed distributions obtained during Phase I and Phase II of the study, as well as between those recorded under different road surface conditions and at the different measurement locations.

c. An assessment of the speed variations which occur on the approach to, and within, road curves.

d. A determination of the basic relationships between vehicle speed, lateral acceleration and side-friction factor and the curve geometry parameters.

e. Multivariate analyses to relate the variations in speed and lateral acceleration to curve geometry, approach speed characteristics and traffic flow.

f. Analysis of the variation in the lateral placement of vehicles at the measurement points of each site with respect to the observed speeds.

g. Examination of speed/distance profiles produced by the test driver/vehicle at selected sites on both single and dual carriageways with respect to public road drivers.

The analysis methods described in this chapter apply equally to the three vehicle classifications considered in the study as well as to the results from the two survey phases. In the following text, unless specifically stated otherwise, references relate to the combined data obtained for the three study vehicle classifications.

5.2 EXAMINATION OF VEHICLE SPEED AND LATERAL ACCELERATION DISTRIBUTIONS AND NORMALITY TESTS

A computer program was written for the analysis of the speed and lateral acceleration data and to test the form of the observed speed and lateral acceleration distributions (see listing in Appendix C).

Each speed distribution obtained during the survey periods at each survey location and at each directional study site was considered separately.

The measured vehicle speed data was classified and grouped into speed cells of varying width depending on the size of the distribution, and a series of statistical parameters such as mean, median, standard deviation, skewness, kurtosis and the coefficient of variation were calculated. At the same time the observed 85th, 90th, 95th and 99th percentile speed values were produced.

Previous experience [3,22] had shown that the speed distribution of free-flowing vehicles on a straight, level section of road could be successfully approximated by a normal distribution. The validity of this assumption was tested by means of the chi-squared and Kolmogorov-Smirnov tests at a 5 per cent significance level. The chi-squared test was applied four times on each individual data set, each time with a different grouping arrangement of the observed and the theoretical frequency values, since the sensitivity of the test is dependent on the system of aggregation. The basic statistical requirement that the value of the theoretical frequencies in a particular group had to be equal or greater than 5 was given most consideration. Where it produced substantial differences from the other three frequency grouping arrangements, additional tests with different groupings data were also applied. When the Kolmogorov-Smirnov test was used, normality tests were applied twice, once for ranked categories (frequency distributions) and once for rankable scores (now data consideration).

At the same time the theoretical (normal) 85th, 90th, 95th and 99th percentile speed values were also determined[88,89]. This allowed comparisons to be made between the higher percentiles of the observed and theoretical speed distributions, and the validity of the normality assumption to be checked for the upper end of the observed speed distribution where considerable deviations from the theoretical were suspected. A typical example of these calculations and checks performed on the computer is shown in Figure C1 of Appendix C.

Observed, smoothed and theoretical speed distributions, together with percentage cumulative frequency distributions were also plotted separately for visual inspection. Typical examples of these plots are shown in Figures C2 and C3 of Appendix C.

Goods vehicle sample sizes were generally low for meaningful tests using the chi-squared test. For that reason only the more rigid Kolmogorov-Smirnov test was applied to the finally selected goods vehicle speed distributions.

It should be noted here that individual speeds for the survey locations within the study sites were computed by dividing the fixed distance of about 20 metres by the time taken for each vehicle to pass. The mean values of the speed distributions produced were thus time-mean speeds for direct comparison with the mean spot speeds of vehicles recorded by the radar speed-meter.

The lateral accelerations developed by the sampled vehicles at the centre of the curves were calculated from the speed of the vehicles at the middle of the road curve (V^2/R). These values were expected to be very similar to the actual lateral acceleration values, where the radius of the actual path of the vehicle was considered instead of the radius of the centre-line of the carriageway. The predominance of the speed squared value resulted in a very low sensitivity to small changes in the magnitude of R.

Simple bivariate tests were carried out at the end of Phase I to test the significance of the replacement of the radius of the actual vehicle path by the geometric radius of the centre-line of the carriageway. In these, lateral acceleration values of identical vehicles were calculated using both the geometric and the actual instantaneous vehicle path radii. The latter was determined over the middle 20 metres survey distance by means of vehicle lateral placement data collected at the two end-points of the corresponding section. In all cases the results obtained substantiated the argument that geometric radius could safely be used for the determination of the study sites. A typical example of these tests is given in Figure C.4 of Appendix C.

The form of the all car lateral acceleration distributions developed at the centre of all single and dual carriageway sites was again tested by means of the twofold Kolmogorov-Smirnov test.

5.3 COMPARISON BETWEEN PHASE I AND PHASE II OBSERVED SPEED DISTRIBUTIONS

The consistency of driver behaviour between the two phases and for different road surface conditions was important to ensure that the data collected during the two phases of the study, and under different weather conditions, could be combined for the final analyses.

All the comparisons were carried out by means of a two-tailed t-test assuming that the populations under study were normal. In both comparison tests, i.e. speed comparison between Phases and speed comparison for different surface conditions, only cars were considered mainly for simplicity. It was assumed that any trends for all cars would be applicable to the other two vehicle classifications, i.e. free cars and goods vehicles, since they were recorded under the same flow and environmnetal conditions.

The hypothesis tested was that the two mean values of the respective distributions were equal, i.e. that $\bar{X}_1 - \bar{X}_2 = 0$, where $\bar{X}_1$ was the mean value of the speed distribution for Phase I and $\bar{X}_2$ the corresponding mean value for Phase II. All tests were carried out by computer, and graphs of the various percentile values of the Phase I and Phase II speed distributions were plotted to supplement the statistical findings by visual inspection.

Bivariate comparison tests were also carried out between vehicle speed distributions obtained at different survey locations within each study site. The main purpose of these tests was to identify the relationships between vehicle speed distributions at different locations before and within the study sites and to establish trends. Various percentile values of approach speed distributions were also plotted against the corresponding values for entry and middle speeds.

5.4 SPEED VARIATION BEFORE AND WITHIN THE STUDY SITES

In the past, there have been relatively few studies of the variation of vehicle speeds around road curves, and results have been found to be contradictory (see Chapter 2). Taragin[50] concluded that speeds were essentially constant on open highway curves, although Kneebone[51] found speed to vary continuously throughout a curve, reaching a minimum near, or shortly after, the centre of the curve. Other experiments have shown speeds to be constant over the central 20 or 25 per cent of the curve.

To examine the validity of these findings and to establish current trends in Britain, the 85th percentile speed-distance profiles of free cars and goods vehicles were plotted for a selected number of single and dual carriageway sites. The individual vehicle speed/distance profiles were also carefully studied at each of these sites, and compared with the overall pattern at that site.

Selected speed/distance profiles of the same study sites produced by the test vehicle/driver combination were superimposed on the public road data plots to substantiate any possible trends observed for a particular site group.

5.5 BIVARIATE PLOTS AND CURVE FITTING

A bivariate analysis between the behavioural parameters currently adopted in the design practices i.e. speed, lateral acceleration and side-friction factor, and the most influential geometric elements was undertaken.

Previous experience[1,3,41,62] had shown that curve radius or its inverse, curvature, were the main geometric elements affecting vehicle speeds around single carriageway road curves under low to moderate flow conditions. These findings were also supported by the results of our preliminary study[3]. The effect of curve radius on vehicle speeds through dual carriageway curves had not been investigated in the past but a similar pattern was initially assumed. Initially bivariate scatter plots were produced between the above mentioned behavioural and geometric parameters for the three study vehicle classifications with distinctions between single and dual carriageways. The following percentile values of the observed vehicle speed, middle lateral acceleration and middle side-friction factor distributions were also considered in the between-sites bivariate analysis:

a. Mean Value.

b. 85th Percentile Value.

c. 99th Percentile Value.

Mean values are useful in the planning and appraisal of schemes whereas the 85th and 99th percentile values constitute basic parameters in the current horizontal design policies[17,36,37].

The following relationships were considered in detail:

a. Approach Speed v Curve Radius.

b. Entry Speed v Curve Radius.

c. Middle Speed v Curve Radius.

d. Lateral Acceleration v Curve Radius.

e. Side-Friction Factor v Curve Radius

f. Lateral Acceleration v Middle Speed.

g. Side-Friction Factor v Middle Speed.

An additional distinction was made between left and right-hand curves for single carriageway all and free cars. Low sample sizes did not allow similar distinctions to be made for goods vehicles or for dual carriageway data.

The bivariate scatter plots were produced using CALCOMP plotting routines available in the library of the main computer. The bivariate scatter diagrams were visually informative and indicated the likely mathematical models which could be fitted. Each of the models selected has been assigned a code which has been used to identify the respective form in the remaining part of the text.

Models Form	Code
a. $Y=A\pm B*X$	I
b. $Y=A\pm B/X$	II
c. $Y=A\pm B*\sqrt{X}$	III
d. $Y=A*B^X$	IV
e. $Y=A*X^B$	V
f. $Y=A*(1-\exp(-BX))$	VI
g. $Y=A*(1-\exp(-B*(X-Rmin)))$	VII

where

Y, X are the variables considered,

A is the constant (intercept)

B is the coefficient (slope), and

Rmin is the minimum turning radius of a particular vehicle class.

The first five models were fitted to all the bivariate scatter plots considered. Model VI, had been fitted by Emmerson[62] to his observed scatter of middle speed against curve radius for single carriageways. This model was initially thought to be superior to the other linear, curvilinear and exponential models (I-V), because a zero value of radius gave a zero value of speed, and speed tended to a constant value for larger radii. Equation VII was developed to overcome the inconsistency in this model as each vehicle has a turning radius limited by its own steering capabilities at an almost zero speed. Equation VII shifts the relationship on the radius axis by a constant value equal to the average minimum turning radius for a particular vehicle classification. The average minimum turning radius for all the sampled cars was found to be 5.06 metres. A corresponding average value of 10.0 metres was taken for goods vehicles[90].

The model fitting was performed by means of simple linear regression analysis after any necessary transformations. An iterative procedure was used for the last two exponential models, and the parameters may, therefore, be slightly sub-optimal.

All bivariate analyses were performed by means of the GENSTAT and HASH statistical packages available in the computer library.

The goodness of fit of each model was principally judged from the coefficient of determination (r^2) and a two-tailed statistical test used at a 95 per cent significance level for the regression coefficient. Detailed description of the statistical tests considered in the regression analyses is given in the following section. The selection of the most appropriate model for a particular data set was also made on conceptual grounds. For example, vehicle speeds around large radius curves were shown to tend to a constant value. This is conceptually correct since very large radius curves, do not differ substantially from straight road sections. The selected model had to conform to this concept. Also whenever the choice lay between curvilinear models, the one with the best statistical fit was selected on the basis that a curvilinear model is only valid for the range of values to which it is applied. However, whenever it was thought appropriate, a second model conceptually more suitable for values outside the available range has also been given.

5.6 MULTIPLE REGRESSION ANALYSIS

Multiple regresssion is a technique to define and quantify the relationship between more than two interrelated variables. The affected variable is defined as the dependent (predicted) variable and the others are the independent (predictor) variables.

The general form of the multiple linear regression model is:

$$Y^1 = a+b_1X_1+b_2+X_2 + \ldots+b_pX_p+\varepsilon \qquad (5.1)$$

where Y^1 is the dependent variable,

$X_1,\ldots,X_p$ are the p independent variables.

a is the constant term,

$b_1,\ldots,b_p$ are the regression coefficients, and

ε is the error term.

The main assumptions implied in a multiple linear regression model are:

a. The independent variables are not intercorrelated.

b. The error term, the residual, $Y-Y^1$ where Y is the observed and Y^1 the estimated values of the dependent variables, is normally distributed with a constant variance and a mean of zero.

Assuming that $\varepsilon = 0$, the model 5.1 became,

$$Y^1 = a+b_1X_1+b_2X_2+\ldots+b_pX_p \qquad (5.2)$$

The constant and regression coefficients can be determined by means of the least squares method, where the sum of the squares of the residuals is minimised.

Hence $\Sigma(Y-\bar{Y})^2 = \Sigma(Y^1-\bar{Y})^2 + \Sigma(Y-Y^1)^2$

where $\bar{Y}$ is the mean value of Y

$Y-\bar{Y}$ is the total deviation of observed values around mean

$Y^1-\bar{Y}$ is the deviation of fitted regression values around mean

$Y-Y^1$ is the deviation around regression line

The general form of the polynomial (curvilinear) model proposed was:

$$Y^1 = a+b_1X+b_2X^2+\ldots+b_pX^p+\varepsilon \qquad (5.3)$$

which after suitable transformations, i.e. $X \equiv X_1$ and $X^2 \equiv X_2$, can be written as a multiple linear regression model identical to 5.1.

The theoretical basis of multiple linear regression and correlation analysis is presented in many textbooks[91,92]. We will not consider this in detail, but some consideration has been given to two properties of the multiple linear regression equation which are of particular importance to the study.

a. Coefficient of determination (r^2), measures the proportionate reduction of total variation in Y associated with the use of the set of X variables.

b. Standard error of estimate (s), represents the standard deviation of the residuals and it is used to indicate the closeness with which the estimated values of the dependent variables agree with the observed values.

The test of a relationship between the dependent variables Y and the set of independent variables X is to choose between the alternatives:

C_1: $b_1=b_2= \quad =b_p=0$

C_2: not all b_k $(k=1,\ldots,p)$ equal 0

The variation of the dependent variables which could be associated with the variance of the independent variables was also checked, using the F-distribution and a specified level of confidence. For this reason one-way analysis of variance tables were also produced for each regression model.

Graphical analysis of the residuals was also used to examine important types of departures from the proposed multiple linear regression model with normal errors. The following five departure types were examined:

a. The regression function was not linear.

b. The error terms did not have constant variance.

c. The error terms were not independent.

d. The model fitted all but one or a few earlier observations.

e. The error terms were not normally distributed.

5.6.1 Method of Analysis

The objectives of the regression analyses were:

a. To broadly identify the variables which influence driver behaviour when negotiating open curves, i.e. speed or lateral acceleration, and to test the significance of this influence by examining observed driving behaviour at the study curves.

b. To develop relationships which would adequately predict driver behaviour around open curves with varying geometry, flow and environmental conditions.

The main part of the analysis was concentrated on the first objective, and attempted to find the combination of independent variables which best explained, in terms of statistical significance, the variations in the dependent variables. At a later stage, the analysis was directed at deriving predictive relationships for vehicle speed and lateral acceleration which were statistically and conceptually acceptable, as well as being mainly based on parameters which are generally known or which can be readily determined.

All multiple regression computations were carried out in a stepwise manner to ensure that the most important independent variables were included. The method chosen for entering independent variables into the equation at each step was the F-method where the variable with the smallest F-to-remove was removed if its F-to-remove value was less than the F-to-remove limit. If no variable met this criterion, the variable with the largest F-to-enter was entered if the F-to-enter exceeded the F-to-enter limit. A tolerance check was also performed to ensure that a variable was not too highly correlated with one or more variables already in the equation. More specifically, an independent variable was not entered in to the equation if it did not pass the tolerance limit; i.e. if its coefficient of determination (r^2) with independent variables already in the equation exceeded 1.0-tolerance, or if its entry would cause the coefficient of determination of any previously entered variable with the independent variables in the equation to exceed 1.0-tolerance.

F-to-enter and F-to-remove limits could be preset from an F distribution for known degrees of freedom. Degrees of freedom are closely related to the sample size and the number of independent values in the equation. With different degrees of freedom at each step, the F-limits taken from an F distribution at a specific confidence level would therefore not be constant, and would be different from the preset value. It was thus decided to use very low F-limits initially, which allowed almost all the independent variables to be entered in the equation. The elimination process was then performed manually with the correct F-limit values considered at each step.

The regression equations were selected, during the elimination process described above, on the basis of the following criteria:

a. A selected regression equation had to have a multiple determination coefficient, r^2, that was significant at the 99 per cent level of confidence,

b. Each of the independent variables in the regression equation had to have coefficients which were significantly different from zero at the 95 per cent level of confidence.

The first requirement was checked by means of the F-value produced for the overall equations. The second requirement was also checked by means of an F-value (F-to-remove) produced for each regression coefficient, equivalent to a two-tailed t-test since F equalled the squared value of t. Bivariate intercorrelations between the independent variables were checked by means of bivariate correlation matrices and a tolerance value of 0.40 was also used for multiple intercorrelations to be performed. Variables which failed to meet the correlation criteria were excluded from the analysis process. It was thus ensured that the set of regression equations obtained were statistically significant and accurate.

Extensive residual analysis was also available with the BMDP statistical package used. Statistics that could be either printed or plotted included observed and predicted values, one-way analysis of variance tables and residuals. These statistics aided in assessing the aptness of the linear models, the fit of the data to the regression, the independence of the independent variable and the sensitivity of the regression equation to the data for each case.

The same selection criteria were applied in the case of the polynomial (curvilinear) regression analyses.

5.6.2. Regression Models Developed in this Study

Multiple regression analysis was performed separately for the following two cases:

Case A: All study sites were considered.

Case B: Only selected study sites were considered.

In the first case regression equations were developed for all the directional road curves on both single and dual carriageways. Thus, the influence of the various geometric characteristics of the approach and of the curve itself as well as the effects of the prevailing flow conditions on vehicle/driver behaviour could be investigated over the entire sample of sites surveyed.

In the second case, regression analysis was performed for only those study sites where curvature was believed to be the main determinant of vehicle/driver behaviour. Curvature was identified for separate examination because, as discussed in Chapter 2 it was believed to account for a large amount of the variation in vehicle/driver behaviour around open road curves at low to moderate traffic flows.

5.6.2.1 *Dependent Variables*

Separate analyses were carried out for 85th percentile speed and lateral acceleration values. As explanatory and predictive relationships for these parameters are likely to be of most use in design and traffic engineering considerations, this dependent variable was subjected to more detailed scrutiny than were the 50th and the 99th percentile values.

The following dependent variables were considered in the multiple regression analysis process:

a. The 85th percentile speed at the curve entry, k.p.h.

b. The 85th percentile speed at the curve centre, k.p.h.

c. The 85th percentile lateral acceleration at the curve centre, m/sec^2.

Initially, some consideration was also given to the 50th and the 99th percentile speed and lateral acceleration values. Since vehicle speeds and lateral acceleration were taken to be normally distributed (see Section 5.2) it was considered that 50th and 99th percentile regression equations could be obtained from the 85th percentile value relationships by applying a simple normal distribution relationships., i.e. $V(99)/V(85) = V(85)/V(50) = \sqrt[4]{2} = 1.19$ This was subsequently found to be case.

Dependent variables a, b and c were considered separately for all cars, free cars and goods vehicles. They were also considered separately, for regression cases A and B (see sub-section 5.6.2), as well as for the combined single and dual carriageway data.

5.6.2.2 *Independent Variables*

Curve Geometry. The following basic parameters were considered for horizontal road curves.

a. Curve radius, metres.

b. Curve length, metres (by direction).

c. Road width, metres; middle and entry road widths were considered for middle and entry speeds respectively. Lane width was used for single carriageway sites whereas carriageway width was input in the regression analyses for dual carriageway sites.

d. Verge width, metres; the average verge width for both sides of the carriageway at the centre of each curve.

e. Superelevation, metres per metre; superelevation at the centre-point of each carriageway.

f. Gradient, per cent; average gradient over the middle or entry 20 metres survey distance was considered for middle and entry speeds respectively.

g. Sight distance, metres; minimum sight distance at a point close to the centre of each directional curve.

Supplementary analyses were undertaken using only the verge width of the inside of the curves.

The results of the Literature Review discussed in Chapter 2 showed that curve radius was the most important of the geometric parameters, listed above. However there was some uncertainty as to whether radius provides the best measure for the representation of empirical speed/curve geometry observations. Separate analyses were therefore carried out with curve goemetry represented in the following terms:

a. Radius	-	the geometric radius of the centre-line of the carriageway, metres.
b. Curvature	-	the inverse of the radius, degrees per 100 feet.
c. Total Angle	-	the directional curve length divided by the radius, expressed in radians.
d. Rate of change of Total Angle (Bendiness)	-	the total angle turned divided by the directional curve length measured in km. It was expressed in radians per kilometre.

In the case of lateral acceleration, additional computer runs were made where radius did not feature as an independent variable, to account for the possibly high intercorrelation existing between these variables ($A = V^2/R$).

<u>Traffic Parameters</u>. The following traffic parameters were considered in the regression analysis:

a. Approach speed, k.p.h.

b. Design speed, k.p.h.

c. Traffic flow, vehicles per hour; total and directional traffic flows averaged over the two study phases were considered for single and dual carriageways respectively.

Approach speed was taken to be the desired travel speed at which drivers would choose to travel on the approaches to the curves under study if unconstrained by other drivers, and other horizontal alignment features.

Design speed was calculated (see Section 4.2) from the current horizontal alignment design policies[17] using the available geometric information of the road section within which the curve under study was situated. Design speed is assumed to represent a measure of the quality of the road alignment, and therefore considered to be a useful measure.

Environmental Parameters. Weather, road surface condition, and time period parameters were not considered in the regression analysis process since they were not found (see Section 5.3) to seriously affect driving behaviour around open roads.

Regression equations were developed separately for:

a. All directional curves.

b. Left-hand curves.

c. Right-hand curves.

d. Directional uphill curves.

e. Directional downhill curves.

The purpose of performing these separate analyses was to investigate the importance of directional and gradient parameters on driving behaviour. Only groups (a) and (d) could be studied separately for dual carriageways because of the low site sample sizes.

The sample sizes of groups (a) to (e) for the different vehicle classes, road types, and the two cases A and B considered in the regression analyses are shown in Tables 5.1 and 5.2. It should be noted that, especially in the selected Case B sites, subdivision of the sample resulted in rather low sample sizes for individual groups. The corresponding models are not therefore of the same explanatory or predictive power as those produced for the complete sample of study sites.

Curvilinear regression models were produced for group (a) with only radius (or curvature) and approach speed being used as independent variables, since they were believed to be the main curve speed determinants[3,22]. Similar multiple linear and curvilinear models, were also compared for cases A and B. The final regression model selected for a particular case and vehicle classification was that which accounted for the greatest amount of the variation in the dependent variable, as well as being conceptually acceptable.

The dependent and independent variables used in the regression analyses together with the codes as they appear in the regression models are listed in Table C1 of Appendix C.

5.7 VEHICLE LATERAL PLACEMENT ANALYSIS

In recent horizontal design policies[15,17,18,35,36], the determination of safe vehicle speeds around horizontal curves is based on the assumption that vehicles will travel at a constant speed, the design speed, and that they will follow the geometry of the road curve precisely.

Glennon and Weaver[77] have shown that unless the radius of a curve becomes very large (C<4.0 degrees), the geometric radius of the lane-centre line and the radius of the actual vehicle path would not coincide. It had also been suggested[41] that actual vehicle paths are likely to vary with curvature and speed. Data on the lateral placement of vehicles at a selected number of single and dual carriageway sites was related to vehicle speed and speed changes at and between the different survey locations within each site to investigate these effects. In general, the variations in path are small and can be considered insignificant with respect to calculations of such factors as lateral acceleration (see later and Section 3.9).

The lateral placement of vehicles at the different locations within each horizontal curve was expected to be highly dependent on the level of the prevailing traffic interactions. Therefore, only free cars were considered. Inclusion of free-moving goods vehicles was not feasible because of the low sample sizes observed. Sites for this analysis were selected on the grounds that curvature seemed to be the main factor controlling vehicle/driver behaviour, with the other geometric, flow and environmental variables being of minor importance. Left-and right-hand directional curves were considered separately to enable possible directional patterns to be identified. Table 5.3 lists all single and dual carriageway sites considered in the vehicle lateral placement analysis.

Vehicle lateral placement information was collected at the middle, entry and exit locations within each directional study site as described in Section 3.6. Thus, the shorter the curve the closer the measurement positions and the more accurate the estimation of the actual path of individual vehicles.

Between-site analysis was considered to be of little importance since any grouping of the data would have given results representing different driver populations, which could not be compared. Therefore, only within-site analyses were performed.

Free car lateral placement data for the selected sites was analysed in three separate stages as follows:

a. Bivariate analysis between vehicle lateral placement and vehicle speed parameters.

b. Bivariate analysis of vehicle lateral placement data obtained at different survey locations within each site.

c. Multivariate analysis between vehicle speed and vehicle lateral placement parameters.

The following two groups of variables/parameters were considered in all three stages of these analyses:

GROUP A: SPEED VARIABLES (PER DIRECTION)

ASP - Approach speed, k.p.h.

ESP - Entry speed, k.p.h.

MSP - Middle speed, k.p.h.

EXSP - Exit speed, k.p.h.

D1 - Difference between approach and entry speed divided by approach speed.

D2 - Difference between entry and middle speed divided by entry speed.

D3 - Difference between middle and exit speed divided by the middle speed.

D4 - Difference between approach and exit speed divided by approach speed.

GROUP B: LATERAL PLACEMENT VARIABLES (PER DIRECTION)

ENL1 - Lateral placement at the first entry location, metres.

ENL2 - Lateral placement at the second entry location, metres.

ML1 - Lateral placement at the first middle location, metres.

ML2 - Lateral placement at the second middle location, metres.

EXL1 - Lateral placement at the first exit location, metres.

EXL2 - Lateral placement at the second exit location, metres.

A1 - Average entry lateral placement, metres.

A2 - Average middle lateral placement, metres.

A3 - Average exit lateral placement, metres.

B1 - Difference between average entry and middle lateral placement, metres.

B2 - Difference between average middle and exit lateral placement, metres.

B3 - Difference between average entry and exit lateral placement, metres.

C1 - Difference between the actual average middle lateral placement and the theoretical average entry lateral placement adjusted for middle road width, metres (see following paragraph).

C2 - Difference between the actual average exit lateral placement and the theoretical average middle lateral placement adjusted for exit road width, metres (see following paragraph).

C3 - Difference between the actual average exit lateral placement and the theoretical average entry lateral placement adjusted for exit road width, metres (see following paragraph).

All computations and graph plots were carried out using the BMDP statistical package.

5.7.1 Bivariate Analysis Between Lateral Placement and Speed

The following two assumptions were tested in the first stage of the analysis.

Assumption I: A driver uses the nearside edge of the carriageway as a reference to adjust his path.

Assumption II: A driver follows precisely the geometry of the centre-line of the carriageway.

Assumption I implied that a driver tries to keep the centre-point of his vehicle at exactly the same distance from the nearside edge of the carriageway, throughout the entire length of the curve. Vehicle lateral placement values were expressed as distances from the nearside edge of the carriageway for the particular direction under study. Therefore, in order to evaluate assumption I, variables B1, B2 and B3 were related to speed and speed change parameters.

Assumption II implied that a driver would follow precisely the geometry of the centre-line of the carriageway, adjusting his path only for differences in lane width between different locations within the curve. This is the assumption made in the current design policies for the determination of safe speeds around horizontal road curves. Variables D1, D2 and D3 were evaluated against speed and change parameters in order to examine the validity of that assumption.

In order to derive suitable expressions for analysis, it was assumed that the average lateral placements of a vehicle at the entry and the middle of a directional curve were X_1 and X_2 respectively, and that the lane widths at these curve-points were W1 and W2 respectively. A variable C1 was then calculated from the following formula:

$$C1 = \frac{(X2-X1)*W2}{W1}$$

Variables C2 and C3 were calculated in the same way from actual average lateral placement and lane width values, for the different locations around the curves. In both cases, bivariate graphs were plotted, and observed data was fitted with a simple linear regression line. The quality of the fit was expressed in terms of values of the correlation coefficient determined for each case. At a second stage, a series of graphs were produced between other lateral placement measures and speed or speed change parameters in order to identify relationships between lateral and forward vehicle movements.

5.7.2 Bivariate Analysis Between Lateral Placement Data Collected at Different Survey Locations.

The consistency of individual drivers with respect to lateral placement at the survey locations within each study site was studied. If no major lateral adjustments were undertaken by individual drivers as they negotiated each curve, curvature and entry speed probably had very little influence on lateral placement. This could be due to geometric or behavioural features.

A series of five graphs of the lateral placement data at the different survey locations were produced for selected sites. These were:

a. ENL1 values plotted against ENL2 values.

b. ENL2 values plotted against ML1 values.

c. ML1 values plotted against ML2 values

d. ML2 values plotted against EXL1 values.

e. EXL1 values plotted against EXL2 values.

Higher correlation coefficients were expected for cases a, c and e because of the short fixed distance of about 20 metres between the corresponding survey locations. However, correlation values for cases b and e were considered to be of greater importance because they would explain lateral driving behaviour over the largest part of the sites under study. Between-sites analysis could also be considered.

5.7.3 Multivariate Analysis Between Lateral Placement and Speed

In the third stage of this analysis an attempt was made to investigate the effects of speed or speed change parameters on the lateral placement of vehicles at the different survey locations. The analysis was performed by means of multiple linear regression techniques, separate analyses being carried out for approach speed, entry speed and their differences divided by the approach speed variable, D1. Middle and exit speed or speed changes were excluded from the list of the dependent variables on the grounds that they were highly effected by curvature and might also be closely related to approach and entry speeds. Individual and average lateral placement variables were considered separately.

The statistical significance of the multiple linear regression models developed was checked by means of a two-tailed t-test as well as by means of residual plots.

TABLE 5.1 : MULTIPLE REGRESSION SUB-GROUP SAMPLE SIZES - CARS

Description	All Curves	Left-Hand Curves	Right-Hand Curves	Uphill Curves	Downhill Curves
(a) All Cases					
Single Carriageways	56	28	28	29	27
Dual Carriageways	22	-	-	14	-
Single and Dual Carriageways	78	38	40	45	35
(b) Selected Cases					
Single Carriageways	37	19	18	19	18
Dual Carriageways	13	-	-	8	-
Single and Dual Carriageways	50	25	25	27	23

TABLE 5.2 : MULTIPLE REGRESSION SUB-GROUP SAMPLE SIZES - GOODS VEHICLES

Description	All Curves	Left-Hand Curves	Right-Hand Curves	Uphill Curves	Downhill Curves
(a) All Cases					
Single Carriageways	31	14	17	17	14
Dual Carriageways	12	-	-	6	-
Single and Dual Carriageways	43	20	23	23	20
(b) Selected Cases					
Single Carriageways	16	8	8	11	5
Dual Carriageways	9	-	-	5	-
Single and Dual Carriageways	25	12	13	16	9

TABLE 5.3: SELECTED SITES FOR VEHICLE LATERAL PLACEMENT ANALYSIS

SINGLE CARRIAGEWAYS

Site Code	Group	Curve No.	Code*	Radius (m)	Length (m)
1	100	1	1	34.00	77.85
2	100	1	2	34.00	77.85
5	102	1	2	290.00	121.00
6	102	1	1	290.00	121.00
7	103	1	1	45.00	47.90
8	103	1	2	45.00	47.90
12	104	2	2	161.00	112.00
17	130	11	1	469.60	201.00
18	130	11	2	469.60	201.00
29	140	2	1	237.40	223.50
30	140	2	2	237.40	223.50
43	145	4	2	143.50	154.80
44	145	4	1	143.50	154.80

DUAL CARRIAGEWAYS

Site Code	Group	Curve No.	Code*	Radius (m)	Length (m)
4	1192	3	2	160.30	84.00
10	1192	20	2	297.20	153.50
12	1194	4	1	72.50	157.50
14	1195	2	1	311.40	151.50
22	1211	1	2	208.00	159.35

*1 - Left-hand Curves

2 - Right-hand Curves

CHAPTER SIX

RESULTS

6.1 INTRODUCTION

The results of the normality tests undertaken on the speed and lateral acceleration distributions are presented in Sections 6.2 and 6.3 respectively.

Comparisons between data collected during the phases and between environmental conditions are presented in Sections 6.4 to 6.6. The variations of vehicle speeds through the directional curves are also discussed in Section 6.7.

Bivariate analysis results between behavioural and geometric parameters are presented in Section 6.8.

The results of the multiple regression analyses performed in this study are described and discussed in Section 6.9.

Finally, the results of the analysis of vehicle lateral placement are presented in Section 6.10.

Where necessary, data for single and dual carriageways have been treated separately but in a similar manner.

6.2 SPEED DISTRIBUTIONS

6.2.1 Basic Statistics

The basic evaluation parameters of mean, median, standard deviation, skewness, kurtosis and percentile values were produced for all observed speed distributions at both single and dual carriageway sites. Typical examples are given in Figure C1 of Appendix C.

Single Carriageways. The overall 50th, 85th and 99th speed percentile values were found to vary around the sample of curves studied in a very similar manner for both all and free cars. On average, a change of about 4.0 k.p.h. in mean speed was observed between the approach, entry and the middle survey locations, the lowest speed being at the mid point. That change was reduced to about 2.0 k.p.h. between the middle and the exit curve points with the middle speed being again the lower of the two. A similar trend was also observed for the higher percentile speed values with only a different magnitude of speed change. Thus, a 5.0 k.p.h. change between the first three location points and a 3.0 k.p.h. change between the middle and the exit curve points was found for the 85th percentile speed. The corresponding figures for the 99th percentile speed were about 7.0 and 5.0 k.p.h. respectively.

The same pattern was also observed for goods vehicles with entry speeds being slightly higher than exit speeds and the lowest speed always being at the middle of a curve. On average, the mean, 85th and 99th percentile speeds were found to reduce by about 3.0, 4.0 and 5.0 k.p.h. between the approach, entry and the middle survey locations. The corresponding values between the middle and the exit points were about 1.0, 1.0 and 2.0 k.p.h. respectively. The speeds of goods vehicles were always lower, in absolute terms, than the speeds of cars, the greatest difference being found between approach speeds, and the lowest difference occurring between middle speeds.

Average standard deviation values over the entire site sample exhibited a similar trend to that of speed values. In general, standard deviation values were higher on the approach, with those at the middle being always the lowest. No marked differences were observed between averaged standard deviation values at the entry and exit points of the curves. That trend was identical for the three vehicle categories considered in the study.

Table 6.1 contains a summary of vehicle percentile speed values averaged over all single carriageway sites and averaged standard deviation values at different survey locations are also given in Table 6.2.

Dual Carriageways: The variations in the 50th percentile value of speeds observed at dual carriageway sites was not found to be as consistent as those for the single carriageway sites. On average changes of 2.0, 5.0 and 4.0 k.p.h. was observed between approach and entry, entry and middle, and middle and exit locations for cars. Corresponding values observed for the higher percentile speeds were, 4.0, 5.0 and 4.0 k.p.h. for the 85th percentile speed, and 5.0, 5.0 and 5.0 k.p.h. for the 99th percentile speed.

Absolute speed percentile values for goods vehicles were again lower than the corresponding values for cars, although a similar speed variation pattern was observed. On average all three percentile speed values were found to reduce by 3.0, 5.0 and 2.0 k.p.h. between approach, entry, middle and exit curve points respectively.

Average standard deviation values at the different survey locations were very similar to those observed for single carriageway sites. Small increases were recorded mainly at the within-curve survey locations. These greater speed ranges could be justified on the grounds that, with more freedom of lateral movement available on dual carriageways, car speeds were less dependent on the road curvature and therefore less restricted by the geometry of the curve.

A summary of percentile speeds averaged over all dual carriageway sites is contained in Table 6.3. Mean standard deviation values at the different survey locations are given in Table 6.2.

Discussion: The average 85th and 99th percentile speed values obtained for cars indicated that at both single and dual carriageway sites, fast vehicles decelerated rather harder than those at an average speed. Acceleration rates on the exits from the curves were also greater for the faster vehicles at single carriageway sites, but not at dual carriageway sites.

The average standard deviation values for car approach speed distributions, were similar for single and dual carriageway sites with values of 10.23 k.p.h. and 10.64 k.p.h. respectively. These values were lower than the average standard deviation values of free car speed distributions, of 13.0 k.p.h. found by Bennett[80] and of 12.0 k.p.h. found in our preliminary study[3]. This has an effect on the sample size of speeds required at a particular location as discussed in Section 3.3. A value of 10.60 k.p.h. for the average standard deviation of car speed distribution reduces the required sample for the satisfactory estimation of mean car speeds from 72 to 48 cars. Sample sizes required for the estimation of higher percentile speeds are also reduced from 115 and 180 cars to 76 and 120 cars for 85th and 99th percentile values respectively.

Average standard deviation values for goods vehicle speed distributions were identical with those found in the preliminary study.

6.2.2 Coefficient of Variation

Studies of free car speeds on rural roads have generally indicated that, while the mean free speeds may be site dependent, the coefficient of variation (being the ratio of the standard deviation to the mean value) tend to assume a constant value. This has led to the practice of standardising rural free speed distributions by expressing them in terms of observed speed divided by the sample mean speed. British Studies[93] reported a value of 0.19 for the coefficient of variation of free-moving passenger cars. In Australia Leong[94] and McLean[22] reported averaged values of 0.17 and 0.14 respectively. The observed approach all and free car speed distributions recorded in this study were therefore examined to see if they exhibited a particular constant coefficient of variation.

The 112 all and free car speed distributions observed on the approaches to the single carriageway curves had coefficients of variation ranging from 0.088 to 0.175 with an average value of 0.137 for all cars and 0.136 for free cars. The corresponding values for the coefficient of variation for the 44 all and free car approach speed distributions observed for dual carriageways were 0.126 and 0.125 respectively. Coefficients of variation found for goods vehicle speed distributions on the approaches were 0.118 for single carriageway sites and 0.110 for dual carriageway sites. The average values for the coefficient of variation found for the speed distributions of the three vehicle classifications observed at the four survey locations for all single and dual carriageway sites are shown in Table 6.4.

The coefficient of variation for cars was found to vary throughout single carriageway sites, the minimum value being observed at the curve mid points. On dual carriageway sites an almost constant value was found to exist at the different locations for the all car speed distributions. However, a pattern similar to that observed at single carriageway sites was found for the free car speed distributions. No consistent pattern was observed for the variation of the coefficient of variation for goods vehicles.

The assumption that coefficient of variation values were not site dependent was tested by bivariate analyses. In these analyses coefficient of variation values for free car and goods vehicle distributions observed at the approach and the centre of the study sites were plotted against radius and a simple linear regression line was fitted. Typical examples are given in Figures 6.1(a) and (b) for single carriageway sites and in Figures 6.2(a) and (b) for dual carriageway sites.

From these results it was seen that coefficient of variation values observed on both the approach and the middle locations remained constant throughout the curvature range for single and dual carriageway sites.

Three main issues emerge from this analysis of the coefficients of variation.

a. The rural free speed coefficients of variation are lower than earlier values. This could be caused by changed characteristics such as increased mean speeds, reduced speed variances or both.

b. Coefficients of variation for car speed distributions observed on dual carriageway sites are lower than the corresponding values for single carriageway sites. No such pattern was found for goods vehicles.

c. When vehicle speeds are constrained by alignment geometry, the usual practice of assuming a constant coefficient of variation value for all speed distributions appears to be valid. The data does not infer a statistically significant relationship between the coefficient of variation and vehicle mean speed or curve radius.

6.2.3 Properties of Speed Distributions

Normal distributions were fitted to each of the 624 car and the 172 goods vehicle speed distributions observed. The goodness of fit was tested by means of the Chi-squared test and the Kolmogorov-Smirnov test. The Chi-squared test was sensitive to the grouping used, as expected, and the Kolmogorov-Smirnov test was taken as a basis for checking the normality assumption. The results for the normality tests are given in Tables 6.5, 6.6 and 6.7.

Of the 448 car speed distributions observed at single carriageway sites, 29 (6 per cent) displayed significant departures from the normal distribution at the 5 per cent level of significance. Only one of the 124 goods vehicle speed distributions was found to be significantly different from a normal distribution at the same level of significance.

Of the 176 car speed distributions observed on dual carriageway sites only 7 (4 per cent) were significantly different from normal at a 5 per cent level of significance. None of the 48 goods vehicle speed distributions was found to be different from normal at the same level of significance.

The goodness of fit was found to vary slightly between observed speed distributions at the four different reference locations before and within each study site but no consistent pattern could be identified for either single or dual carriageways.

These normality test results showed substantial improvements on those from recent speed studies in Australia(22) where from 240 observed speed distributions, at the approach and the middle of road curves, 45 (18.8 per cent) showed significant ($p<.05$) departures from the normal distributions.

The shape of the observed speed distributions was also checked by means of skewness, which measures the asymmetry, and kurtosis, which describes whether the distribution is flat or peaked. Positive values for the skewness statistic indicates that the majority of speed values lie below the mean value. Equally, positive values for the kurtosis statistic indicated peaked, leptokurtic, speed distributions. The results of these tests are shown in Tables D1, D2 and D3 of Appendix D. Most of the observed vehicle speed distributions were found to be positively skewed. Platikurtic speed distributions were rather more common for free car and goods vehicle speed distributions although no clear trend was evident.

A further check of the normality assumption was made by comparing mean, 85th, 90th, 95th and 99th percentile values for the observed vehicle speed distributions against the corresponding theoretical values obtained from the fitted normal distributions. The deviations found for the very high percentile values, i.e. 99th percentile speed, were rather substantial in some cases, indicating that distribution fitting of greater precision may be required if values for the upper part of the speed distributions, i.e. 95th 99th percentile, were needed for the necessary simulation of traffic, for example.

A typical normality test calculation is given in C1 of Appendix C and typical observed and fitted speed distributions are shown in Figures C2 and C3 of the same appendix.

Detailed investigation of the non-normal distributions was not carried out but visual inspection showed no consistent pattern to these departures.

6.3 LATERAL ACCELERATION DISTRIBUTIONS

Lateral accelerations at the middle of all the directional curves were calculated for the three vehicle classifications.

The lateral acceleration, determined as the square of the vehicle speed at the middle of a curve divided by the radius of the centre-line of the carriageway, was taken as being a close estimate of the maximum lateral acceleration value developed within a curve by individual drivers. In practice, there may be some small variations between sites depending on the shape of the curves, the speed/distance profile and the actual path adopted by individual drivers.

It was assumed, on the basis of the speed distribution results that observed lateral acceleration distributions for the other two vehicle groups would be similar to those of all cars at the study sites. Analyses were therefore, concentrated on that particular vehicle classification.

In general, high lateral accelerations were observed with the average 85th percentile values being 2.32 m/sec^2 for single carriageway and 2.10 m/sec^2 for dual carriageway sites. The corresponding values for the mean and the 99th percentile were 1.85 and 3.08 for single carriageway and 1.68 and 2.74 for dual carriageway sites respectively.

The shape of the observed all car lateral acceleration distributions was studied in detail by means of the Kolmogorov-Smirnov test and by examining the skewness and the kurtosis values of these distributions. Of the 56 distributions observed on single carriageways, 49 (87.5 per cent) showed no significant departure from a normal distribution at a 5 per cent level of significance. On dual carriageways 20 (90.9 per cent) of the 22 observed distributions were found not to be statistically different from normal. Almost all the observed lateral acceleration distributions were found to have positive skewness values. Most of the single carriageway distributions were found to be leptokurtic and an equal spread between leptokurtic and platykurtic was observed for the dual carriageway sites. The results are given in Tables 6.8 and 6.9.

6.4 COMPARISONS OF THE TWO PHASES

The survey procedures used during Phase II were identical to those adopted in Phase I. This ensured, as much as possible, that any variation in the results between the two Phases would only be due to different environmental and traffic conditions. The basis for the comparison was taken to be the average speed performance of all cars measured during the two Phases of the study for both single and dual carriageway sites. The comparison was twofold:

a. The overall means of the average all car speeds at the same survey location for all the study sites were compared. Single and dual carriageways were treated separately.

b. The means of all car speeds at the same location and for each individual study site were compared. Single and dual carriageway sites were again considered separately.

The purpose of the first test was to provide information on the consistency of driver behaviour between the two study Phases, as well as to ensure the adequacy of the sample sizes. Inconsistency in driving behaviour at a particular location or survey site was then checked by means of the second test. Within-site variation could be caused by many factors, such as changes in sampling procedure or environmental conditions which are difficult to identify. Even so, the level of inconsistency could be used as a positive criterion to decide whether or not additional data needed to be collected at any of the study sites. All the performance comparisons were carried out by means of a two-tailed t-test (see Section 5.3), assuming that the compared populations were normal (see Section 6.2.3).

The results are summarised in Tables 6.10 and 6.11. As indicated in (a) above, the hypothesis that the means were not statistically different was tested at a series of levels of significance. Theoretically, there can be no firm rules about which significance level permits us to draw the conclusion that an assumption is true or not. In the case of the t-test the higher the level, the more certain we are of the results. However, since a 5 per cent level of significance is usually used in traffic engineering studies, all comments made about these findings will refer to that level.

Approach mean speeds showed the highest consistency between phases with 85 per cent of the single carriageway sites and 90 per cent of the dual carriageway sites exhibiting a consistency at the 5 per cent level of significance. At the other three survey locations, i.e. entry, middle and exit, a slightly lower level of consistency was observed mainly due to different composition of samples, in terms of flowing mode, between the two phases, with a minimum of 68 per cent of single carriageway sites showing a consistency at the 5 per cent level of significance between the two Phases at the middle location. Dual carriageway mean speed data was found to be more consistent between Phase I and Phase II. This was expected since the higher alignment quality of the dual carriageways generally allows mean speeds to remain at about the same level even with considerable changes in vehicle composition and the amount of traffic.

To complete the between-phase comparison study, the mean, 85th and 99th percentile values of the Phase I observed speed distributions were plotted against the corresponding values for Phase II. Separate plots were produced for the four survey locations, and single and dual carriageway sites were treated separately. A 45 degree line was also superimposed on each figure to illustrate the consistency of the all car speed distribution observed during the two Phases of the study. Typical examples of these graphical comparisons are shown in Figures 6.3, 6.4 and 6.5 for both single carriageways (a) and dual carriageway sites (b).

6.5 COMPARISONS BETWEEN THE DIFFERENT SURVEY LOCATIONS

The purpose of this analysis was twofold:

a. To identify those directional curves where vehicle speeds within the curve were in excess of those on the approach.

b. To investigate the relationships that existed between vehicle speed distibutions obtained at the various survey locations of the study.

In both cases single and dual carriageway sites were treated separately.

Comparison (a) above,of within-curve and approach speed distributions revealed that, for some of the sites, within-curve speeds tended to be in excess of the approach speeds. Under these circumstances, it could not be guaranteed that it was the characteristics of the curve geometry which were constraining vehicle speeds. Furthermore, in almost all the cases the differences between approach and within-curve speeds (mainly entry) were low i.e. 1.0 or 2.0 k.p.h. and they did not necessarily have the same sign for the mean, 85th and 99th percentile speed. A meaningful comparison could not, therefore, always be made.

Data for sites at which within-curve speeds were in excess of approach speeds were not therefore, removed from subsequent analysis except for the case of the multiple regression analysis. None-the-less, as described later a series of additional regression models were developed in which all sites where approach speeds were lower than the within-curve speeds were excluded, to ensure that curvature was the dominant speed determinant.

The relationships between observed vehicle speed distributions at different locations before and within the study sites were investigated by means of bivariate analyses. Mean, 85th and 99th observed approach percentile speeds were plotted against the corresponding values of the observed entry and middle speed distributions for both single and dual carriageways. A simple linear regression line was also fitted to each data set. The correlation coefficients between the percentile speeds at the above mentioned measurement locations were also determined for each vehicle classification. Typical data and results are shown in Figures D1 to D4 of Appendix D for single carriageway (a) and dual carriageway (b) sites respectively.

For cars, the correlation coefficients ranged from 0.60 to 0.55 for the approach-entry and approach-middle speed relationships on single carriageway sites. The corresponding figures for dual carriageway sites were 0.80 and 0.65 respectively. Results obtained for goods vehicles showed a remarkable difference between single and dual carriageway data. The correlation coefficient ranged from 0.20 to 0.30 for the approach-entry and approach-middle speed relationships on single carriageway sites, whereas the corresponding figures for dual carriageway sites were substantially higher and equal to 0.90 and 0.80 respectively.

The generally high level of correlation between curve and approach speed distributions implied that a comparison of percentile values between curve and approach conditions would provide a reasonable representation of behaviour on road curves.

Correlation analysis results also confirmed the early findings, discussed in Section 6.2, that the behaviour of public road drivers was more consistent on dual than on single carriageway sites.

6.6 COMPARISONS BETWEEN WET AND DRY ROAD SURFACE CONDITIONS

The effect of wet or dry road surface conditions on vehicle/driver behaviour was compared by means of a two-tailed t-test. The null hypothesis, that the mean speed values under both wet and dry condition were equal, was tested against the alternative hypothesis that they were statistically different at a particular level of significance.

Most wet road surface speed data was collected during the winter in Phase I and 31 speed distributions at single carriageway sites and 4 at dual carriageways were compared. The range of environmental conditions is large and this analysis could, therefore, only reflect general trends.

The analysis procedure followed was the same as that for the comparison of Phase I and Phase II car speed distributions in which the overall means were initially compared for each of the sites considered, before the means at the same location were compared.

The results of the overall mean comparison analysis are summarised in Table 6.12 for both single and dual carriageways. Overall means were found to be statistically equal at the very high level of significance of 20 per cent.

The results of the comparisons between individual car mean speeds for wet and dry road surface conditions at each site, considered in this analysis, are summarised in Table 6.13. Approach mean speeds showed the highest consistency between the two different road surface conditions with 85 per cent of the single carriageway speed distributions considered having statistically equal mean values at the 5 per cent level of significance. For the speed distributions observed at the three survey locations within each curve, a slightly lower level of consistency was observed, due mainly to different sample composition between the two observations. Middle speeds showed the minimum consistency with the 68 per cent of mean values for the dual carriageway sites being statistically equal at a 5 per cent level of significance. Meaningful comparisons between single and dual carriageway sites could not be made because of very low sample sizes observed for the latter.

The results of these comparisons showed that, for the prevailing traffic flows, speed distributions for cars were similar for wet and dry road surface conditions. Speed data from Phase I and II was therefore merged for subsequent analysis.

6.7 VARIATION OF VEHICLE SPEEDS AROUND DIRECTIONAL ROAD CURVES

The analysis procedure adopted was as follows:

a. The 85th percentile speed/distance profiles were produced for a selected number of single and dual carriageway sites. Unimpeded cars and all goods vehicles were considered in this analysis.

b. Each profile was compared with that of the test driver averaged over three runs.

c. Within each of the sites selected, individual vehicle speed/distance profiles were compared to the 85th percentile profile produced for the entire data sample of that particular site.

The selected sites were sub-divided into four radius groups, for analysis. These were as follows: from 0 to 100 metres, from 100 to 200 metres, from 200 to 300 metres and from 300 to 500 metres for analysis. Free car speed/distance profiles obtained for the selected single carriageway sites are shown in Figures 6.6(a), (b), (c) and (d) for the four different radius groups. The corresponding profiles for goods vehicles are shown in Figure 6.7(a), (b), (c) and (d). Free car and goods vehicle speed/distance profiles for the selected dual carriageway sites are shown in Figures 6.8 and 6.9 respectively. The same grouping procedure was also adopted for dual carriageway sites. The detailed average speed/distance profiles of the test-driver have also been superimposed on the free car plots for both single and dual carriageway sites.

It can be seen from Figures 6.6 and 6.8 that the 85th percentile speed/distance profiles for free cars on each single and dual carriageway site were consistent with those of the test driver at the same sites. The magnitude of the speed at a particular location and of the speed change, acceleration rate, between two locations was often slightly different, as expected, but the overall speed variation pattern remained the same for almost all the selected sites.

The magnitude of the speed variation around these sites was found to be highly dependent on the degree of curvature. For high curvature values free car speeds were found to change considerably on both single and dual carriageway sites (see Figures 6.6(a) and 6.8(a). Marked-speed changes were also observed at sites with radii between 100 and 200 metres, (see Figures 6.6(b) and 6.8(b)).

For the two other radius groups, curvature seemed to have little effect on vehicle/driver behaviour. In almost all cases, however, some speed variation was evident around the selected sites for both the public road and the test driver results.

Similar patterns of speed variation around open road curves were observed for the goods vehicles. The only difference found was that even for high curvature values, speeds were found to remain fairly constant through the second part of the directional curves. This was attributed to the different performance characteristics, particularly lower acceleration rates, of goods vehicles.

In general, for almost all the sites studied, vehicle speeds were found to vary around open road curves, with the level of variation depending upon the curve radius. Minimum values were always observed at the mid point of each curve. The level of approach speeds seemed to have less effect on the variation pattern and the acceleration, or deceleration rates adopted. The results indicated transitional behaviour around road curves with radii up to about 200 to 300 metres, with a more constant speed pattern existing for higher values of curves radius. The early suggestion of complete speed adjustment before entering a road curve, made by Taragin(50) was not supported by the evidence for free cars. There were, however, strong indications that the major speed adjustments for goods vehicles were made on the approach to the curves. This was more pronounced for high curvature values.

Holmquist(54) suggested that car speeds remained constant over the central 20 or 25 per cent of the curves, but this was not supported by the results for either public road drivers or the test driver. However, it should be noted that since public road speed/distance profiles were produced by means of speed values at only four survey locations, small variations in speed patterns could not be identified. However, the validity of the test driver/vehicle to repesent the more general public conditions enables us to interpret between those locations.

The consistency between overall (85th percentile) and individual free car or goods vehicle speed patterns around each selected site was also tested by grouping individual patterns into three classes as follows:

a. 'Mean' Performance - Performance similar to the overall.

b. 'Constant' Performance - Vehicle speed almost constant throughout the study site.

c. 'Non-Mean' Performance - Performance different to that in a and b.

Left and right-hand curves as well as single and dual carriageway sites were treated separately.

The results of these comparison tests are given in Tables 6.14 and 6.15 for single and dual carriageway sites respectively. In the case of free cars, most individual patterns were identical to the overall group patterns for both single and dual carriageway sites. A division was observed between the constant and the 'non-mean' performance for the remaining cases. No particular trends were noted for either left or right-hand curves.

The same consistency between individual and overall speed patterns was not, however, found for goods vehicles on either the selected single or dual carriageway sites. Even though 'mean' performance again represented the majority of the individual speed patterns, a considerable number of goods vehicles showed a constant or 'non-mean' speed performance. This had been indicated previously by the overall speed/distance profiles shown in Figures 6.7 and 6.9. Again no distinctive patterns for left or right-hand curves were found.

Overall a changeable speed pattern around the selected sites was observed with vehicles reaching a minimum speed near the centre of the curve. Also, deceleration rates at the entry of a curve were found to be higher than acceleration rates at the curve exit. The latter finding, however, should be treated with care since no detailed speed/distance profiles were studied apart from those of the test-driver.

6.8 BIVARIATE ANALYSIS AND CURVE FITTING

Bivariate relationships between behavioural parameters such as vehicle speed, lateral acceleration and side-friction factor, and curve radius, were studied by means of regression analysis (see Section 5.5). A series of bivariate linear and curvilinear models were fitted to the observed data to obtain the best explanatory relationships. Mean, 85th and the 99th percentile values were considered separately, as, were the three vehicle classifications for both single and dual carriageway sites. A distinction was made between left and right-hand curves for car speed data collected on single carriageways.

6.8.1 Relationships Between Vehicle Speed and Curve Radius

Bivariate graphs were separately plotted for the three vehicle classifications and for both single and dual carriageway sites. The bivariate models, described in Section 5.5, were then fitted. The derivation of the forms of these relationships was interactive with visual inspection of the graphs and findings from previous work.

As expected, approach speed and curve radius was not found to be highly correlated. The most meaningful statistical relationships obtained were all of a linear form with coefficients of determination ranging between 0.01 and 0.28 for cars and between 0.02 and 0.39 for goods vehicles (see Figures 6.10 and 6.11 and Figures D5 to D8 – Appendix D). All these relationships indicated a slight increase in the approach speed for higher values of radius. That could be explained on the grounds that shallow curves were more likely to occur on a road section with a high quality of alignment, which would result in higher vehicle speeds than would occur on a road section of lower alignment standard.

In the case of entry speed studied against curve radius, the curvilinear models were found superior to the linear models (see Figures 6.12 and 6.13 and Figures D9 to D12 – Appendix D). Models II, V and VI (Emmerson's) and VII were found to explain more of the observed variation in the dependent variable-speed. Coefficients of determination ranged between 0.63 and 0.82 for car speeds on single carriageway sites. The corresponding figures for dual carriageway sites were between 0.40 and 0.53. The relationships obtained for goods vehicles were not as powerful as those for cars on single carriageway sites and in general they ranged between 0.40 and 0.64 for both road types. Tables 6.16 and 6.17 list the formulae obtained for the three models (II, VI, VII) and the three vehicle classifications, for single and dual carriageway sites respectively. The choice of model involved both conceptual and statistical judgements.

The relationships obtained for the two car classifications were very similar, indicating the similarity in overall performance of the two groups. This was somewhat expected because of the low to moderate traffic flow conditions prevailing at the study sites, which resulted in the vast majority of cars being free-moving.

Overall, car entry speeds were found to be influenced by curve radius more on single carriageways than on dual carriageways. This was not the case for goods vehicle entry speeds which were found to depend equally on curve radius at both single and dual carriageways. Mean and 85th percentile entry speeds of cars were found to increase sharply with curve radii up toabout 200 to 250 metres for single and dual carriageway sites, and then to tend to a constant value. The flattening of the entry speed/curve radius curve was more pronounced in the case of single carriageways. 99th percentile values were found to increase more significantly with curve radius over the entire curvature range. Entry speeds for goods vehicles were found to tend to a constant speed for curve radii greater than 150 to 200 metres for single and dual carriageway sites.

The same fitting procedure was also adopted in the case of the middle speed and curve radius relationships. Models II, V, VI and VII were also found to explain the variation in the dependent variable-speed-better than the others. Selection of the best model for the particular case was then made again on both statistical and conceptual grounds.

Middle speeds of cars were found to depend more upon curve radius than entry speeds, with curve radius explaining between 73 and 85 per cent of the total variation on single carriageway sites. Between 64 and 69 per cent of the total variation in middle car speed was explained by road curvature at dual carriageways. Mean speeds on single carriageways were found to be rather more dependent upon curve radius than were the 85th and 99th percentile values. No clear difference between the various percentile values was observed on dual carriageway sites.

Curve radius was also found to explain about the same amount of variation in goods vehicle speeds observed at the curve centre as that of goods vehicle speeds obtained at the curve entry. This supported the validity of an earlier finding (see Section 6.7), that goods vehicle speeds were adjusted before the entry to a curve.

As with entry speeds, mean and 85th percentile middle speeds of cars on single carriageway were observed to increase rapidly up to curve radii of about 200 metres after which they tended to a constant value. The 99th percentile middle speed values were,however, again found to increase significantly with curve radius over the whole curvature range. A similar trend was also observed for the three percentile speed values on dual carriageway sites, although the rate of increase was lower. The relationships obtained are shown in Figures 6.24 and 6.15 and in Figures D13 to D16 of Appendix D. The various formulae obtained for the four best relationships are also shown in Tables 6.18 and 6.19.

No substantial differences were observed between left-hand and right-hand curves, indicating that sight distance differences probably did not affect driver behaviour on horizontal curves to any marked extent. The results obtained for single carriageway right-hand and left-hand curves are shown in Figures D17 to D20 of Appendix D.

6.8.2 Relationships Between Vehicle Lateral Acceleration/Side-Friction Factor and Curve Radius

Design practices assume that the lateral acceleration/side-friction factor is the parameter that determines driver behaviour on horizontal curves. To test this assumption, a series of bivariate scatter plots were produced for the mean, 85th and the 99th percentile lateral acceleration/side-friction factor values against curve radius for the three vehicle classifications and for single and dual carriageway sites separately.

The first five mathematical models were fitted to the observed data and the selection of the best model was again based on statistical and conceptual grounds. Models III, IV and V were found to explain about the same amount of the variation in the dependent variable. Model IV was chosen since it gave a better conceptual fit at the two ends of the relationships in almost all the cases considered.

In general, curve radius was found to explain a larger amount of the variation in lateral acceleration/side-friction factor than it did in the case of vehicle speed. On single carriageways coefficients of determination for cars ranged from 0.82 to 0.92. The corresponding values for dual carriageways were 0.70 to 0.76.

A lower proportion of the variation in the lateral acceleration/side-friction factor was found to be accounted for by curve radius when goods vehicle data was considered. Coefficients of determination ranged between 0.62 and 0.70 for single carriageway sites and between 0.51 and 0.73 for dual carriageway sites.

The lateral acceleration/side-friction factor was observed to decrease with curve radius in all cases. On single carriageways the lateral acceleration/side-friction factor developed by cars at the curve middle decreased rapidly up to a radius value of about 250 to 300 metres, and then more slowly over the rest of the curvature range. The rate of decrease at dual carriageway sites was not as high as the corresponding rate for single carriageway sites. An almost constant rate was observed throughout the curvature range.

A nearly identical pattern was also observed for the goods vehicle data with the lateral acceleration/side-friction factor decreasing at a higher rate on single carriageway sites than on dual carriageway sites.

It also became clear that drivers accepted much higher lateral acceleration/side-friction factor values around short radius curves than around larger radius curves. (It should be noted, however, that lateral acceleration/side-friction values are found to be nearly constant for large radius curves.) Car drivers were found to develop side-friction factor values as high as 0.30 at curves with radii less than 100 metres and 0.18 at curves with radii between 100 and 250 metres (85th percentile values). The corresponding values for goods values were 0.20 at a radius less than 100 metres and about 0.10 at about 250 metres curve radius.

On short radius curves observed levels of lateral acceleration/side-friction values for both single and dual carriageways were found to be similar even though speeds on dual carriageways were slightly higher. This was attributed to large deviations in vehicle path on dual carriageway short radius curves. On longer radius curves, however, with radii more than 200m, where drivers were found to follow the road geometry reasonably closely, no significant differences in the values of f are observed between single and dual carriageway curves.

Overall lateral acceleration/side-friction factor values were found to correlate very strongly with curve radius, a fact that substantiates early suggestions by Good[41,57] that such a relationship could be of fundamental importance in the determination of design standards.

The relationships between lateral acceleration/side-friction factor values and curve radius for all cars are shown in Figures 6.16, 6.17 and 6.18, 6.19 for single and dual carriageway sites respectively. Free car and goods vehicle relationships are shown in Figures D21 to D28 of Appendix D for both single and dual carriageway sites.

The lateral acceleration/side-friction factor values of cars plotted against curve radius separately for single carriageway left-hand and right-hand curves are also shown in Figures D29 to D32 of Appendix D. No distinctive differences were observed, although left-hand curves exhibited slightly higher lateral acceleration/side-friction factor values.

6.8.3 Relationships Between Lateral Acceleration/Side-Friction Factor and Vehicle Speed at the Curve Centre

The lateral acceleration/side-friction factor and curve middle speed relationship constitutes one of the basic criteria on most current design practices. Previous research (see Chapter 2) on single carriageways has indicated however that the association between these two variables is not sufficiently strong to justify its use as a basic design relationship. Lateral acceleration/side-friction factor percentile values were therefore plotted against speed percentile values for the three vehicle classifications and for both single and dual carriageway sites. A linear model was found to provide the best fit to the observed data, but, in general, a relatively small amount of the variation in lateral acceleration/side-friction factor was found to be explained by vehicle speed at the curve centre.

On single carriageways, the relationships obtained for cars were found to exhibit coefficient of determination values between 0.35 to 0.59. Corresponding values for goods vehicles ranged between 0.03 and 0.12. On dual carriageways the relationships for both cars and goods vehicles were not statistically significant with coefficients of determination ranging from 0.01 to 0.24.

In general, lateral acceleration/side-friction factor values were found to decrease with curve middle speed, although the low explanatory power of the relationships did not allow specific remarks to be made about the rate of decrease between single and dual carriageways and the different vehicle classifications.

These results substantiated the earlier suggestion[3,22,41,73] that the relationship between lateral acceleration/side-friction factor and curve middle speed is not statistically powerful enough to be used as an explanatory relationship of driving behaviour around road curves. Instead, lateral acceleration/side-friction factor could be considered against a fixed geometric parameter such as curve radius with which it correlates strongly.

The relationships between lateral acceleration/side-friction factor and speed values are shown in Figures 6.20, 6.21, 6.22, 6.23 and in Figures D33 to D40 of Appendix D.

6.9 MULTIPLE REGRESSION ANALYSIS

Regression analysis was performed in two stages as described in Section 5.6.

6.9.1 Relationships Between Variables

The first part of the analysis determined the linear relationships between the dependent variables and the independent variables and between the independent variables. These are shown for the 85th percentile entry speed and independent variables by the correlation matrices given in Tables D4 to D8 of Appendix D for both single and dual carriageway sites. The correlation matrices for the 85th percentile middle speed and lateral acceleration and the independent variables are given in Tables D9 to D13 of Appendix D, again for both single and dual carriageway sites.

Significant correlations between independent variables were noted to check for possible anomalies which might occur in subsequent regression relationships. Since curve radii and approach speed were expected to be significant determinants of the dependent variable (i.e. speed or lateral acceleration) more emphasis was given to the levels of the correlation of those two variables with the rest of the independent variables. (Design practice would tend to lead to such correlation.)

Curve radius (curvature) was found to significantly correlate (r=0.60 to 0.70) with superelevation for both single and dual carriageway sites. The curve radii of the sites were also found to correlate with curve length at a rather lower level. Curve radius showed a significant correlation with traffic flow for single carriageway sites (r=0.69).

The approach speeds of both cars and goods vehicles was not found to correlate highly with road geometry or traffic parameters. The only exception was in the case of the selected dual carriageway sites considered, where car approach speeds showed a correlation of r=0.60 with curve length.

6.9.2 Explanatory Regression Models

The linear regression analyses were carried out in five separate steps for the three vehicle classifications:

Step 1. Regression of speed or lateral acceleration against approach speed, curve geometry and traffic flow parameters separately for all single and dual carriageway sites;

Step 2. Regression of speed or lateral acceleration against design speed, curve geometry and traffic flow parameters separately for all single and dual carriageway sites;

Step 3. Regression of speed or lateral acceleration against approach speed, curve geometry and traffic flow parameters separately for selected single and dual carriageway sites;

Step 4. Regression of speed or lateral acceleration against approach speed, curve geometry and traffic flow parameters for all single and dual carriageway sites considered together; and

Step 5. Regression of speed or lateral acceleration against approach speed, curve geometry and traffic flow parameters for selected single and dual carriageway sites considered together.

The purpose of the curvilinear analysis was twofold. Firstly, to account for possible anomalies observed in the residual distributions of the linear regression models and secondly, to check whether or not higher order radius (or curvature) models would explain more of the variation in the dependent variables than the linear models.

Curvilinear analysis was not performed for middle lateral acceleration because the linear models were thought to be very satisfactory in explanatory terms. In addition to that, curvilinear speed models which would be found superior to linear models, could be used for the calculation of lateral acceleration values. Design speed was not found to be an important determinant of the dependent variable during the linear analysis and was omitted from the curvilinear analyses.

The regression equations resulting from the analyses of the first stage are given in Tables D14 to D97 of Appendix D. The independent variables included in each case are those which make a statistically significant ($p<.05$) improvement to the mean sum of squares explained by the regression.

One-way analysis of variance tables were produced for all the regression models developed. A typical sample is given in Tables D98 to D117 of Appendix D. These provide an indication of the relative importance of the significant variables involved in the regression.

Residuals for all the regression models developed were also plotted against the speed predicted by the regression equation and the more important independent variables. These plots together with the normality residual plots were used to check the validity of the regression models. A typical sample of these residual plots is given in Figures D41 to D52 of Appendix D.

Additional linear regression analyses were performed. These included regression of speed and lateral acceleration against curve geometry and traffic flow parameters with directional verge width considered. Speed and lateral acceleration was also regressed against approach/design speed, curve geometry, traffic flow and width of the inside verge.

Curve geometry and traffic flow parameters were found to explain less of the variation in the dependent variable than they did with the addition of the approach speed.

The consideration of the inside curve verge width instead of the average verge width was not found to improve the explanatory power of the regression models.

6.9.3. Interpretation of the Explanatory Regression Models

Linear multiple regression analyses were performed separately for various site groups arranged with respect to the direction of travel and the sign of gradient for either single or dual carriageways. Curve radius was considered separately as radius, curvature, total angle and rate of change of total angle.

Curvilinear multiple regression analyses were initially performed only for all study curves and with curve radius being expressed in actual radius and curvature terms. Since curvilinear regression models were found to be less powerful in conceptual terms than the all curve linear models no further analyses were undertaken.

(a) Entry Speeds

Step 1.

Radius (or curvature) and approach speed appeared to be the most significant independent variables for both single and dual carriageways. On single carriageways, radius (or curvature) was found to be the most significant car entry speed determinant with approach speed explaining less of the variation in the dependent variable. Contrary to that, approach speed was found to be superior to curve radius (or curvature) in explaining the variation in the car entry speed on dual carriageways. Approach speed was found to be the most significant independent variable for goods vehicle entry speeds with curve radius (or curvature) being the second best.

Verge width, sight distance, traffic flow, curve length and road width also appeared as significant variables in some of the linear regression models. The influences of those independent variables, while significant, were considerably smaller. Superelevation and gradient were not found to have a statistically significant effect on either car or goods vehicle entry speeds when all study sites were considered in the analysis. A linear relationship containing curve radius or total angle explained a lower proportion of the speed variability for the data range and for all vehicle classifications considered, than did a linear relationship containing curvature or rate of change of total angle.

On single carriageways, linear regression models produced for car entry speeds explained a much higher proportion of the variability in the dependent variables than did the corresponding models developed for goods vehicles. On dual carriageways all the models were found to be almost equally powerful in explanatory terms. Overall about 90 per cent of the variation in car entry speeds were explained by the linear models for either single or dual carriageway sites. In the case of goods vehicles the corresponding figures were about 68 per cent for single carriageways and 96 per cent for dual carriageways (Tables D14 to D19 – Appendix D).

Curvilinear regression models, developed only for all the study curves, were not found to be superior to the linear models in explanatory terms. Additionally, the inclusion of higher order curve radius (or curvature) terms produced models whose overall form was not as satisfactory as that of the linear models (Tables D38 to D39 – Appendix D).

An examination of the residuals of the linear model did not suggest significant non-linearity, a result supported by the normality residual plots. However, goods vehicle residual plots were less consistent than those of cars mainly due to the low sample size available. A typical sample of residual plots for all site entry speed regression models are shown in Figures D41, D42, D44 and D45 of Appendix D.

Step 2.

Design speed was not found to be a statistically significant determinant of vehicle entry speeds for almost all the different site groups considered in the analysis. The linear regression models developed in this step were also found to be less powerful in explanatory terms than those developed in the previous step and no curvilinear regression analyses were therefore undertaken. The regression relationships developed in this step are shown in Tables D20 to D25 of Appendix D. It is noticeable that curve radius (or curvature) is again the most important entry speed determinant with verge width and sight distance explaining far less of the variation in the dependent variable.

Step 3.

For the linear relationships, developed for the selected study sites only (see Section 5.6) much the same remarks apply as for Step 1. Surprisingly sight distance was found to be the only significant variable for free car entry speed at uphill dual carriageway sites. That was probably due to the small sample size and to the nature of the sites selected.

Curvature was again the most important determinant of car entry speeds for single carriageways, whereas approach speeds were found to explain more of the variation in car entry speeds on dual carriageways and for goods vehicle speeds on both single and dual carriageways.

For the selected single carriageway sites sight distance and lane width appeared to have a significant effect as well as radius on car entry speeds, whereas only verge width was found to explain some of the variation in the dependent variable when curvature was considered. However, the proportion of variability attributable to those variables was relatively small.

Curvature explained more of the entry speed variability than radius for both vehicle classifications and road types. The value of the coefficient of determination (r^2) ranged from 0.80 to 0.97 for cars and from 0.80 to 0.98 for goods vehicles.

Selected site linear regression models developed in this step are given in Tables D26 to D31 of Appendix D. Sample sizes for some of the selected site groups were low and so the regression models developed should be treated with caution.

An examination of the residuals of the linear car or goods vehicle entry speed models suggested a possible non-linearity. This might have occurred because of the need to consider other variables or the different sample size considered in the analysis. Higher order terms of curvature were statistically significant only for the goods vehicle regression models on single carriageways, and, when those were considered, the residual plots revealed a rather more acceptable spread of residual values. However, high order (curvilinear) regression models (Tables D40 to D41 – Appendix D) were found to explain less of the variability in the dependent variable than the linear models.

Step 4.

The results of this step were much the same as those in Step 1. The most noticeable feature of the results was the importance of approach speed as an independent variable to explain entry speeds, particularly when curve geometry was expressed in terms of curvature. The influences of other independent variables such as verge width, sight distance, curve length, road width, gradient and superelevation, while statistically significant for different site groupings, were considerably smaller.

The linear regression models produced in this step, shown in Tables D32 to D34 of Appendix D, were found to account for large proportions in the variation of the entry speeds. Coefficients of determination (r^2) ranged between 0.87 and 0.93 for cars and between 0.63 and 0.85 for goods vehicles.

Figure D43 of Appendix D reveals an even spread of residuals when entry speed is expressed in terms of approach speed, radius, verge width and road width thus indicating a considerable linearity of the model.

When curvature was expressed in higher order terms, approach speed appeared to be a significant additional variable. The curvilinear models, shown in Table D42 of Appendix D were less successful in explaining entry speed variability when all single and dual carriageway sites were considered together.

Step 5.

Again, curvature and approach speed appeared as the dominant variables in the linear regression models developed for selected single and dual carriageway sites, Tables D35 to D37 of Appendix D. Approach speed was only found to be superior to curvature for goods vehicles on uphill curves. Verge width also appeared to be of some significance although this was again small in comparison to curvature and approach speed effects. Coefficients of determination (r^2) ranged between 0.91 and 0.96 for cars and between 0.84 and 0.92 for goods vehicle entry speeds for different site groupings.

An examination of the residual plots revealed no significant departures from linearity.

Higher order curvature terms did not appear to have a significant effect on car entry speed whereas the square of curvature was found to be significant for goods vehicle entry speed together with approach speed and first order curvature (Table D43 - Appendix D). Curvilinear models were less successful in explaining car speed variability than the linear models, whereas the introduction of second order curvature terms resulted in more successful, in explanatory terms, regression models for goods vehicles.

(b) Middle Speeds

Step 1.

The linear car middle speed regression models were dominated by either curve radius or curvature and approach speed, with small, but statistically significant effects from curve length, sight distance, verge width and road width for the various site groupings and for both carriageway types (Tables D44 to D49 – Appendix D).

The form of the linear regression models was less clear for goods vehicle speeds. Approach speed appeared to be the major determinant of middle speeds on dual carriageways with curvature second. On single carriageways no clear pattern between the various site groupings was observed. Curvature and approach speed were the main speed determinant of middle speeds for all and right-hand curves. Approach speed was also a significant variable for left-hand curves whereas it had no effect on middle speeds at downhill curves. Superelevation was of only slight significance for middle speeds on uphill curves.

Coefficients of determination ranged between 0.87 and 0.92 for car regression models and between 0.40 and 0.92 for goods vehicle models among the various site groupings and when curve radius was represented by curvature.

An examination of the residual plots (Figures D46, D47 and D50 – Appendix D) suggested a possible non-linearity for the car linear regression models.

Non-linear terms were significant for both curve radius and curvature regression models with the curvature model being always the most powerful of the two in explanatory terms. The inclusion of higher order curvature terms resulted in curvilinear regression models with a more even spread of the residual values and which explained slightly more, of the variability in the dependent variable, (Tables D68 to D69, and Figure D49 – Appendix D). However, higher order curvature terms were found to explain only a very small proportion of the total variation in middle speed.

Step 2.

Design speed did not appear to be a dominant independent variable in linear regression models for both vehicle classification and road type (Tables D50 to D55 – Appendix D). The linear regression models produced in this step accounted for less variation in the dependent variable than those from Step 1.

Step 3.

Selected site regressions were dominated by curve radius (or curvature) and approach speed. Curvature appeared as the predominant independent variable in car models whereas approach speed featured as the most significant middle speed determinant in most of the goods vehicle models (Tables D56 to D61 - Appendix D). With radius or curvature in linear form, sight distance appeared as a significant independent variable, explaining a small proportion of the middle speed variability. Surprisingly, sight distance appeared as an important speed determinant on single carriageway right-hand curves, but not on left-hand curves where it is usually shorter. That could be attributed to the nature of the sample as well as to its size.

Linear regression models accounted for middle speed variability ranging between 85 per cent and 95 per cent for cars and between 83 per cent and 94 per cent for goods vehicles when linear terms of curvature were considered. Possible non-linearity was observed when residual plots of the linear regression models were studied.

When higher order values of radius or curvature were included in the models to account for the non-linearity a more even spread of the residual values was obtained. In general, higher order terms of radius or curvature appeared to be statistically significant speed determinants, with curvature always explaining more of the variation in the dependent variable. However, higher order curvature terms accounted for only a small proportion of middle speed variation.

Overall, curvilinear regression models produced in this step (Tables D70 to D71 - Appendix D) were found to explain slightly more of the total variation in middle speeds than the linear models.

Step 4.

For the linear relationships, much the same remarks apply as for Step 1 regressions, except that road width appeared to be a statistically significant independent variable for car middle speeds, together with curvature, approach speed and verge width. However, verge and road width explained only a small proportion of the variation, (Tables D62 to D64 - Appendix D).

The linear models developed in this step appeared to account for a considerable proportion of middle speed variation, ranging between 85 per cent to 93 per cent for cars and between 65 per cent to 86 per cent for goods vehicles where curve radius was expressed in curvature terms.

However, an examination of residual plots (Figure D48 - Appendix D) for the linear regressions revealed possible non-linearities.

As before, the introduction of higher order terms of radius or curvature resulted in a rather more even spread of the residual values, but it did not produce more powerful regression models (Table D72 - Appendix D) in explanatory terms. None-the-less higher order curvature or radius terms appeared to be statistically significant variables explaining a small proportion of middle speed variability.

Step 5.

Curve radius (or curvature) and approach speed were again the dominant independent variables with verge width, road width and sight distance appearing as stastistically significant middle speed determinants but explaining only a small proportion of speed variability (Tables D65 to D67 – Appendix D).

Coefficients of determination (r^2) ranged between 0.89 to 0.94 for cars and between 0.73 to 0.97 for goods vehicles when curve radius was expressed in curvature terms.

Higher order radius or curvature terms appeared to account for the possible non-linearities observed in the residual plots for the linear models but they did not result in better regression models (Table D73 – Appendix D). The only exception was the all curve goods vehicle curvilinear model which explained 5 per cent more than the corresponding linear model.

(c) Middle Lateral Acceleration

Step 1.

Approach speed did not appear as a statistically significant independent variable for the linear 85th percentile lateral acceleration regression models on single carriageways. However, when linear terms of radius were considered, approach speed was found to be the second best lateral acceleration determinant on dual carriageways (Tables D74 to D79 – Appendix D). Curve radius or curvature were again the most important independent variables, with verge width, flow and road width having a small but statistically significant effect. Also, in the case of goods vehicles, superelevation appeared to be of some importance to the middle lateral accelerations.

In general, linear regression models were found to account for a lower proportion of the variation in lateral acceleration than they did for entry and middle speeds. Also, on examination, the residual plots (Figures D51 and D52 – Appendix D) indicated the existence of strong non-linearities mainly due to the curvilinear relationship between lateral acceleration and curve radius.

Curvilinear regression models developed between lateral acceleration and higher order terms of radius or curvature (see Section 6.8) resulted in a more even spread of the residual values, although they were not significantly superior in explanatory power.

Therefore, since middle lateral acceleration could be determined by means of middle speed and curve radius, the use of the more powerful middle speed regression models was suggested.

Step 2.

Contrary to earlier findings for entry and middle speeds, design speed was found to be the second best lateral acceleration determinant on single carriageways with curve radius explaining most of the variation in the dependent variable. When linear terms of curvature were considered only verge width, flow and superelevation appeared as statistically significant independent variables for the various site groupings, although they explained only small proportions of the total lateral acceleration variation, (Tables D80 to D85 - Appendix D).

Step 3.

The results were similar to those for Step 1 regression models, curve radius or curvature being the predominant independent variables for the selected site lateral acceleration linear models, (Tables D86 to D91 - Appendix D). Sight distance, traffic flow, superelevation, verge and road width appeared as statistically significant variables for the various site groupings although they explained only small proportions of the total variability. Approach speed was not found to have a significant effect on lateral acceleration in most of the cases considered.

Residual plots revealed strong non-linearities caused by the significant curvilinear relationship between lateral acceleration and curve radius.

Non-linearities were found to be accounted for by simple curvilinear models between radius or curvature and lateral acceleration, but again the use of the speed regression models for the explanation of lateral acceleration variation were thought to be superior.

Step 4. and 5.

Linear regression models developed for all and selected single and dual carriageway sites considered together, were again dominated by radius (or curvature) as being the statistically most important middle lateral acceleration determinant (Tables D92 to D97 - Appendix D). Approach speed, verge width, superelevation, flow, road width and curve length appeared to be statistically significant independent variables for various site groupings but explaining only small proportions of the variability in middle lateral acceleration for all vehicle classifications.

Examination of the residual plots revealed strong non-linearities, again due to the curvilinear relationship between middle lateral acceleration and curve radius or curvature. Linear speed regression models for the determination of lateral acceleration were thus chosen.

6.9.4. Outliers

Examination of the residual values for the various 85th percentile entry for middle speed regression models for the various vehicle classifications and road types revealed a small number of significant departures (differences of more than one standard deviation) from the mean values.

Subsequent tests suggested that most of those departures could be partly attributed to the prevailing geometric or flow conditions on the approaches to the particular road curves. Uphill grades and the existence of developments were found to be such restricting factors (Sites 7, 8, 25, 35 and 49 for cars and sites 16 and 20 for goods vehicles on single carriageways). However, in other cases, such as on dual carriageway sites 12, 17 and 20 the observed departures for the car speed models could not be attributed to obvious geometric or traffic restrictions. Since the purpose of the study was to investigate geometric, traffic and environmental effects on vehicle/driver behaviour around road curves, these later sites were not removed from the all site regression models. However, whenever appropriate, they were excluded from the subsequent selected site analyses.

6.9.5 Comparisons of the Explanatory Regression Models

The explanatory power of the various linear and curvilinear regression models for the 85th percentile entry or middle speeds of both vehicle classifications and road types was examined by means of the chi-squared test performed between the observed and the predicted speed values at a 5 per cent level of significance. Table 6.20 gives the summarised results of the comparison tests for entry and middle speed regression models.

In all, four different regression models were considered for the comparison tests. They were as follows:

A	- Linear Regression Model	(Single or Dual Carriageways)
B	- " " "	(Single and Dual Carriageways)
C	- Curvilinear " "	(Single or Dual Carriageways)
D	- " " "	(Single and Dual Carriageways)

Separate tests were carried out for all car and goods vehicle regression models. Free car models were not considered since they were found to be almost identical to the all car regression models. Entry and middle speed models were also treated separately. Observed speed values were plotted against predicted values resulting from the four regression models for each separate case (Figures 6.25 to 6.31).

In general, linear regression models appeared to have a more satisfactory overall form than curvilinear models for either entry or middle speeds and vehicle classifications. That, was found to be the case particularly for the lower end of the radius range where even linear models could not adequately explain the variability in entry or middle speeds. Significant differences between observed and predicted values were also found for the all car curvilinear models on single carriageways (see Table 6.20).

Also no significant difference appeared to exist between regression models developed separately for single or dual carriageway sites and those for the two road types data joined together. Higher chi-squared values observed for the joint data models could not be used for comparison purposes since they corresponded to different levels of degrees of freedom.

Linear and curvilinear regression models developed for selected site 85th percentile speed data was validated using data from the non-selected sites. Again, significant departures were only observed for all car and goods vehicle curvilinear models on single carriageways, with all but one of the linear models being statistically acceptable as shown in Table 6.20. Overall no significant differences were observed between the all site and the selected site regression models, although for the second case higher chi-squared values were recorded for the same level of degress of freedom. Therefore, although the two types of models were not different in terms of the coefficient of determination (r^2). the selected sites regression models were less satisfactory over the entire radius data range considered in the study.

Much the same remarks apply to the comparison between linear and curvilinear modles, especially in the case of middle speeds where although curvilinear models appeared to be superior in terms of correlation (r^2) they were in most of the cases less satisfactory than the linear models in the overall form.

6.9.6 Comparisons with Earlier Studies

Taragin(50) presented observed speed and geometry data for the inside and outside lanes of 35 curves in rural, two-lane highways in the USA. He obtained the following linear regression relationship between mean car speeds measured at the centre of a curve and curvature.

$$V(50) = 46.26-0.749C \qquad (6.1)$$

$$r^2 = 0.67$$

Apart from an overall increase in operating car speed, since 1954, this equation is in general agreement with the equivalent regression equation, shown below, that was developed in this study.

$$V_{CM}(50) = 76.00-0.794C \qquad (6.2)$$

$$r^2 = 0.85$$

Linear multiple regression models developed by Oppenlander(59) and O'Flaherty and Coombe(63,64,65,66) for various percentiles of middle car speed on single carriageways had a common feature with the equivalent models shown in Tables D44 to D73 of Appendix D. Curvature was the predominant determinant, with other variables such as sight distance, length and superelevation explaining only small proportions of the speed variability.

The New South Wales Department of Main Roads[36] collected curve speed and radius data for cars at a number of single carriageway sites in Australia. That data gave the following linear speed radius relationship.

$$V(85) = 52.3+.098R \qquad (6.3)$$

$$r^2 = 0.91$$

This was of similar form to that derived in this study (see equation 6.2 in Table D44 – Appendix D).

In his comprehensive study on vehicle speeds around single carriageway curves in Australia, McClean[22,67] developed a series of linear and curvilinear regression models to explain the variation in middle vehicle speed. He suggested the following two models for car and goods vehicle curve middle speeds.

$$V_{CM}(85) = 50\ 9+0.446AS-2.82C+0.7C^2+0.015SD \qquad (6.4)$$

$$r^2 = 0.94$$

and

$$V_{GM}(85) = 41.3+0.42AS-2.01AS+0.05C^2+0.013SD \qquad (6.5)$$

$$r^2 = 0.95$$

Both these models are in general agreement with equivalent regression models developed in this study (Tables D68, D70-73 – Appendix D). The only exception is that McLean found the approach (desired) speed to be the predominant determinant for both car and goods vehicle curve middle speeds with curvature being the second best independent variable, whereas the contrary was found to be true in this study. The reason for that difference lies mainly with the site sampling procedure. McLean[22] reported that:

> *"The roads on which data were collected had generally been designed according to what has become known as 'balanced design'. Having due regard to traffic volumes, topography and financial feasibility, either the designers or the specified standards attempt to achieve balance, or compromise, between the geometric elements of cross-section, horizontal alignment and vertical alignment."*

Lower radii curves were thus likely to be associated with steeper grades, shorter sight distances, lower traffic volumes and narrower carriageways and verge widths. Since approach speeds are generally influenced by all these factors a certain bias was introduced in his site sample.

In this work additional care was taken to ensure that the amount of bias introduced in the data due to these factors would be kept to a minimum. Curves exhibiting different combination of geometric element were considered at road sections with varying environment speed'[20].

Wortman's[60] linear regression model, developed for middle car speeds on dual carriageways, did not include curvature as a significant speed determinant. That was probably due to the inclusion of only low curvature road curves in the sample.

A comparison of the r^2 values indicates that some of the data[36,56] showed stronger relationships between curve middle speed and the main independent variables. This can be partly attributed to site selection. Sites for the DMR studies were for example selected such as to ensure that curvature had the dominant influence on driver speed. This study attempted to identify the effect of road curvature on vehicle speed under a variety of conditions, thus weakening the apparent overall influence of curve radius.

6.9.7 Discussion of the First Stage Regression Models

(a) Factors affecting curve speeds

The objective of the first stage of the regression analysis was to determine the factors which influence vehicle speeds on curves, as indicated by the statistically significant independent variables. The results suggested that curve speeds - either entry or middle - were primarily influenced by the approach speed on the road section before a curve, and by the curve radius. The second variable appeared to be the statistically predominant variable in most of the cases considered. Other geometric or traffic factors were found to have less influence. Verge width appeared to affect vehicle speeds and particularly car speeds by only about 0.6 to 0.8 k.p.h. per 1.0m of available verge width. Sight distance appeared to influence both cars and goods vehicle speeds at the mid point of the curves by about 0.5 to 0.6 k.p.h. per 100m of available sight distance. Gradient did not appear in most of the cases as a significant speed determinant. That was expected for the goods vehicles as no sites with gradient greater than 3 per cent had been included in the analysis. For cars, it seemed that curve speeds were not influenced by the existence of gradient.

It should be emphasised that the non-inclusion of a variable in the models resulting from the regression analysis does not necessarily mean that it has no effect on curve speeds. Rather it has no statistically significant influence for the data under consideration. Lack of statistical significance could have arisen either from an inadequate range of values or because the effect of the independent variable was so small as to be trivial.

(b) Form of the Regression Relationships

The analysis showed that over the entire curvature range considered, there were statistically significant non-linearities in the linear regression models for both vehicle classification and road types. No real differences were observed between the all car and the free car models. When the non-linearities were allowed for, higher order curvature relationships were found to explain more of the variability in observed curve speed. However, the overall form of the curvilinear models was not found to be as satisfactory as that of the linear models over the entire range of curve radii considered. Linear regression models were, therefore, given preference in the subsequent development of predictive relationships for curve speed.

(c) Approach Speed Considerations

The concept of approach speed, as used in this study, was defined as the speed at which drivers would wish to travel if not constrained by road alignment. The influence of traffic flow was also taken to be trivial since most of the study sites were located on roads with low levels of flow. It could, therefore, be considered to be the desired speed at which drivers would choose to travel over the particular road sections. The 85th percentile car approach speed has been found to vary with the terrain type and the overall alignment of the road(22,95). It could also be considered as a better representation of the fast drivers for whom alignment constraints are likely to have a greater effect, and therefore, could be used as a measure of the drivers' perception of the overall road standard.

The desired speed for goods vehicles is not expected to show the same consistency as that of cars. The performance characteristics of goods vehicles will vary according to load and power characteristics which can be reflected as between-site variations in the speed distributions. It can thus only be used as an approximate measure of the 'environment speed'(20).

6.9.8 Predictive Regression Models

The first stage regression analysis showed that the most successful relationship for explaining variation in 85th percentile vehicle speed on road curves in either statistical or conceptual terms was of the following form:

$$V(85) = a - bC + cAS \pm dX$$

where

a, b, c and d the regression coefficient and

X a statistically significant independent variable

Analysis of variance showed that the changes in vehicle speed explained by the regression were almost all attributed to the approach (desired) speed and curvature. Other independent variables, i.e. X, explained only very small proportions of the speed variation. Additionally, in terms of design, those geometric variables could be seen as elements provided for a specified speed, rather than speed determinants. A relationship based on curvature and approach speed could therefore be more useful as a predictive model.

The most useful application of a curve speed prediction model would be to investigate the relationship between vehicle speed and curvature within a particular 'environment speed' range as quantified by an approach speed. However, since prediction of the approach speed of a particular vehicle or group of vehicles cannot be made accurately for a specified road section, the use of an 'environment speed' depending on the terrain type and the general alignment of the road section was thought to be more appropriate.

Separate regression analyses between the 85th percentile entry and middle speed and curvature were carried out for data grouped according to approach speed. All the study sites are included in the analyses, as there was general agreement between all site and selected site explanatory regression models, and a sufficiently large sample was required. Cars and goods vehicles were treated separately and predictive models were produced for single and dual carriageways as well as for all combined sites. Regression models were not produced for goods vehicles at dual carriageways because of the small site samples available. The resulting linear speed/curvature regression models are given in Tables 6.21 and 6.22 for entry and middle curve speeds respectively. Groupings are arranged according to the available sample and to design considerations[17]. The predictive models showed a consistent pattern for all the cases considered. The intercept appeared to increase with increasing 'environment speed' which was intuitively satisfactory.

Predictive models can be used as the basis for the development of a family of curve speed prediction relationships for specified 'environment speed' ranges to be used in the curve design process.

6.10 VEHICLE LATERAL PLACEMENT ANALYSIS

Analysis of vehicle lateral placement data was performed on a selected number of single and dual carriageway sites as described in Section 5.7 (see Table 5.2). Only free car data was considered and left-and right-hand curves were treated separately. Site selection was performed on the basis of curvature which was found to be the predominant vehicle/driver behaviour determinant.

6.10.1 Bivariate Analysis Between Lateral Placement and Speed

A series of bivariate graphs were produced between variables B and C (see Section 5.7) and speed for the different survey locations before and within road curves to test assumptions A and B concerning the reference direction which drivers would choose when travelling around curves. At the same time relationships between average vehicle placement at the various survey locations and the behavioural parameters of speed, forward or lateral acceleration, were assessed by bivariate plots.

In general, relationships were found to be insignificant in either explanatory (r) or statistical terms (F-test). Car speeds appeared not to significantly correlate with lateral placement at the fixed survey locations within the selected sites. The results were identical for both single and dual carriageways and for both left-and right-hand curves.

Figures 6.32 to 6.41 show typical examples of the resulting relationships for a small sample of directional single and dual carriageway sites. It can be seen, from these figures, that curvature made no difference to the quality of the relationship between the two variables. However, on tight single carriageway curves, with radii between 0 and 150m, cars tended to decrease the curvature level by 'cutting the corner'. This 'all transitional path', mentioned by Good(41), is clearly indicated by the lateral placement distributions at the different survey locations within the curves (Figures 6.32 to 6.35). The trend was found to be more pronounced for right-hand curves, probably because of the larger sight distances available (Figures 6.34 and 6.35). Surprisingly, it was observed that this driving behaviour was not solely associated with the higher speed vehicles where drivers would tend to reduce lateral forces by increasing the radius of their vehicle path, but was revealed to be a common practice for a high proportion of public drivers travelling around short radius curves. The trend was also observed for short radius curves on dual carriageways. On site 12, for example, which was a short radius (R=72.50m) left-hand curve, cars tended to make full use of the whole carriageway near the entry point and then move closer to the inside edge of the curve in order to reduce the curvature of their path (Figure 6.38), than lowering the amount of the applied lateral forces.

On road curves with radii larger than about 200 metres, a rather different behaviour was observed with drivers following the curve geometry rather more closely on both single and dual carriageways (Figures 6.36, 6.37 and 6.41). No difference was observed between left-and right-hand directions within that curvature range.

Finally it should be noted that the loose associations between lateral placement and speed at different locations within road curves could be partly attributed to the data collection procedure and its level of accuracy.

6.10.2 Bivariate Analysis Between Lateral Placement Data Collected at Different Survey Locations

The correlations between lateral placement data at different survey locations within the selected directional curves for single and dual carriageways are shown in Table 6.23 (see Section 5.7.2). As expected, in most of the cases correlation coefficients (r) were high, ranging between 0.17 to 0.99, for the relationships between lateral placements taken at the two ends of the fixed 20.0 metres survey distance at the entry, middle and exit points of a curve. However, especially on single carriageways, the degree of correlation, was found to be highly dependent on curvature with curve length having insignificant effect. On short radius curves, such as 34.0 and 45.0 metres, values as low as 0.14 and 0.17 were observed for the correlation coefficient. On larger radii curves a more consistent behaviour in vehicle placement terms was observed with r values ranging between 0.47 and 0.92. On those curves drivers tended to adopt a more constant path avoiding major lateral movements along the curves.

On dual carriageways a significantly more consistent behaviour was observed over the entire range of curvature considered. The only exception was the rather poor correlation (r=0.46) between the two middle locations of a 72.50 metres radius left-hand curve. That clearly indicated that even on dual carriageways with no oncoming traffic and more freedom of lateral movement the consistency of the path adopted over at least certain sections of the curve was varied slightly with the curvature.

When, however, relationships between lateral placement data, identical for entry, middle or exit locations were considered (Cases B and D - described in Section 5.7.2), correlations were found to be less significant, depending more on curve length than on curvature. Substantial differences were again observed between single and dual carriageway sites with the first exhibiting a significantly less consistency in path selection. Changes in lateral placement around single carriageway curves seemed to vary randomly being unrelated to the entry location or speed. The inconsistent behaviour observed was also found (see Table 6.23) to be more pronounced for left-hand single carriageway curves. A considerably more consistent behaviour was shown, however, on dual carriageway curves, where with no oncoming traffic and ample freedom for lateral movement, drivers were able to select their best path.

A typical sample of the bivariate plots is shown in Figures 6.42 to 6.49 for single and dual carriageways.

6.10.3 Multivariate Analysis Between Lateral Placement and Speed

The introduction of more than one lateral placement variables into the linear regression analysis with speed parameters (see Section 5.7.3) made no significant improvements on the simple linear relationships obtained in Section 6.10.1. Coefficients of determination ranged between 0.02 and 0.22 for both single and dual carriageway sites with most of the values being statistically insignificant at a 5 per cent level of significance.

These results confirmed the earlier findings, Section 6.10.1, that there was a small correlation between speed and lateral placement within a curve and that lateral placement adjustments were almost entirely independent of speed.

TABLE 6.1: COMBINED VEHICLE SPEED DATA - SINGLE CARRIAGEWAYS

MEASUREMENT SPEED PARAMETER		SPEED (k.p.h.)		
		Minimum	Maximum	Average
ALL CARS				
Approach	Mean	56.80	85.31	74.39
	85th Percentile	65.75	98.00	84.77
	99th Percentile	72.20	116.47	99.37
Entry	Mean	46.43	83.37	70.50
	85th Percentile	53.00	98.00	79.61
	99th Percentile	56.45	113.00	92.45
Middle	Mean	36.87	78.83	66.42
	85th Percentile	41.00	91.00	74.64
	99th Percentile	49.05	109.00	85.91
Exit	Mean	42.67	84.85	68.73
	85th Percentile	48.00	95.00	77.40
	99th Percentile	54.11	114.16	90.04
FREE CARS				
Approach	Mean	57.30	86.46	75.14
	85th Percentile	66.00	98.00	85.29
	99th Percentile	72.56	118.40	99.70
Entry	Mean	46.66	84.19	71.40
	85th Percentile	53.00	98.80	80.48
	99th Percentile	57.26	113.24	93.00
Middle	Mean	37.17	81.69	67.38
	85th Percentile	41.00	93.40	75.53
	99th Percentile	49.14	109.84	86.32
Exit	Mean	42.96	85.80	69.90
	85th Percentile	48.00	95.05	78.30
	99th Percentile	54.20	114.93	90.59

... continued

TABLE 6.1: ... continued

MEASUREMENT SPEED PARAMETER		SPEED (k.p.h.)		
		Minimum	Maximum	Average
GOODS VEHICLES				
Approach	Mean	58.64	75.15	67.17
	85th Percentile	65.80	85.00	74.62
	99th Percentile	70.00	98.14	83.07
Entry	Mean	43.13	71.95	64.33
	85th Percentile	47.40	81.00	70.99
	99th Percentile	54.52	93.00	78.78
Middle	Mean	36.04	75.81	61.06
	85th Percentile	40.00	86.20	68.25
	99th Percentile	43.76	98.00	74.63
Exit	Mean	36.13	68.13	62.04
	85th Percentile	40.00	79.00	69.00
	99th Percentile	43.76	91.20	76.52

TABLE 6.2: MEAN VALUES OF STANDARD DEVIATION AT DIFFERENT LOCATIONS FOR SINGLE AND DUAL CARRIAGEWAY SITES

LOCATION	STANDARD DEVIATION (k.p.h.)		
	All Cars	Free Cars	Goods Vehicles
SINGLE CARRIAGEWAYS			
Approach	10.23	10.22	7.93
Entry	9.13	9.02	7.32
Middle	8.38	8.22	7.18
Exit	8.98	8.62	7.24
DUAL CARRIAGEWAYS			
Approach	10.64	10.66	7.69
Entry	10.03	9.82	7.59
Middle	9.50	9.26	7.24
Exit	10.06	9.97	7.84

TABLE 6.3: COMBINED VEHICLE SPEED DATA - DUAL CARRIAGEWAYS

MEASUREMENT SPEED PARAMETER		SPEED (k.p.h.)		
		Minimum	Maximum	Average
ALL CARS				
Approach	Mean	66.54	97.24	84.31
	85th Percentile	76.00	110.00	95.01
	99th Percentile	82.49	126.40	109.86
Entry	Mean	60.33	99.42	81.36
	85th Percentile	68.00	110.00	91.34
	99th Percentile	80.88	126.00	104.86
Middle	Mean	49.97	96.06	76.86
	85th Percentile	57.00	107.00	86.55
	99th Percentile	63.61	125.18	99.09
Exit	Mean	59.95	100.67	80.52
	85th Percentile	66.00	114.85	90.53
	99th Percentile	75.44	134.13	104.90
FREE CARS				
Approach	Mean	67.87	98.01	84.97
	85th Percentile	76.10	110.00	95.40
	99th Percentile	82.74	128.20	110.23
Entry	Mean	61.24	100.23	82.33
	85th Percentile	69.00	111.35	92.15
	99th Percentile	82.80	126.00	105.27
Middle	Mean	50.83	97.02	77.84
	85th Percentile	57.00	107.00	87.14
	99th Percentile	63.70	125.38	99.46
Exit	Mean	60.85	101.82	81.62
	85th Percentile	66.75	115.00	91.45
	99th Percentile	76.40	135.83	105.36

... continued

TABLE 6.3: ... continued

MEASUREMENT SPEED PARAMETER		SPEED (k.p.h.)		
		Minimum	Maximum	Average
GOODS VEHICLES				
Approach	Mean	60.50	78.00	70.48
	85th Percentile	68.00	86.65	77.86
	99th Percentile	71.83	93.77	84.10
Entry	Mean	48.18	79.55	67.45
	85th Percentile	52.00	88.95	74.36
	99th Percentile	55.32	94.42	81.61
Middle	Mean	44.24	74.35	62.45
	85th Percentile	48.45	86.00	69.30
	99th Percentile	52.32	90.71	76.08
Exit	Mean	49.06	76.76	64.94
	85th Percentile	52.45	88.00	71.48
	99th Percentile	54.66	93.84	80.31

TABLE 6.4: MEAN VALUE OF THE COEFFICIENT OF VARIATION AT DIFFERENT LOCATIONS FOR SINGLE AND DUAL CARRIAGEWAY SITES

LOCATION	COEFFICIENT OF VARIATION		
	All Cars	Free Cars	Goods Vehicles
SINGLE CARRIAGEWAYS			
Approach	0.137	0.136	0.118
Entry	0.130	0.126	0.114
Middle	0.126	0.122	0.118
Exit	0.128	0.123	0.117
DUAL CARRIAGEWAYS			
Approach	0.126	0.125	0.110
Entry	0.124	0.119	0.114
Middle	0.124	0.119	0.117
Exit	0.125	0.120	0.122

TABLE 6.5: SUMMARY OF RESULTS OF NORMALITY TESTS: NUMBER OF SITES AT WHICH SPEEDS WERE FOUND TO BE NORMALLY DISTRIBUTED*
(All car speed distributions at the different locations)

CONDITION	CARRIAGEWAY TYPE															
	Single								Dual							
	Approach		Entry		Middle		Exit		Approach		Entry		Middle		Exit	
	x^2	K-S	x^2	K-S	x^2	K-S	x^2	K-S	x^2	K-S	x^2	K-S	x^2	K-S	x^2	K-S
Normal (%)	47 (83.9)	54 (96.4)	48 (85.7)	53 (94.6)	51 (91.1)	51 (91.1)	49 (87.5)	50 (89.3)	19 (86.4)	18 (81.8)	21 (95.5)	22 (100.0)	18 (81.8)	22 (100.0)	22 (100.0)	22 (100.0)
Non-Normal (%)	9 (16.1)	2 (3.6)	8 (14.3)	3 (5.4)	5 (8.9)	5 (8.9)	7 (12.5)	6 (10.7)	3 (13.6)	4 (18.2)	1 (4.5)	0 (0.0)	4 (18.2)	0 (0.0)	0 (0.0)	0 (0.0)
Total No. of Sites	56	56	56	56	56	56	56	56	22	22	22	22	22	22	22	22

*x^2: Chi-Squared Test
K-S: Kolmogorov-Smirnov Test

TABLE 6.6: SUMMARY OF RESULTS OF NORMALITY TESTS: NUMBER OF SITES AT WHICH SPEEDS WERE FOUND TO BE NORMALLY DISTRIBUTED

(Free car speed distributions at different locations)

CONDITION	CARRIAGEWAY TYPE															
	Single								Dual							
	Approach		Entry		Middle		Exit		Approach		Entry		Middle		Exit	
	x^2	K-S	x^2	K-S	x^2	K-S	x^2	K-S	x^2	K-S	x^2	K-S	x^2	K-S	x^2	K-S
Normal (%)	50 (89.3)	55 (98.2)	46 (82.1)	53 (94.6)	47 (83.9)	51 (91.1)	49 (87.5)	52 (92.9)	18 (81.8)	21 (95.5)	19 (86.4)	20 (90.9)	21 (95.5)	22 (100.0)	22 (100.0)	22 (100.0)
Non-Normal (%)	6 (10.7)	1 (1.8)	10 (17.9)	3 (5.4)	9 (16.1)	5 (8.9)	7 (12.5)	4 (7.1)	4 (18.2)	1 (4.5)	3 (13.6)	2 (9.1)	1 (4.5)	0 (0.0)	0 (0.0)	0 (0.0)
Total No. of Sites	56	56	56	56	56	56	56	56	22	22	22	22	22	22	22	22

x^2: Chi-Squared Test

K-S: Kolmogorov-Smirnov Test

TABLE 6.7: SUMMARY OF RESULTS OF NORMALITY TESTS: NUMBER OF SITES AT WHICH SPEEDS WERE FOUND TO BE NORMALLY DISTRIBUTED

(Goods Vehicle speed distributions at the different road locations)

CONDITION	CARRIAGEWAY															
	Single								Dual							
	Approach		Entry		Middle		Exit		Approach		Entry		Middle		Exit	
	x^2	K-S	x^2	K-S	x^2	K-S	x^2	K-S	x^2	K-S	x^2	K-S	x^2	K-S	x^2	K-S
Normal (%)	30 (96.8)	30 (96.8)	29 (93.5)	31 (100.0)	31 (100.0)	31 (100.0)	29 (93.5)	31 (100.0)		12 (100.0)		12 (100.0)		12 (100.0)		12 (100.0)
Non-Normal (%)	1 (3.2)	1 (3.2)	2 (6.5)	0 (0.0)	0 (0.0)	0 (0.0)	2 (6.5)	0 (0.0)		0 (0.0)		0 (0.0)		0 (0.0)		0 (0.0)
Total No. of Sites	31	31	31	31	31	31	31	31	12	12	12	12	12	12	12	12

x^2: Chi-Squared Test

K-S: Kolmogorov-Smirnov Test

TABLE 6.8: SUMMARY OF RESULTS OF NORMALITY TESTS: NUMBER OF SITES WHERE LATERAL ACCELERATIONS WERE FOUND TO BE NORMALLY DISTRIBUTED
(All Car Middle Lateral Acceleration Distributions)

CONDITION	CARRIAGEWAY TYPE	
	Single	Dual
	Middle, K-S	Middle, K-S
Normal	49	20
(%)	(87.5)	(90.9)
Non-Normal	7	2
(%)	(12.5)	(9.1)
Total No. of Sites	56	22

K-S: Kolmogorov-Smirnov Test

TABLE 6.9: NORMALITY STATISTICS OF ALL CAR MIDDLE LATERAL ACCELERATION DISTRIBUTIONS

–	SKEWNESS		KURTOSIS	
	Positive	Negative	Leptokurtic	Platykurtic
SINGLE CARRIAGEWAY				
Middle	55	1	41	15
(%)	(98.2)	(1.8)	(73.2)	(26.8)
Total No. of Sites	56		56	
DUAL CARRIAGEWAY				
Middle	22	0	11	11
(%)	(100)	(0)	(50)	(50)
Total No. of Sites	22		22	

TABLE 6.10: COMPARISON BETWEEN OVERALL MEAN SPEEDS FOR PHASE I AND PHASE II

Description	Mean Speed Phase I (k.p.h.)	Mean Speed Phase II (k.p.h.)	Speed Difference (k.p.h.)	t	Degree of Freedom	Significance Level*
(i) SINGLE CARRIAGEWAYS						
Approach Speed	74.54	74.04	0.50	0.41	108	0.20
Entry Speed	70.10	70.91	-0.81	0.45	108	0.20
Middle Speed	66.80	66.34	0.46	0.23	108	0.20
Exit Speed	68.87	68.79	0.08	0.02	108	0.20
(ii) DUAL CARRIAGEWAYS						
Approach Speed	84.70	84.17	0.53	0.24	40	0.20
Entry Speed	81.19	81.26	-0.07	0.03	40	0.20
Middle Speed	77.87	76.20	1.67	0.54	40	0.20
Exit Speed	81.02	80.12	0.90	0.30	40	0.20

*The higher the level of significance is the less likely it is to make a mistake. A 5 per cent level of significance is ususally used in traffic engineering studies.

TABLE 6.11: SUMMARY OF RESULTS FROM t-TEST OF MEAN ALL CAR SPEEDS FOR PHASE I AND PHASE II AT ALL STUDY SITES

Description	No. of Sites (%) Within Level of Significance*				
	20%	10%	5%	2%	≤ 1%
(i) SINGLE CARRIAGEWAYS					
Approach Speed	38 (70%)	6 (11%)	2 (4%)	6 (11%)	2 (4%)
Mean Speed	22 (41%)	6 (11%)	11 (20%)	6 (11%)	9 (17%)
Middle Speed	25 (46%)	7 (13%)	5 (9%)	4 (7%)	13 (24%)
Exit Speed	27 (50%)	8 (15%)	9 (17%)	3 (6%)	7 (13%)
(ii) DUAL CARRIAGEWAYS					
Approach Speed	14 (70%)	3 (15%)	1 (5%)	1 (5%)	1 (5%)
Mean Speed	12 (60%)	2 (10%)	1 (5%)	2 (5%)	3 (15%)
Middle Speed	8 (40%)	4 (20%)	1 (5%)	3 (15%)	4 (20%)
Exit Speed	13 (65%)	2 (10%)	2 (10%)	0 (0%)	3 (15%)

*The higher the level of signficance is the less likely it is to make a mistake. A 5 per cent level of signficance is usually used in traffic engineering studies.

TABLE 6.12: COMPARISON BETWEEN OVERALL MEAN SPEEDS FOR WET AND DRY ROAD SURFACE CONDITIONS

Description	Mean Wet Speed (k.p.h.)	Mean Dry Speed (k.p.h.)	Speed Difference (k.p.h.)	t	Degrees of Freedom	Significance* Level (%)
SINGLE CARRIAGEWAYS*						
Approach Speed	74.40	74.46	-0.06	0.03	60	20+
Entry Speed	70.24	72.41	-2.17	0.98	60	20
Middle Speed	67.71	67.72	-0.01	0.02	60	20
Exit Speed	69.95	70.90	-0.95	0.44	60	20
DUAL CARRIAGEWAYS**						
Approach Speed	82.06	81.21	0.85	0.25	6	20
Entry Speed	73.40	75.93	-2.53	0.31	6	20
Middle Speed	68.99	68.38	0.61	0.06	6	20
Exit Speed	72.36	73.28	0.92	0.12	6	20

*31 sites

** 4 sites

+The higher the level of significance is the less likely it is to make a mistake. A 5 per cent level of significance is usually used in traffic engineering studies.

TABLE 6.13: SUMMARY OF RESULTS FROM t-TEST OF MEAN ALL-CAR SPEEDS FOR WET AND DRY ROAD SURFACE CONDITIONS

Description	No. of Sites (%) Within Level of Significance				
	20%	10%	5%	2%	1% ≤ +
SINGLE CARRIAGEWAYS*					
Approach Speeds	19 (61%)	4 (13%)	3 (10%)	3 (10%)	2 (6%)
Entry Speeds	14 (45%)	2 (6%)	5 (17%)	6 (19%)	4 (13%)
Middle Speeds	14 (45%)	4 (13%	3 (10%)	3 (10%)	7 (22%)
Exit Speeds	14 (45%)	6 (19%)	5 (17%)	0 (0%)	6 (19%)
DUAL CARRIAGEWAYS**					
Approach Speeds	4 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Entry Speeds	2 (50%)	0 (0%)	1 (25%)	1 (25%)	0 (0%)
Middle Speeds	2 (50%)	0 (0%)	1 (25%)	0 (0%)	1 (25%)
Exit Speeds	2 (50%)	0 (0%)	2 (50%)	0 (0%)	0 (0%)

*31 sites

** 4 sites

+ The higher the level of significance is the less likely it is to make a mistake. A 5 per cent level of significance is usually used in traffic engineering studies.

TABLE 6.14: COMPARISON OF INDIVIDUAL PUBLIC DATA DRIVER BEHAVIOUR AGAINST "MEAN" PERFORMANCE OF PUBLIC DATA RESULTS - SINGLE CARRIAGEWAY

FREE CAR

Curve No.	Curve Code	"Mean" Performance	(%)	"Constant" Performance	(%)	"Non-Mean" Performance	(%)
2	R	81	95	1	1	3	4
3	R	93	97	0	0	3	3
6	L	50	52	12	12	35	36
9	L	72	81	3	3	14	16
14	L	40	45	5	6	43	49
23	R	27	27	40	39	34	34
29	L	67	68	2	2	30	30
41	L	72	81	11	13	5	6
44	L	37	42	26	30	25	28
50	L	15	21	19	26	39	53
55	L	94	84	9	8	9	8

GOODS VEHICLES

Curve No.	Curve Code	"Mean" Performance	(%)	"Constant" Performance	(%)	"Non-Mean" Performance	(%)
6	L	12	60	0	0	8	40
8	R	23	96	0	0	1	4
12	R	9	41	2	9	11	50
14	L	18	64	1	4	9	32
21	L	13	45	6	21	10	34
22	R	8	30	8	30	11	40
23	R	6	24	15	60	4	16
24	L	7	32	8	36	7	32
25	L	10	42	7	29	7	29
38	R	18	60	3	10	9	30
45	L	6	20	8	27	16	53
50	L	5	16	14	42	14	42
52	R	13	42	10	32	8	26
54	R	22	67	9	27	2	6

L - Left-Hand Curves
R - Right-Hand Curves

TABLE 6.15: COMPARISON OF INDIVIDUAL PUBLIC DATA DRIVER BEHAVIOUR AGAINST "MEAN" PERFORMANCE OF PUBLIC DATA RESULTS - DUAL CARRIAGEWAYS

FREE CAR

Curve No.	Curve Code	"Mean" Performance	(%)	"Constant" Performance	(%)	"Non-Mean" Performance	(%)
4	R	109	71	19	12	15	17
6	R	74	50	22	15	53	35
12	L	108	94	3	2	4	4
13	R	119	83	18	13	7	6
14	L	104	80	7	5	19	15
15	R	64	51	21	16	41	33
17	L	69	88	6	8	3	4
19	L	47	47	20	21	32	32
21	R	49	64	7	10	20	26
22	R	65	66	19	19	15	15

GOODS VEHICLES

Curve No.	Curve Code	"Mean" Performance	(%)	"Constant" Performance	(%)	"Non-Mean" Performance	(%)
4	R	14	70	2	10	4	20
5	R	12	60	5	25	3	15
12	L	16	94	1	6	0	0
14	L	15	68	5	23	2	9
17	L	15	58	5	19	6	29
18	R	9	41	5	23	8	36
19	L	11	48	2	9	10	43
21	R	13	46	6	22	9	32

L - Left-Hand Curves
R - Right-Hand Curves

TABLE 6.16: RELATIONSHIPS BETWEEN ENTRY SPEED AND RADIUS - SINGLE CARRIAGEWAYS

CONDITION	RELATIONSHIPS		
	$Y=a\pm R^{-1}$ or $Y=aR^{b}$	Y=a (1-exp(-bR))	Y=a(1-exp(-b(R+5.06)))
ALL CARS			
Mean	Y=78.54-1163.78/R r^2=0.7970	Y=74.307(1-exp(-0.025xR)) r^2=0.75	Y=73.998(1-exp(-0.029(R+5.06))) r^2=0.72
85th Percentile	Y=88.50-1289.33/R r^2=0.7495	Y=83.88(1-exp(-0.025xR)) r^2=0.70	Y=83.533(1-exp(-0.029(R+5.06))) r^2=0.68
99th Percentile	$Y=34.44xR^{0.185}$ r^2=0.7612	Y=97.713(1-exp(-0.024xR)) r^2=0.66	Y=97.227(1-exp(-0.028(R+5.06))) r^2=0.63
FREE CARS			
Mean	Y=79.77-1213.28/R r^2=0.8158	Y=75.488(1-exp(-0.024xR)) r^2=0.77	Y=75.117(1-exp(-0.028(R+5.06))) r^2=0.74
85th Percentile	Y=89.89-1362.83/R r^2=0.7574	Y=85.088(1-exp(-0.024xR)) r^2=0.71	Y=84.669(1-exp(-0.028(R+5.06))) r^2 =0.69
99th Percentile	$Y=34.20xR^{0.187}$ r^2=0.7675	Y=98.614(1-exp(-0.023xR)) r^2=0.66	Y=98.037(1-exp(-0.027(R+5.06))) r^2=0.63
GOODS VEHICLES			
Mean	Y=69.32-1077.09/R r^2=0.4770	Y=65.786(1-exp(-0.023xR)) r^2=0.56	Y=65.75(1-exp(-0.026(R+10.0))) r^2=0.55
85th Percentile	Y=76.76-1245.73/R r^2=0.4971	Y=72.752(1-exp(-0.022xR)) r^2=0.57	Y=72.569(1-exp(-0.026(R+10.0))) r^2=0.56
99th Percentile	Y=85.08-1359.94/R r^2=0.3856	Y=80.717(1-exp(-0.022xR)) r^2=0.41	Y=80.40(1-exp(-0.027(R+10.0))) r^2=0.39

TABLE 6.17: RELATIONSHIPS BETWEEN ENTRY SPEED AND RADIUS - DUAL CARRIAGEWAYS

CONDITION	RELATIONSHIPS		
	$Y=a\pm bx^{-1}$	Y=a(1-exp(-bR))	Y=a(1-exp(-b(R+5.06)))
ALL CARS			
Mean	Y=91.09-2316.73/R $r^2=0.5160$	Y=84.863(1-exp(-0.015xR)) $r^2=0.49$	Y=84.632(1-exp(-0.016(R+5.06))) $r^2=0.49$
85th Percentile	Y=102.34-2621.57/R $r^2=0.5192$	Y=95.267(1-exp(-0.015xR)) $r^2=0.49$	Y=95.007(1-exp(-0.016(R+5.06))) $r^2=0.48$
99th Percentile	$Y=45.90xR^{0.147}$ $r^2=0.4848$	Y=108.73(1-exp(-0.016xR)) $r^2=0.44$	Y=108.51(1-exp(-0.017(R+5.06))) $r^2=0.43$
FREE CARS			
Mean	Y=92.06-2319.21/R $r^2=0.5280$	Y=85.863(1-exp(-0.015xR)) $r^2=0.50$	Y=85.628(1-exp(-0.016(R+5.06))) $r^2=0.49$
85th Percentile	Y=103.16-2622.65/R $r^2=0.5437$	Y=96.11(1-exp(-0.015xR)) $r^2=0.51$	Y=95.848(1-exp(-0.016(R+5.06))) $r^2=0.50$
99th Percentile	$Y=48.21xR^{0.139}$ $r^2=0.4550$	Y=108.64(-0.017xR)) $r^2=0.41$	Y=108.48(1-exp(-0.018(R+5.06))) $r^2=0.40$
GOODS VEHICLES			
Mean	Y=76.81-2035.05/R $r^2=0.5374$	Y=70.543(1-exp(-0.016xR)) $r^2=0.54$	Y=70.036(1-exp(-0.019(R+10.0))) $r^2=0.54$
85th Percentile	Y=85.35-2387.47/R $r^2=0.6424$	Y=78.281(1-exp(-0.015xR)) $r^2=0.63$	Y=77.552(1-exp(-0.018(R+10.0))) $r^2=0.62$
99th Percentile	Y=94.37-2772.97/R $r^2=0.5813$	Y=86.58(1.-exp(-0.014xR)) $r^2=0.59$	Y=85.542(1-exp(-0.017(R+10.0))) $r^2=0.59$

TABLE 6.18: RELATIONSHIPS BETWEEN MIDDLE SPEED AND RADIUS - SINGLE CARRIAGEWAYS

CONDITION	RELATIONSHIPS		
	$Y=a\pm bx^{-1}$	$Y=a(1-\exp(-bR))$	$Y=a(1-\exp(-b(R+5.06)))$
ALL CARS			
Mean	$V=76.00-1387.20R^{-1}$ $r^2=0.85$	$Y=71.87(1-\exp(-0.019xR))$ $r^2=0.84$	$Y=71.60(1-\exp(-0.021(R+5.06)))$ $r^2=0.82$
85th Percentile	$V=85.40-1558.30R^{-1}$ $r^2=0.81$	$Y=80.76(1-\exp(-0.019xR))$ $r^2=0.80$	$Y=80.45(1-\exp(-0.021(R+5.06)))$ $r^2=0.78$
99th Percentile	$V=23.58xR^{0.241}$ $r^2=0.82$	$Y=94.07(1-\exp(-).017xR))$ $r^2=0.76$	$Y=92.62(1-\exp(-0.021(R+5.06)))$ $r^2=0.73$
FREE CARS			
Mean	$V=77.16-1417.02R^{-1}$ $r^2=0.85$	$Y=73.31(1-\exp(-0.018xR))$ $r^2=0.85$	$Y=72.64(1-\exp(-0.021(R+5.06)))$ $r^2=0.82$
85th Percentile	$V=86.78-1583.10R^{-1}$ $r^2=o.78$	$Y=82.07(1-\exp(-0.019xR))$ $r^2=0.77$	$Y=81.76(1-\exp(-0.021(R+5.06)))$ $r^2=0.75$
99th Percentile	$V=23.79xR^{0.241}$ $r^2=0.82$	$Y=94.50(1-\exp(-0.017xR))$ $r^2=0.76$	$Y=93.46(1-\exp(-0.020(R+5.06)))$ $r^2=0.73$
GOODS VEHICLES			
Mean	$V=67.27-1339.47R^{-1}$ $r^2=0.61$	$Y=63.14(1-\exp(-0.019xR))$ c $r^2=0.64$	$Y=62.944)1-\exp(-0.022(R+10.0)))$ $r^2=0.64$
85th Percentile	$V=75.49-1561.76R^{-1}$ $r^2=0.60$	$Y=70.844(1-\exp(-0.018xR))$c $r^2=0.62$	$Y=70.55(1-\exp(-0.021(R+10.0)))$ $r^2=0.61$
99th Percentile	$V=82.68-1736.49R^{-1}$ $r^2=0.51$	$Y=77.47(1-\exp(-0.018xR))$ c $r^2=0.53$	$Y=77.149(1-\exp(-0.021(R+10.0)))$ $r^2=0.52$

TABLE 6.19: RELATIONSHIPS BETWEEN MIDDLE SPEED AND RADIUS - DUAL CARRIAGEWAYS

CONDITION	RELATIONSHIPS		
	$Y=a\pm bx^{-1}$	$Y=a(1-\exp(-bR))$	$Y=a(1-\exp(-b(R+5.06)))$
ALL CARS			
Mean	$V=89.53-301.78R^{-1}$ $r^2=0.66$	$Y=82.36(1-\exp(-0.012xR))$ $r^2=0.65$	$Y=82.67(1-\exp(-0.012(R+5.06)))$ $r^2=0.65$
85th Percentile	$V=100.73-3378.17R^{-1}$ $r^2=0.66$	$Y=93.89(1-\exp(-0.011xR))$ $r^2=0.65$	$Y=93.08(1-\exp(-0.012(R+5.06)))$ $r^2=0.64$
99th Percentile	$V=115.86-3994.94R^{-1}$ $r^2=0.65$	$Y=107.54(1-\exp(-0.011xR))$ $r^2=0.65$	$Y=106.61(1-\exp(-0.012(R+5.06)))$ $r^2=0.65$
FREE CARS			
Mean	$V=90.49-3018.57R^{-1}$ $r^2=).66$	$Y=83.38(1-\exp(-0.012xR))$ $r^2=0.66$	$Y=83.69(1-\exp(-0.012(R+5.06)))$ $r^2=0.65$
85th Percentile	$V=101.58-3440.61R^{-1}$ $r^2=0.69$	$Y=94.54(1-\exp(-0.011xR))$ $r^2=0.68$	$Y=93.72(1-\exp(-0.012(R+5.06)))$ $r^2=0.68$
99th Percentile	$V=116.28-4008.77R^{-1}$ $r^2=0.65$	$Y=107.94(1-\exp(-0.011xR))$ $r^2=0.65$	$Y=107.01(1-\exp(-0.012(R+5.06)))$ $r^2=0.65$
GOODS VEHICLES			
Mean	$V=71.13-1885.43R^{-1}$ $r^2=0.46$	$Y=65.32(1-\exp(-0.016xR))$ $r^2=0.47$	$Y=64.856(1-\exp(-0.019(R+10.0)))$ $r^2=0.47$
85th Percentile	$V=79.43-2198.89R^{-1}$ $r^2=0.53$	$Y=72.51\ (1-\exp(-0.016xR))$ $r^2=0.52$	$Y=72.266(1-\exp(-0.018(R+10.0)))$ $r^2=0.52$
99th Percentile	$V=87.46-2469.98R^{-1}$ $r^2=0.57$	$Y=80.108(1-\exp(-0.015xR))$ $r^2=0.57$	$Y=79.364(1-\exp(-0.018(R+10.0)))$ $r^2=0.57$

TABLE 6.20 : RESULTS OF COMPARISON TESTS BETWEEN EXPLANATORY REGRESSION MODELS (x^2-Test)

ENTRY SPEEDS

DESCRIPTION		x^2 - VALUES Regression Relationships			
		A	B	C	D
ALL SITES					
All Cars	- Single Carriageway	10.29	10.61	72.08*	69.10*
All Cars	- Dual Carriageway	1.51	3.02	2.10	3.67
Goods Vehicles	- Single Carriageway	6.85	8.25	7.02	7.82
Goods Vehicles	- Dual Carriageway	0.40	1.65	0.43	1.80
SELECTED SITES					
All Cars	- Single Carriageway	10.02	10.38	75.47*	80.95*
All Cars	- Dual Carriageway	2.67	5.73	3.44	5.38
Goods Vehicles	- Single Carriageway	8.93	11.78	13.53	12.06
Goods Vehicles	- Dual Carriageway	0.51	1.24	1.22	2.13

MIDDLE SPEEDS

DESCRIPTION		x^2 - Value Regression Relationships			
		A	B	C	D
ALL SITES					
All Cars	- Single Carriageway	14.91	15.65	52.00*	44.92*
All Cars	- Dual Carriageway	3.62	6.53	3.24	5.11
Goods Vehicles	- Single Carriageway	7.53	7.90	6.73	6.94
Goods Vehicles	- Dual Carriageway	1.44	2.10	1.43	2.22
SELECTED SITES					
All Cars	- Single Carriageway	17.43	64.60*	53.67*	55.62*
All Cars	- Dual Carriageway	4.20	11.57	5.85	9.31
Goods Vehicles	- Single Carriageway	9.26	10.25	35.49*	11.14
Goods Vehicles	- Dual Carriageway	1.75	2.03	3.60	2.35

*Not statistically significant at a 5 per cent level of significance

A - Linear Regression (Single or Dual Carriageways)

B - Linear Regression (Single and Dual Carriageways)

C - Curvilinear Regression (Single or Dual Carriageways)

D - Curvilinear Regression (Single and Dual Carriageways)

TABLE 6.21: CURVE ENTRY SPEED PREDICTION MODELS

SINGLE CARRIAGEWAYS (All Cars)

AS < 85.0 k.p.h.	$V_{CE}(85) = 82.74-0.59C$	$(r^2 = .84, s = 3.76)$
AS > 85.0 k.p.h.	$V_{CE}(85) = 91.44-0.782C$	$(r^2 = .76, s = 4.36)$

SINGLE CARRIAGEWAYS (Goods Vehicles)

AS < 75.0 k.p.h.	$V_{GE}(85) = 74.31-0.66C$	$(r^2 = .31, s = 4.39)$
AS > 75.0 k.p.h.	$V_{GE}(85) = 78.93-0.74C$	$(r^2 = .69, s = 4.38)$

DUAL CARRIAGEWAYS (All Cars)

AS < 95.0 k.p.h.	$V_{CE}(85) = 95.62-1.15C$	$(r^2 = .71, s = 4.55)$
AS > 95.0 k.p.h.	$V_{CE}(85) = 107.87-1.80C$	$(r^2 = .39, s = 5.75)$

SINGLE AND DUAL CARRIAGEWAYS (All Cars)

AS < 85.0 k.p.h.	$V_{CE}(85) = 82.70-0.59C$	$(r^2 = .84, s = 3.68)$
AS > 85.0 k.p.h.	$V_{CE}(85) = 94.92-0.90C$	$(r^2 = .60, s = 6.12)$

SINGLE AND DUAL CARRIAGEWAYS (Goods Vehicles)

AS < 75.0 k.p.h.	$V_{GE}(85) = 75.58-0.85C$	$(r^2 = .58, s = 4.04)$
AS > 75.0 k.p.h.	$V_{GE}(85) = 80.98-0.80C$	$(r^2 = .59, s = 4.78)$

TABLE 6.22: CURVE MIDDLE SPEED PREDICTION MODELS

SINGLE CARRIAGEWAYS (All Cars)

AS < 85.0 k.p.h.	$V_{CM}(85) = 80.40-0.80C$	($r^2 = .90$, $s = 3.94$)
AS > 85.0 k.p.h.	$V_{CM}(85) = 87.61-0.85C$	($r^2 = .77$, $s = 4.64$)

SINGLE CARRIAGEWAYS (Goods Vehicles)

AS < 75.0 k.p.h.	$V_{GM}(85) = 71.03-0.67C$	($r^2 = .52$, $s = 2.92$)
AS > 75.0 k.p.h.	$V_{GM}(85) = 78.72-0.97C$	($r^2 = .76$, $s = 4.82$)

DUAL CARRIAGEWAYS (All Cars)

AS < 95.0 k.p.h.	$V_{CM}(85) = 94.16-1.58C$	($r^2 = .85$, $s = 4.05$)
AS > 95.0 k.p.h.	$V_{CM}(85) = 106.85-2.31C$	($r^2 = .51$, $s = 5.87$)

SINGLE AND DUAL CARRIAGEWAYS (All Cars)

AS < 85.0 k.p.h.	$V_{CM}(85) = 80.48-0.80C$	($r^2 = .90$, $s = 3.87$)
AS > 85.0 k.p.h.	$V_{CM}(85) = 91.22-1.01C$	($r^2 = .63$, $s = 6.50$)

SINGLE AND DUAL CARRIAGEWAYS (Goods Vehicles)

AS < 75.0 k.p.h.	$V_{GM}(85) = 71.62-0.83C$	($r^2 = .69$, $s = 3.07$)
AS > 75.0 k.p.h.	$V_{GM}(85) = 79.39-0.99C$	($r^2 = .69$, $s = 4.71$)

TABLE 6.23: CORRELATION COEFFICIENTS FOR LINEAR RELATIONSHIPS BETWEEN LATERAL PLACEMENT DATA AT DIFFERENT LOCATIONS WITHIN A CURVE

SITE CODE	CORRELATION COEFFICIENT (r)				
	ENL1 vs ENL2	ENL2 vs ML1	ML1 vs ML2	ML2 vs EXL1	EXL1 vs EXL2
SINGLE CARRIAGEWAYS					
1 - L	.60	.30	.60	.02	.60
2 - R	.67	.42	.69	.58	.69
5 - R	.73	.43	.92	.38	.84
6 - L	.85	.24	.74	.24	.61
7 - L	.54	.74	.14	.78	.58
8 - R	.17	.55	.19	.89	.46
12 - R	.57	.19	.65	.51	.65
17 - L	.85	.33	.70	.41	.75
18 - R	.63	.25	.66	.10	.74
29 - L	.80	.20	.63	.16	.71
30 - R	.78	.33	.78	.27	.67
43 - R	.81	.55	.74	.33	.57
44 - L	.65	.18	.47	.24	.64
DUAL CARRIAGEWAYS					
4 - R	.94	.80	.97	.80	.97
10 - R	.99	.82	.97	.88	.98
12 - R	.92	.33	.69	.46	.85
14 - L	.93	.75	.94	.87	.94
22 - R	.97	.82	.98	.92	.97

L - Left-hand curves

R - Right-hand curves

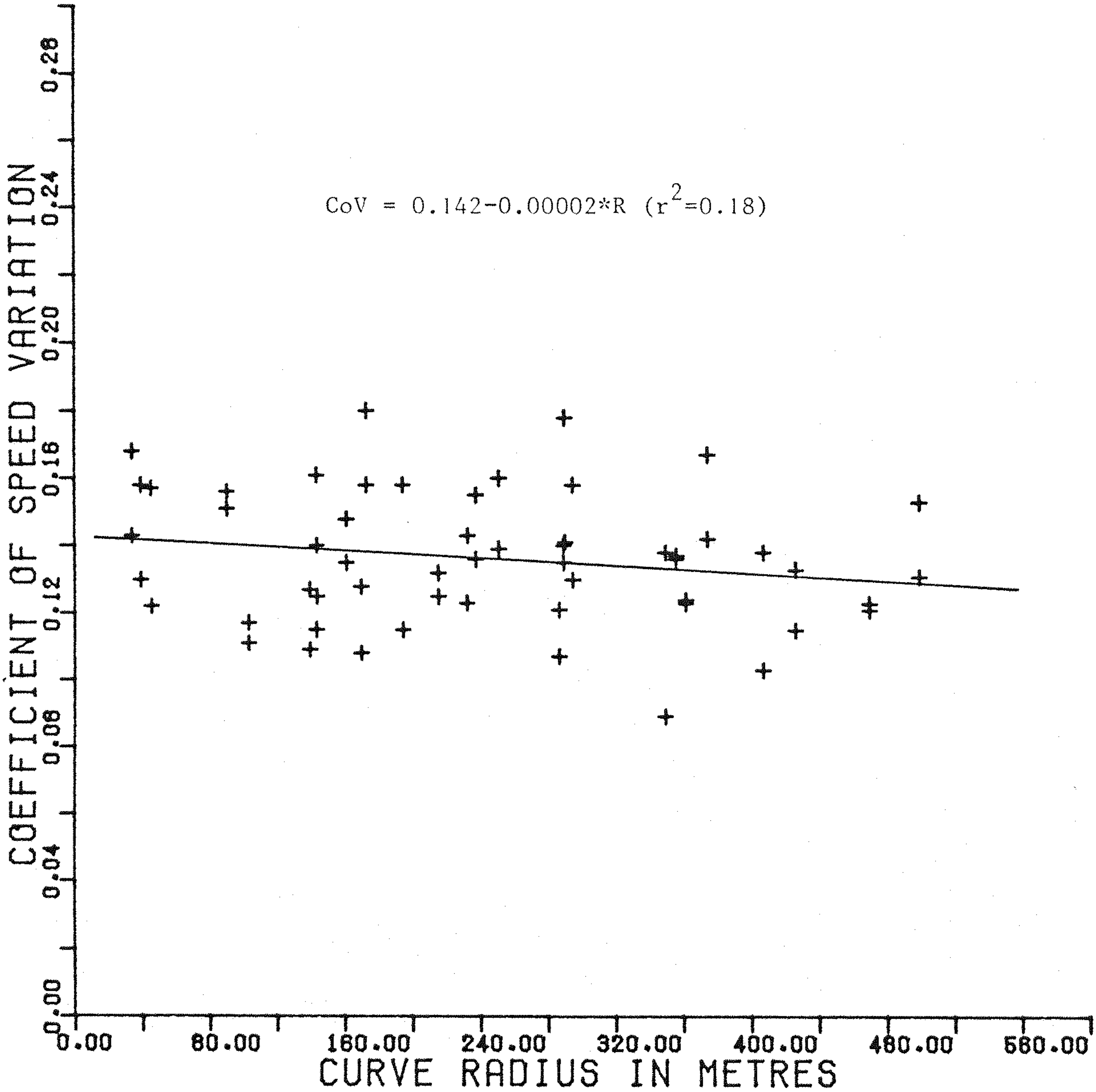


Figure 6.1(a):Relationship between Coefficient of Approach Speed Variation and Curve Radius
(Single Carriageways - Free Cars)

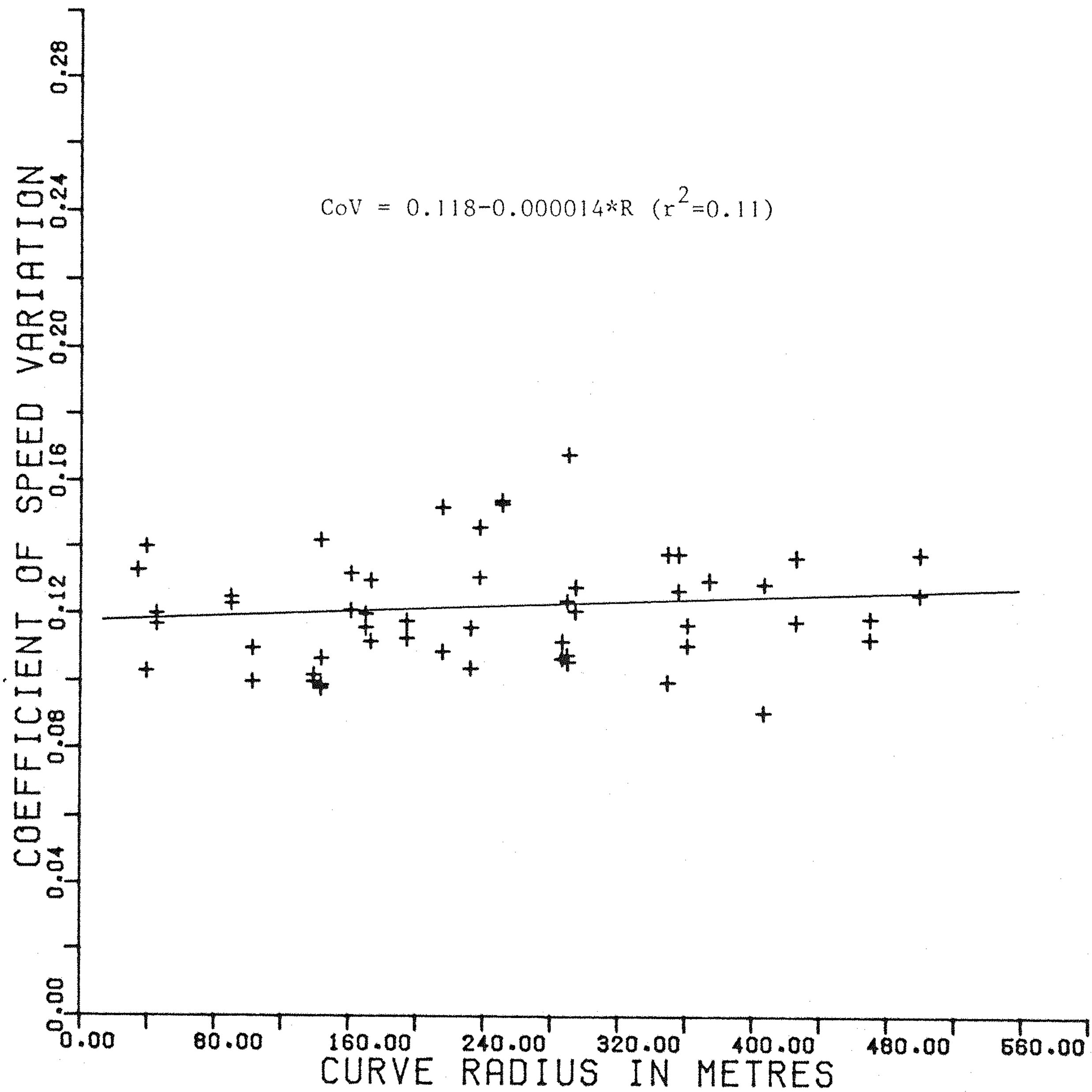


Figure 6.1(b): Relationship between Coefficient of Middle Speed Variation and Curve Radius
(Single Carriageways - Free Cars)

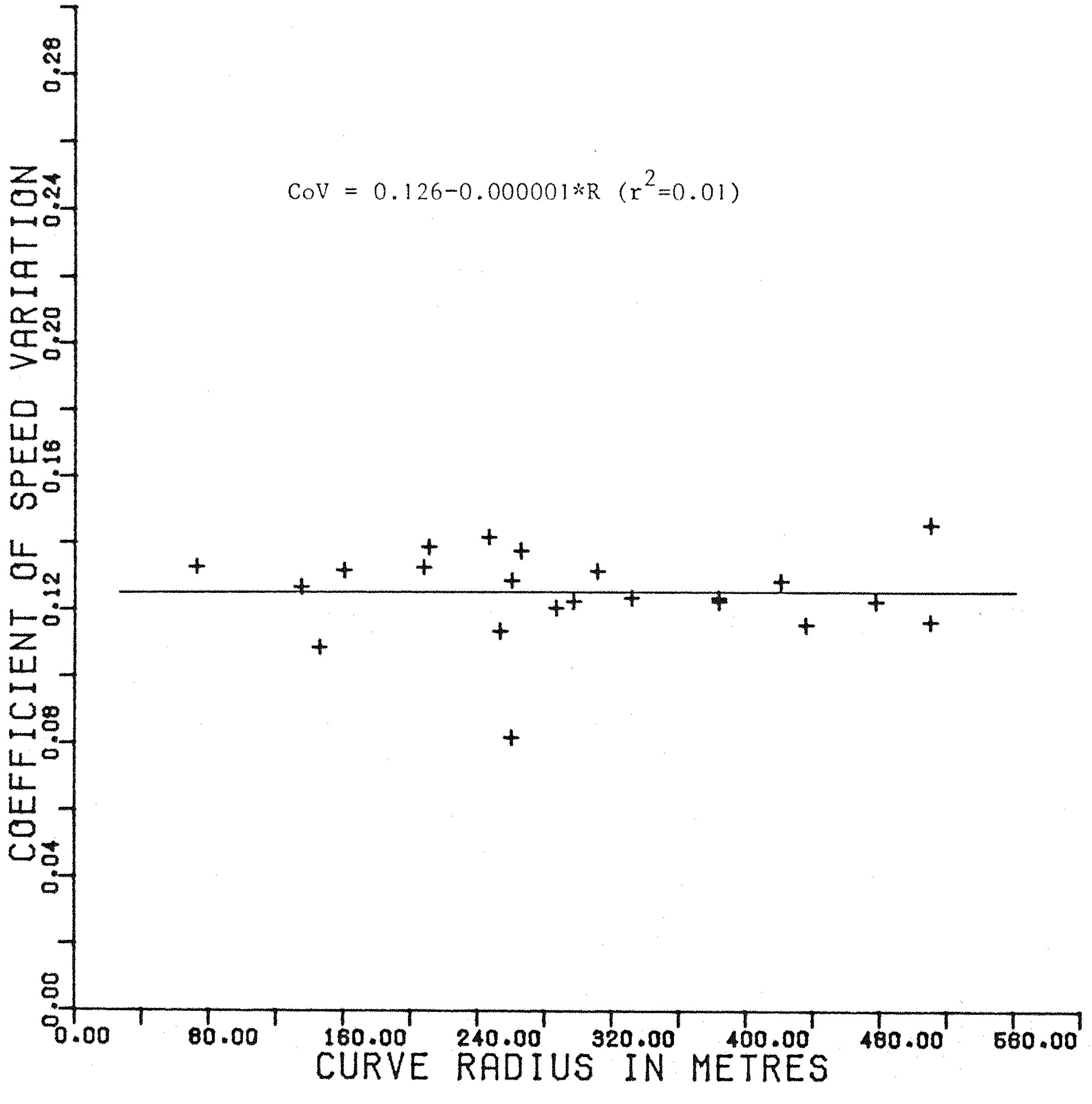


Figure 6.2(a): Relationship between Coefficient of Approach Speed Variation and Curve Radius
(Dual Carriageways - Free Cars)

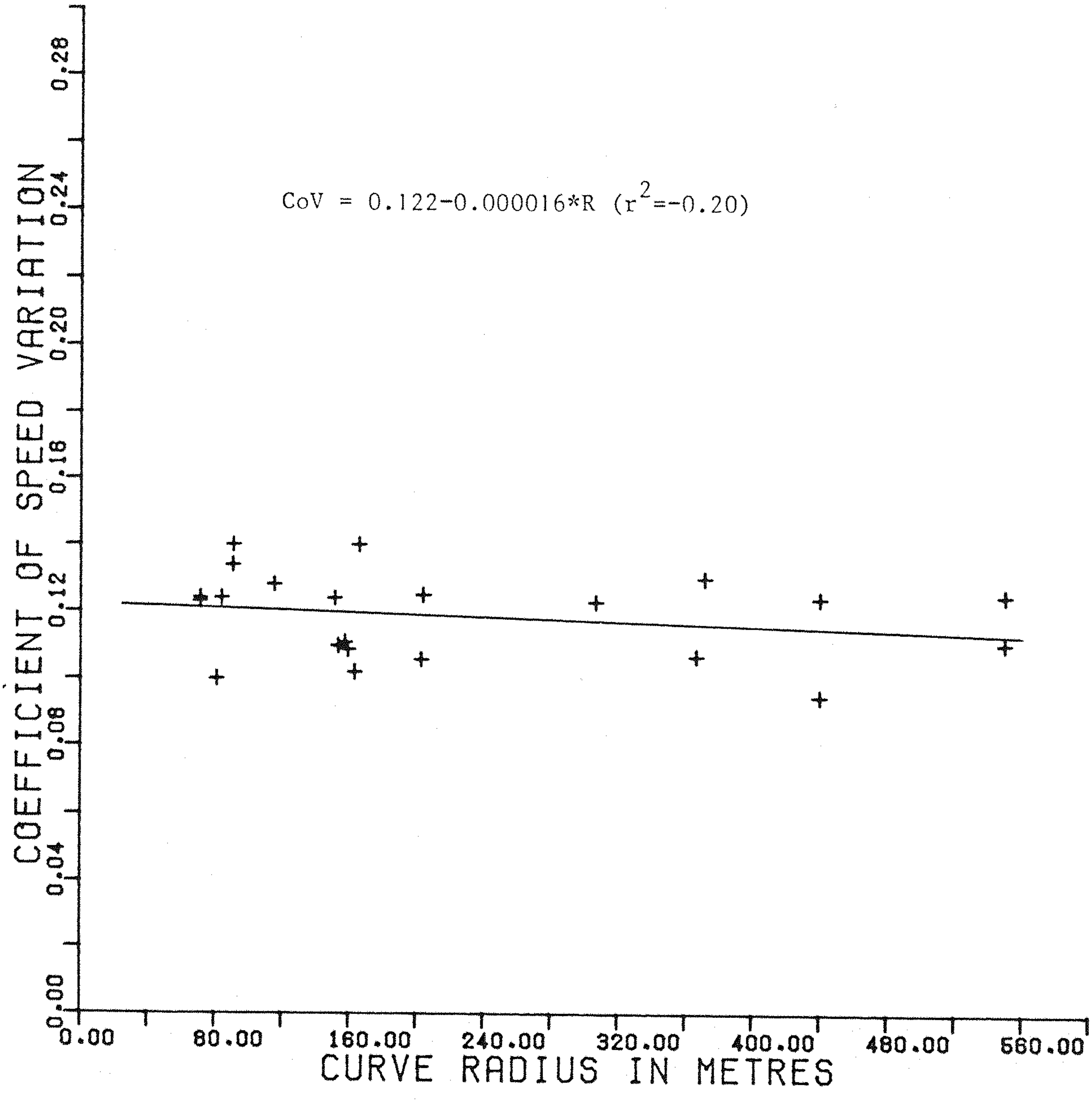


Figure 6.2(b): Relationship between Coefficient of Middle Speed Variation and Curve Radius
(Dual Carriageways - Free Cars)

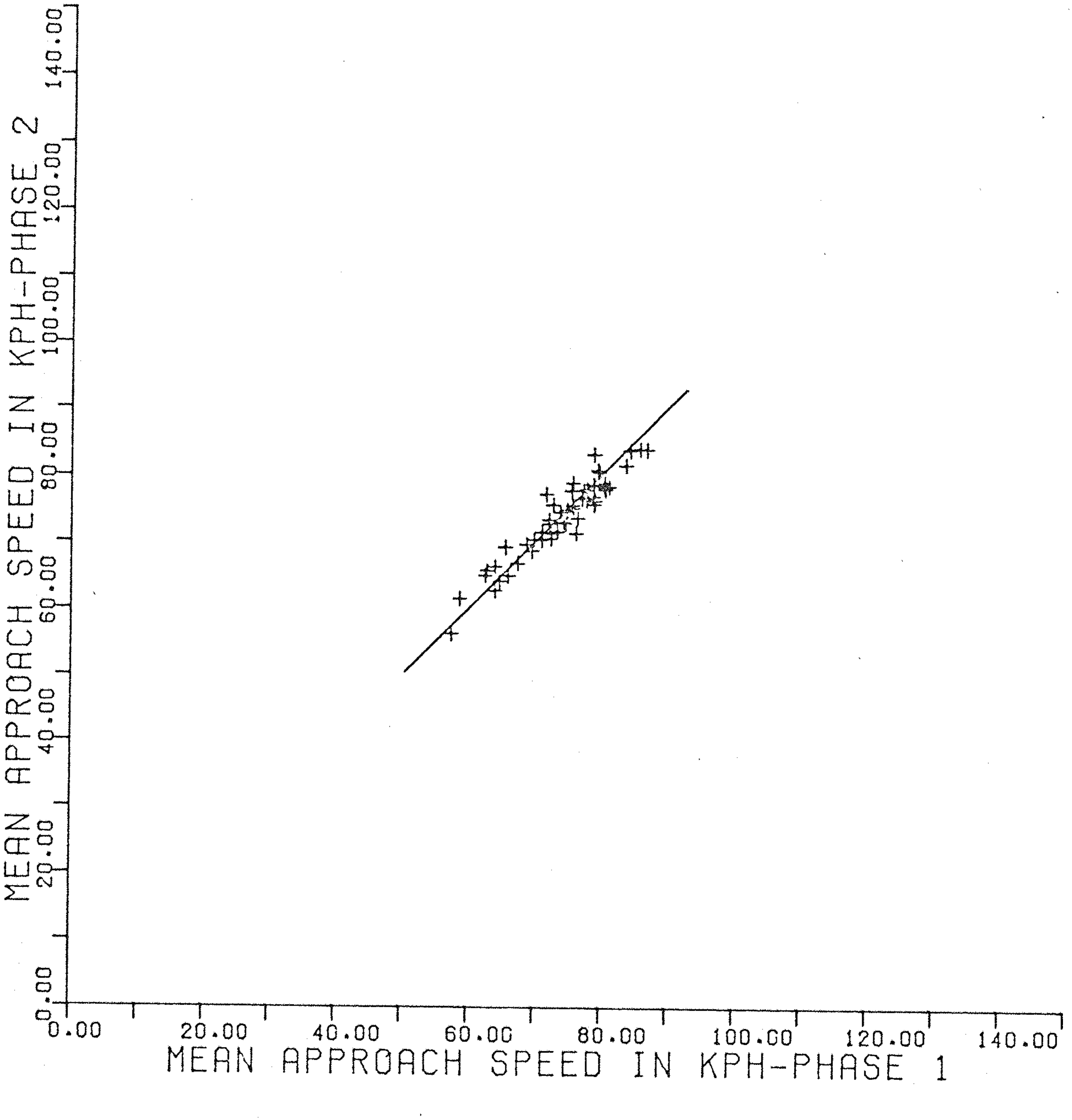


Figure 6.3(a):Relationship between Approach Speeds for Phase 1 and 2
(Single Carriageways - All Cars)

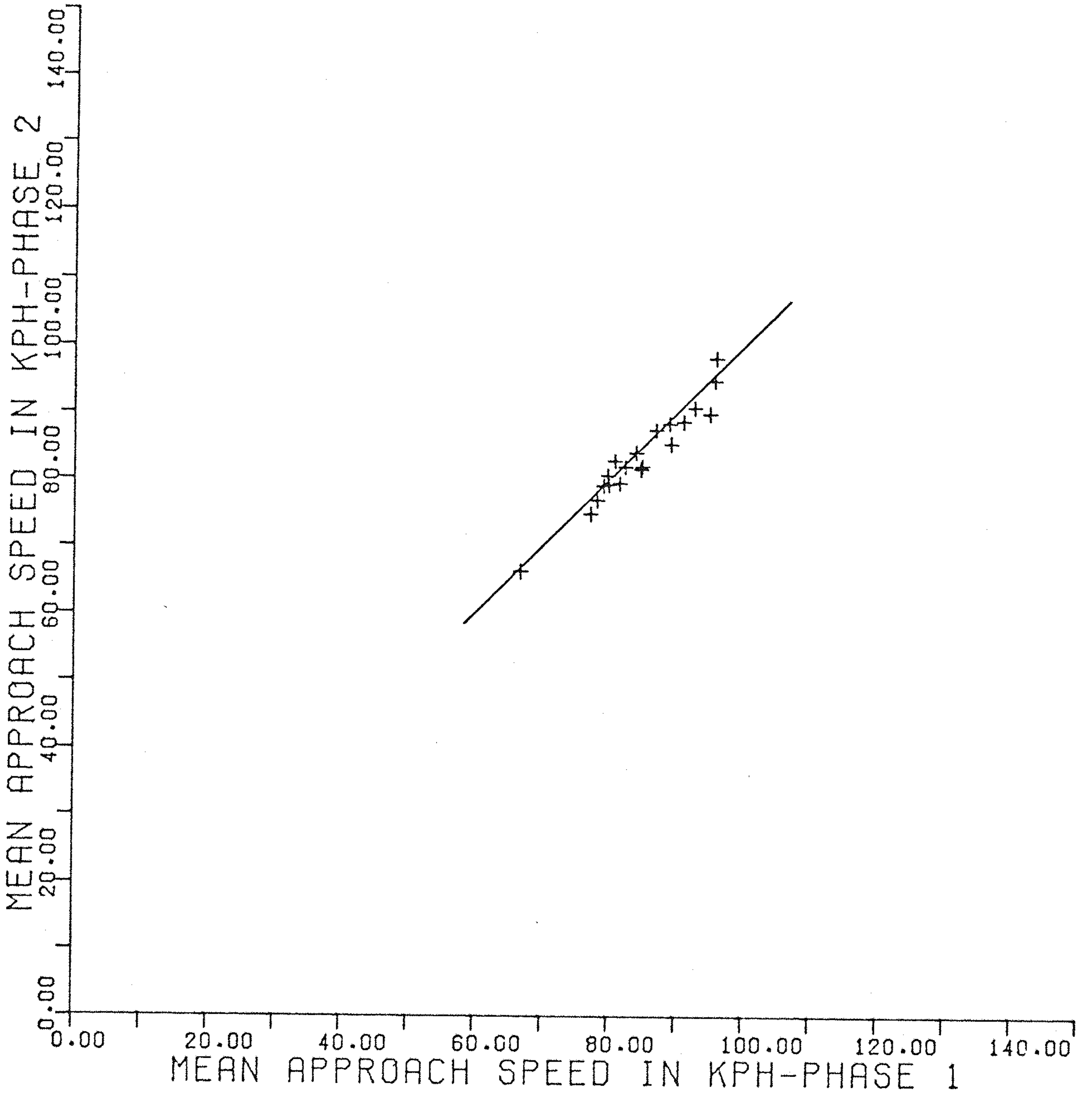


Figure 6.3(b): Relationship between Approach Speeds for Phase I and 2
(Dual Carriageways - All Cars)

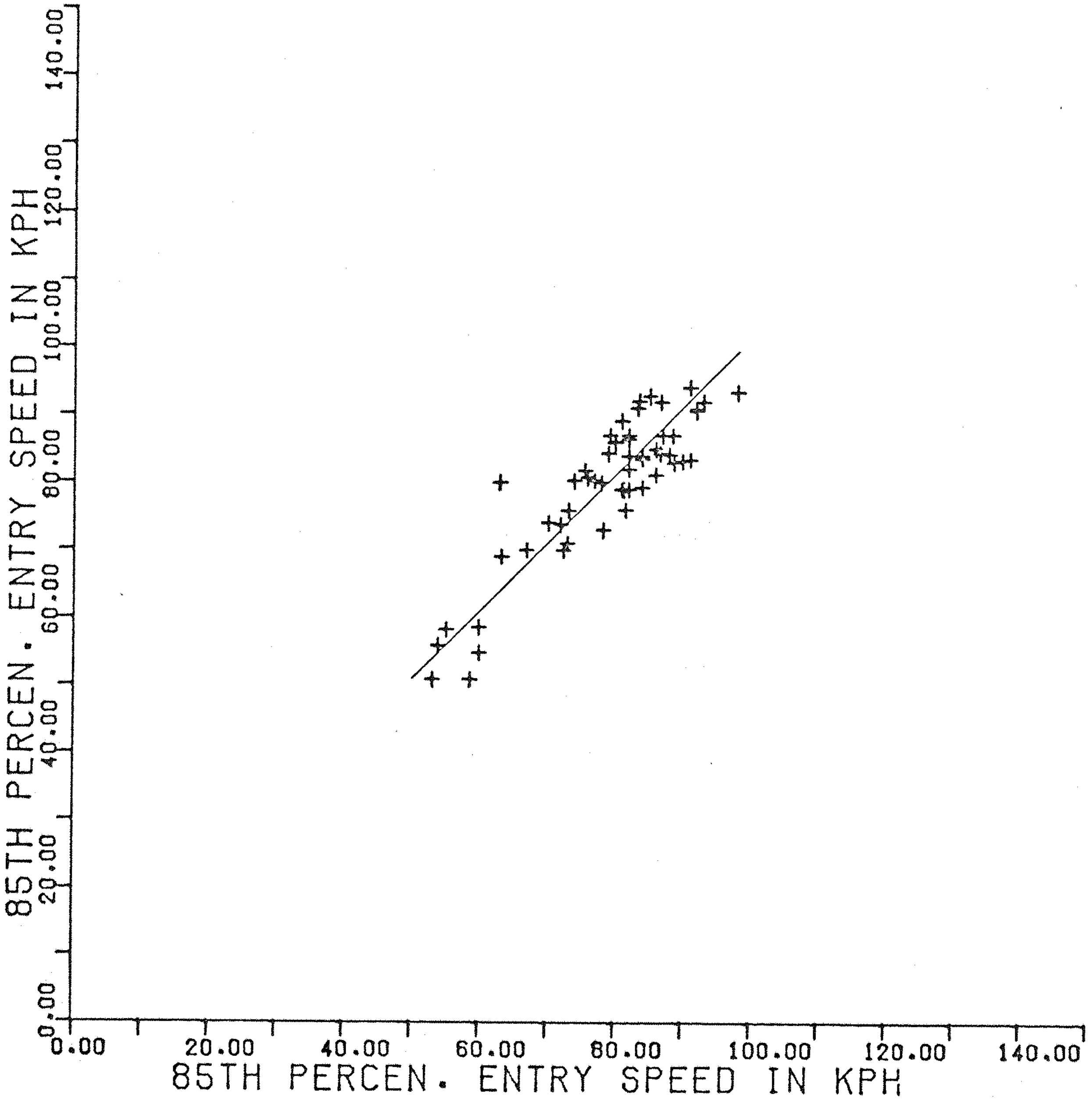


Figure 6.4(a): Relationship between Entry Speeds for Phase 1 and 2
(Single Carriageways - All Cars)

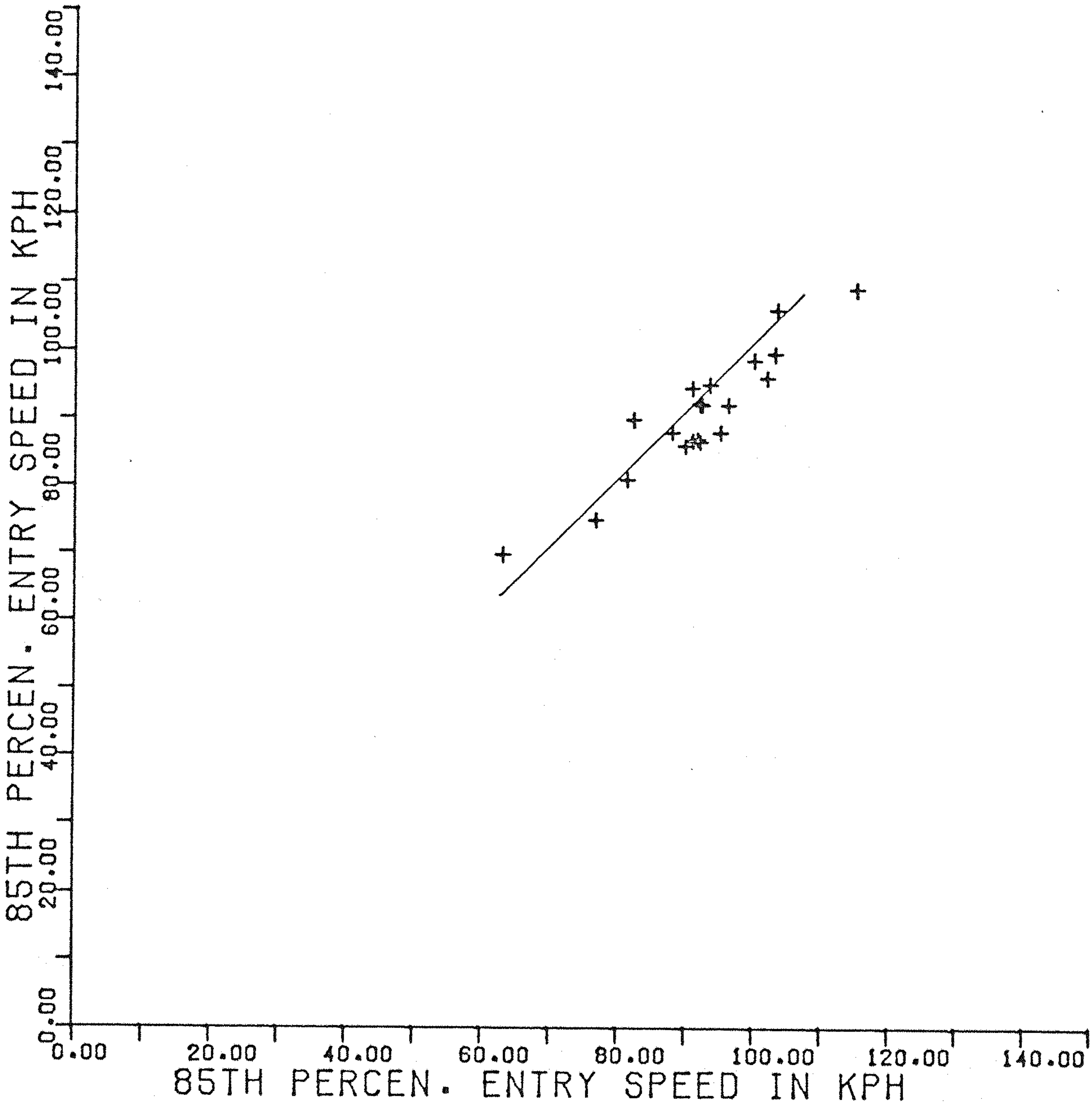


Figure 6.4(b): Relationship between Entry Speeds for Phase 1 and 2
(Dual Carriageways - All Cars)

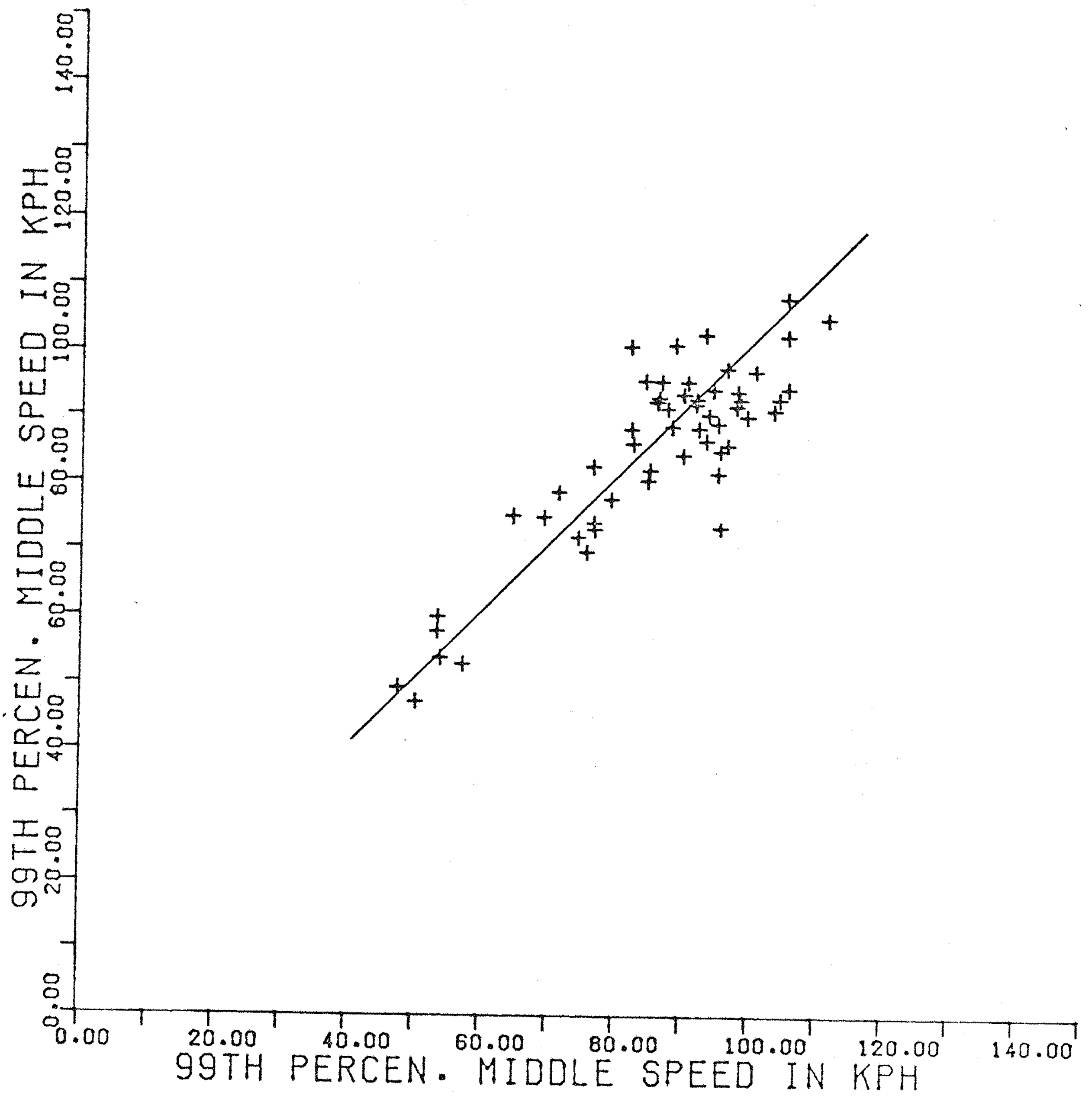


Figure 6.5(a): Relationship between Middle Speeds for Phase 1 and 2
(Single Carriageways - All Cars)

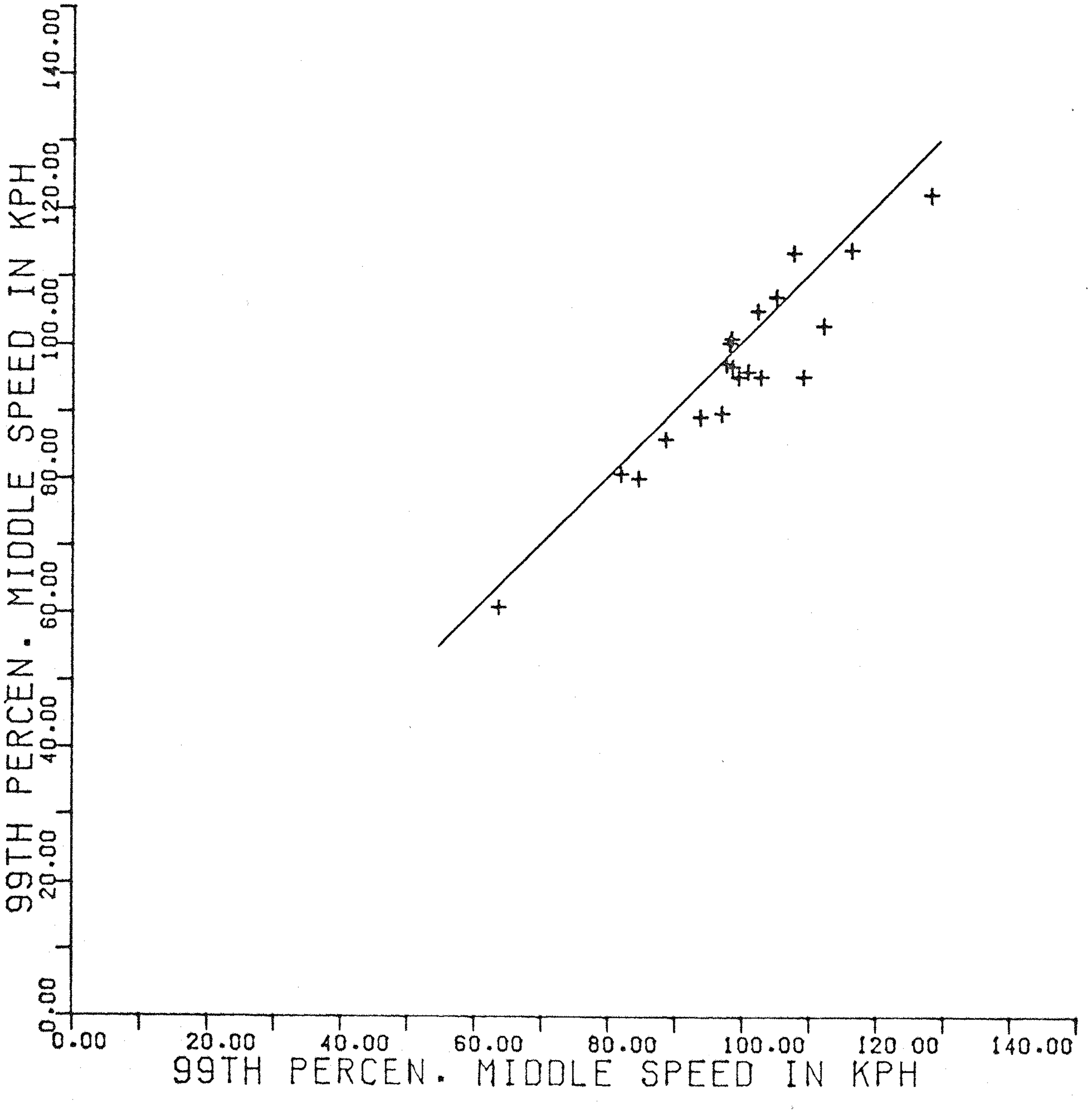


Figure 6.5(b): Relationhsip between Middle Speeds for Phase 1 and 2

(Dual Carriageways - All Cars)

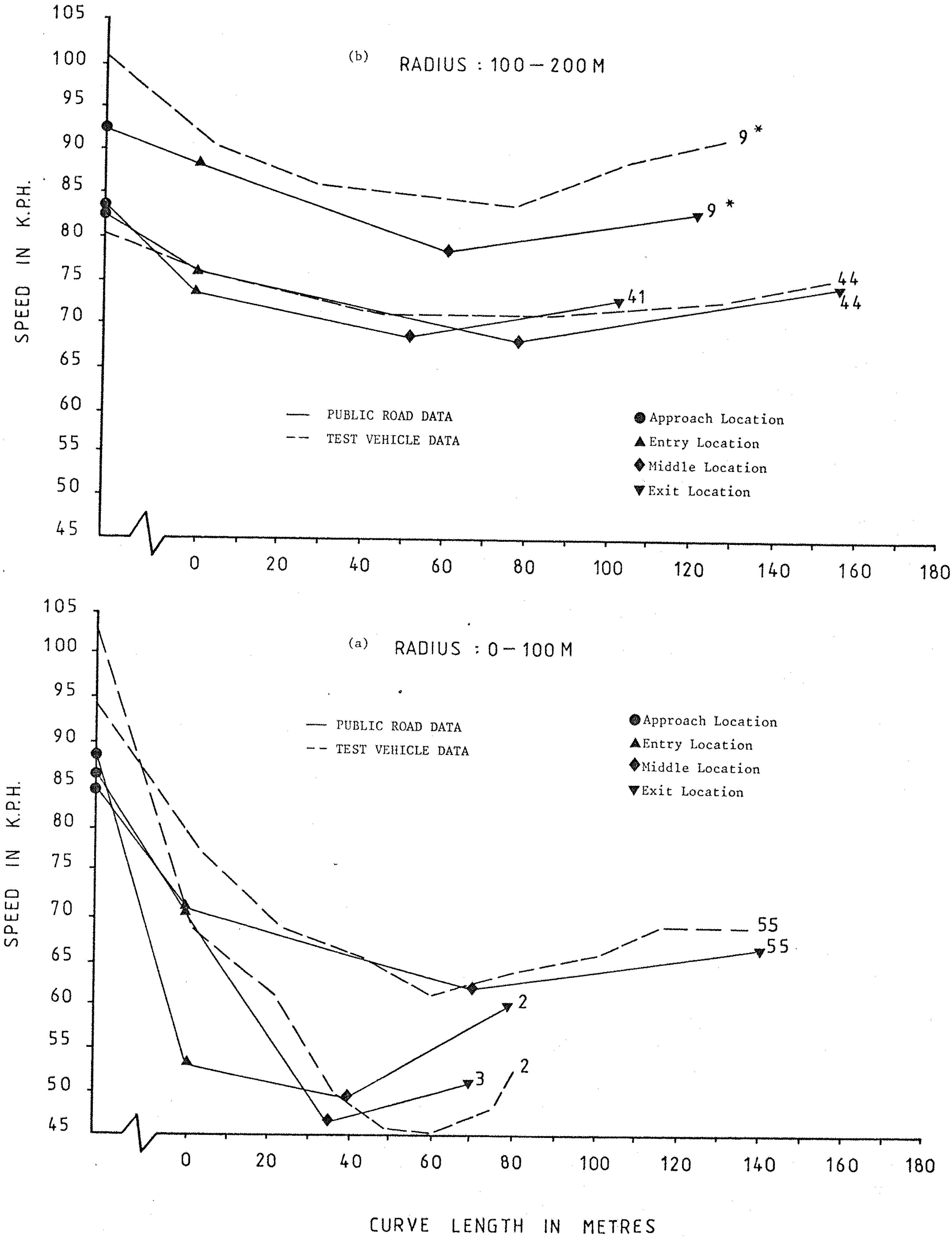
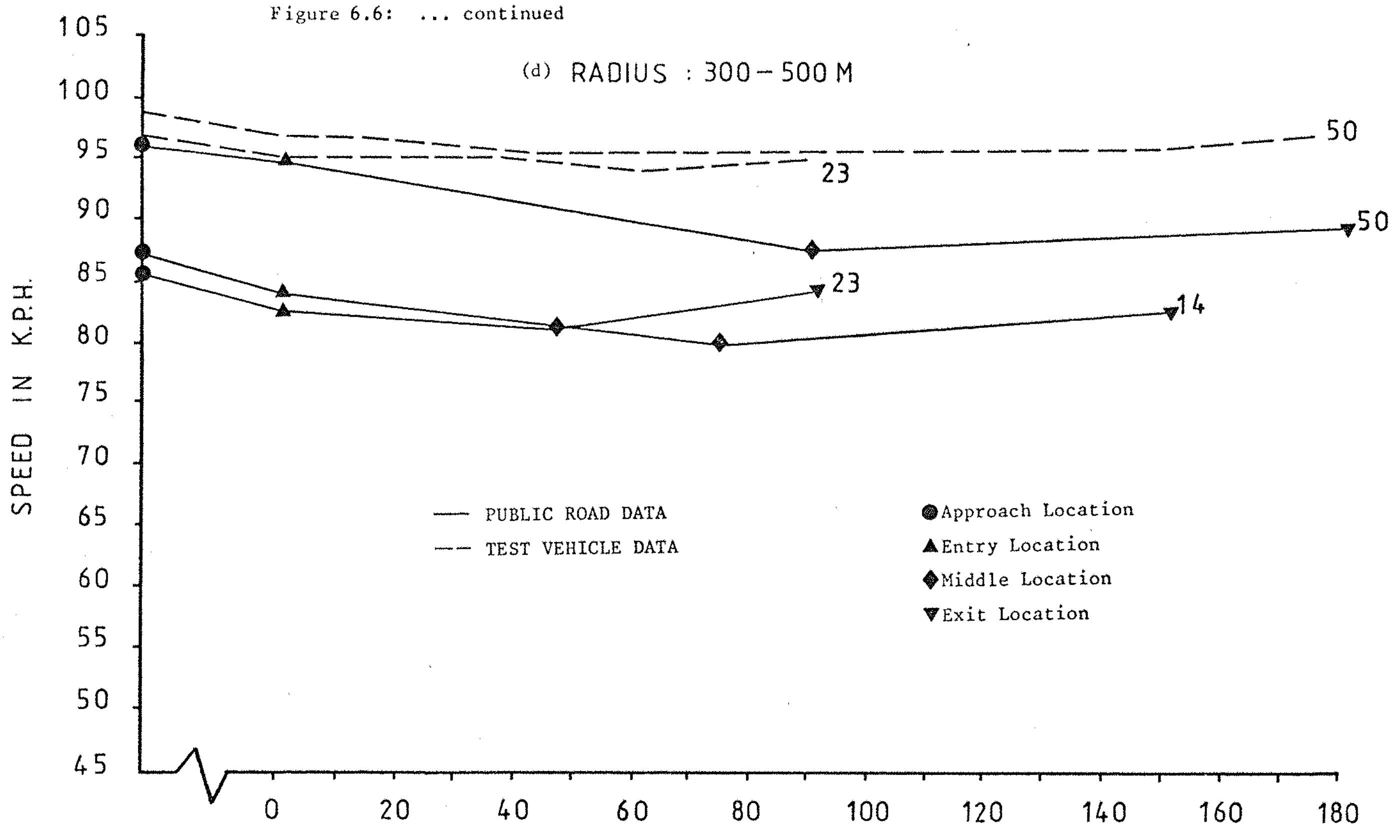
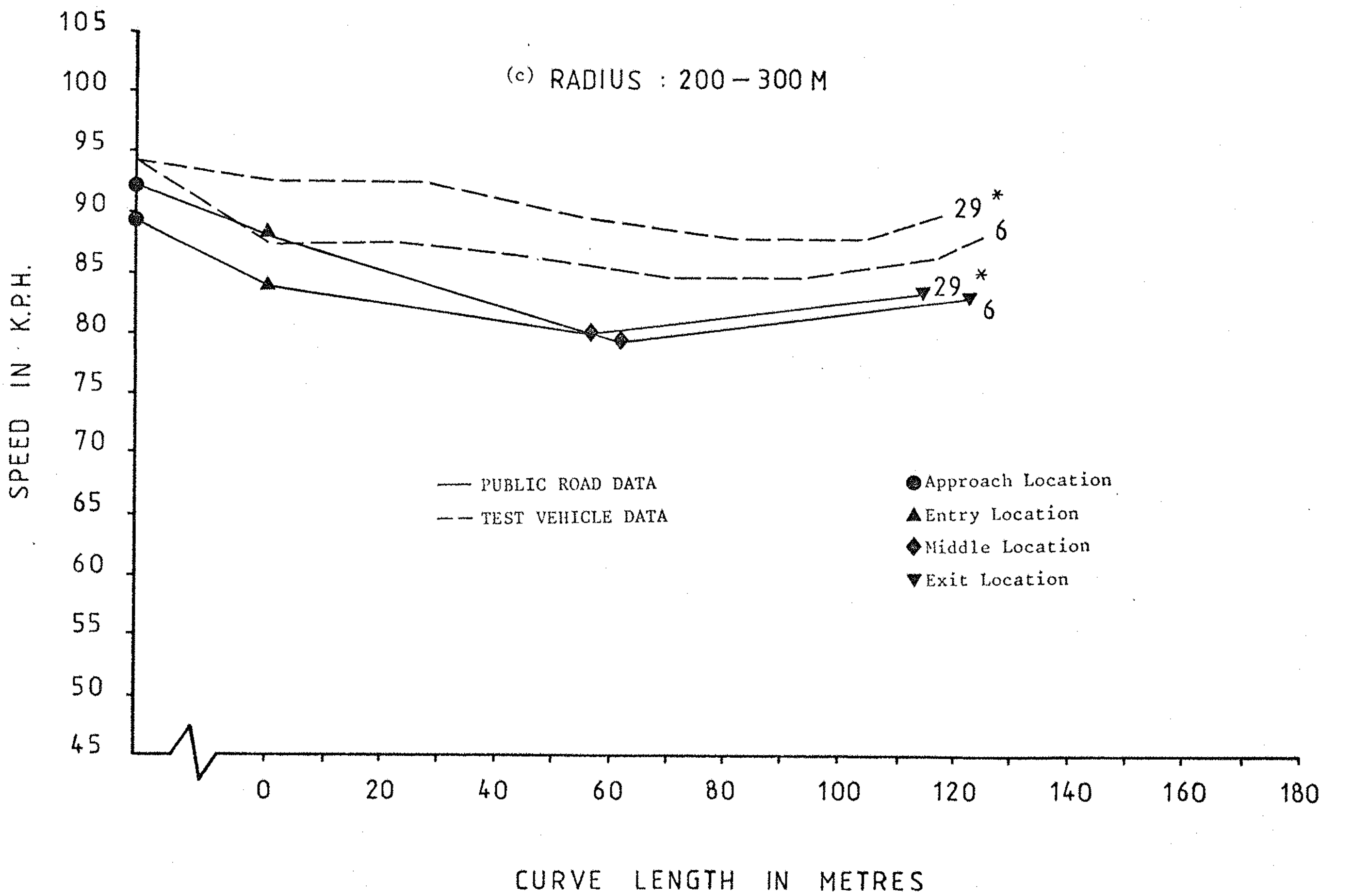


Figure 6.6: Speed/Distance Profiles for Public Road Drivers and Test Vehicle Driver (Single Carriageways - Free Cars)

... continued

Figure 6.6: ... continued





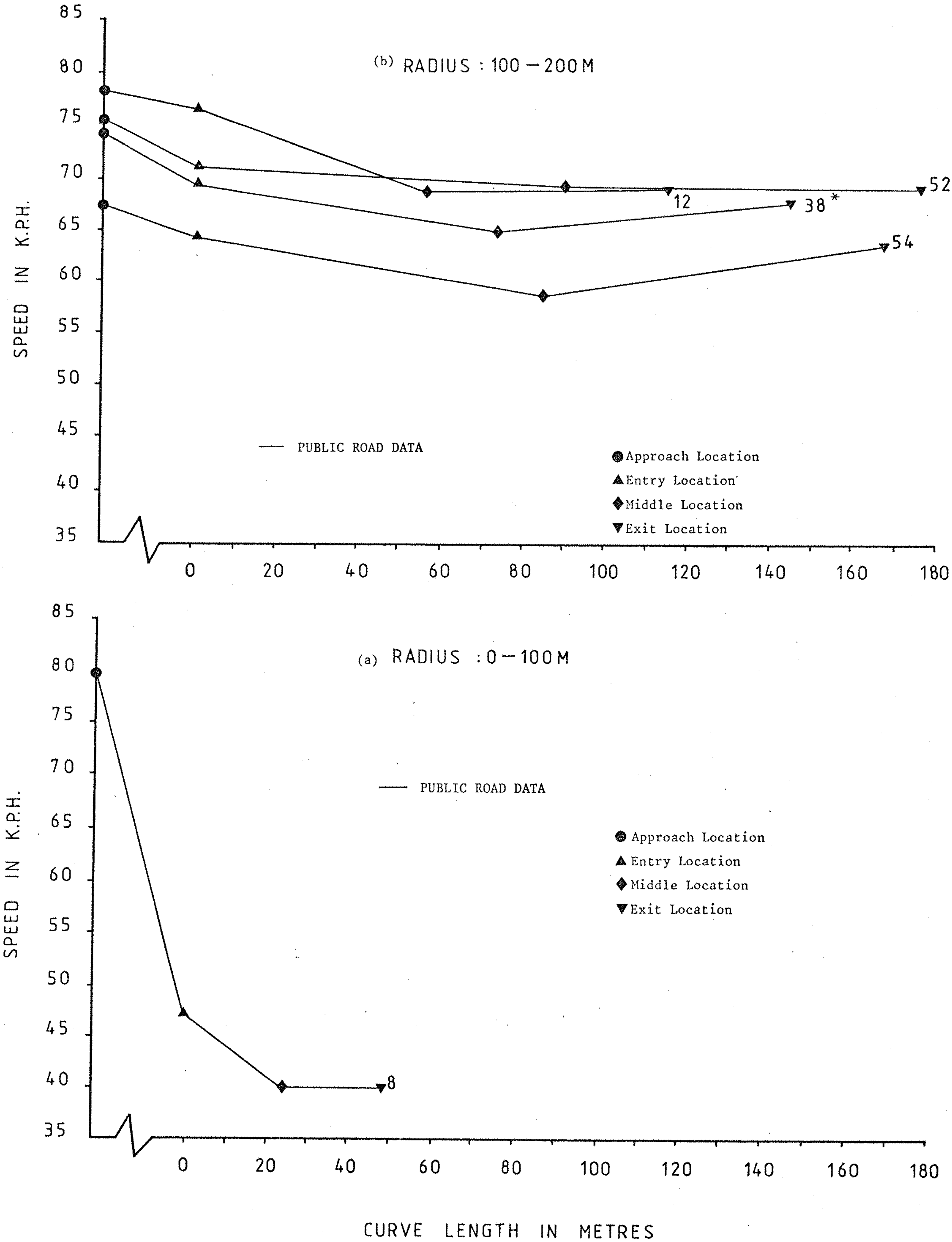
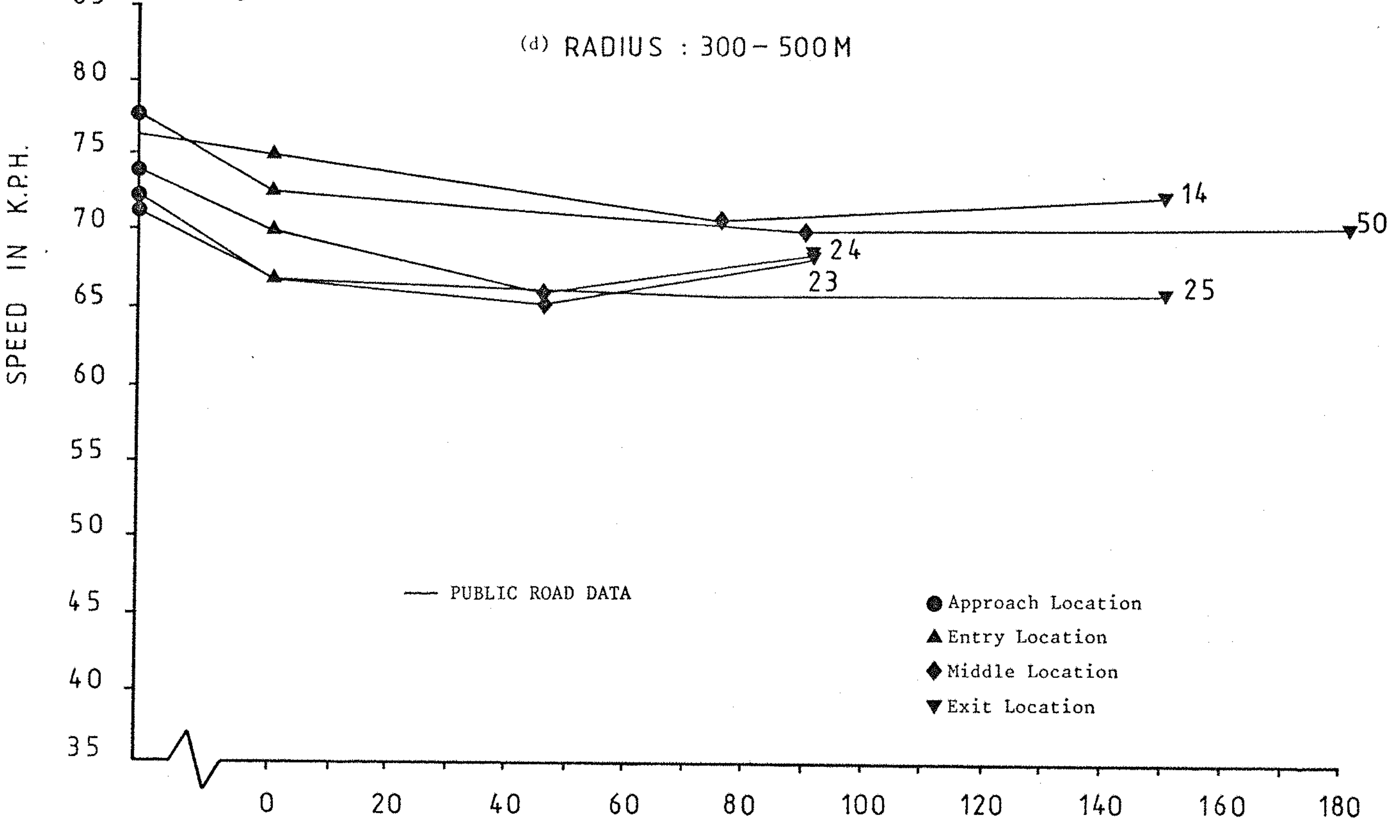
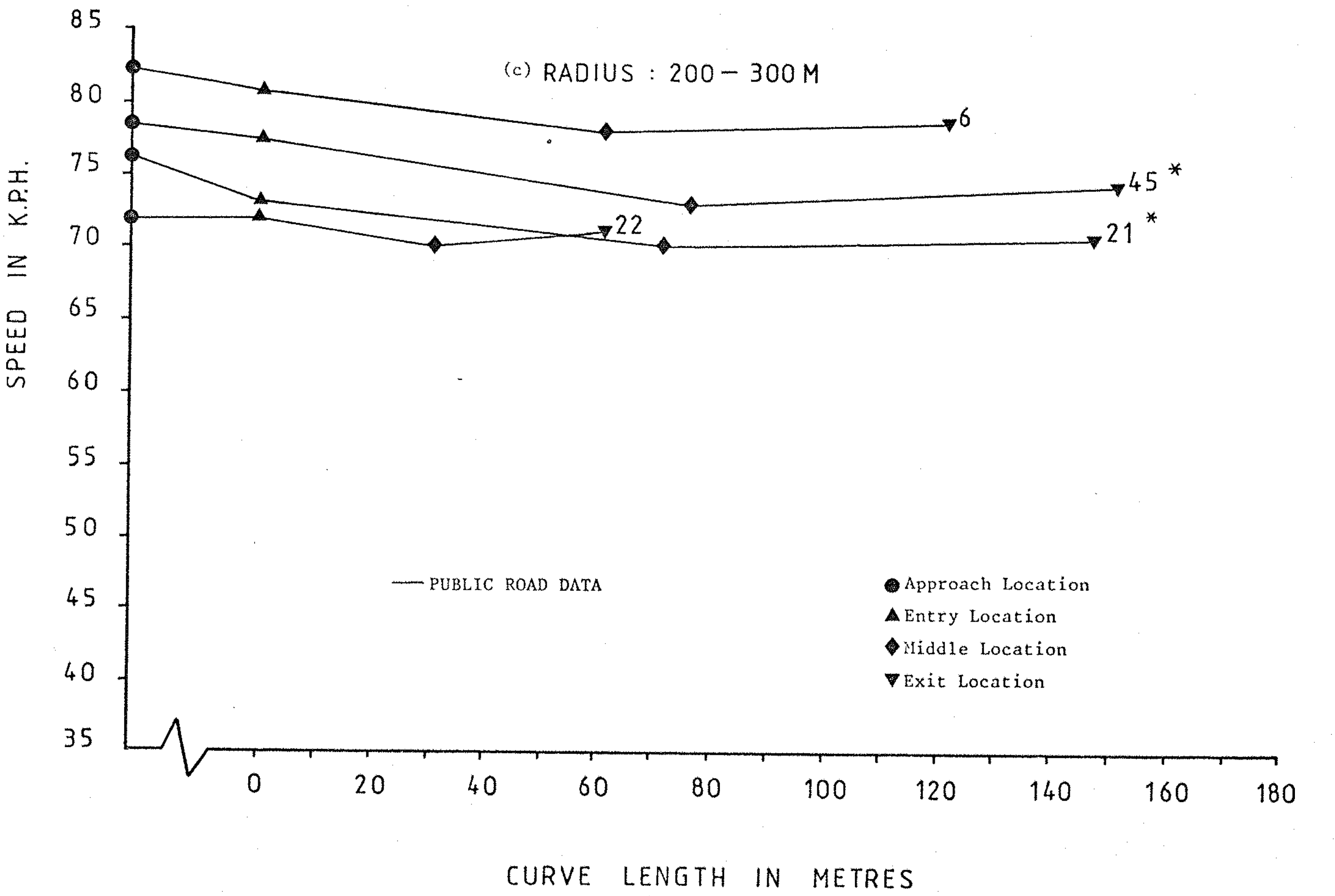


Figure 6.7: Speed/Distance Profiles for Public Road Drivers and Test Vehicle Driver (Single Carriageways - Goods Vehicles)

... continued

Figure 6.7: ... continued





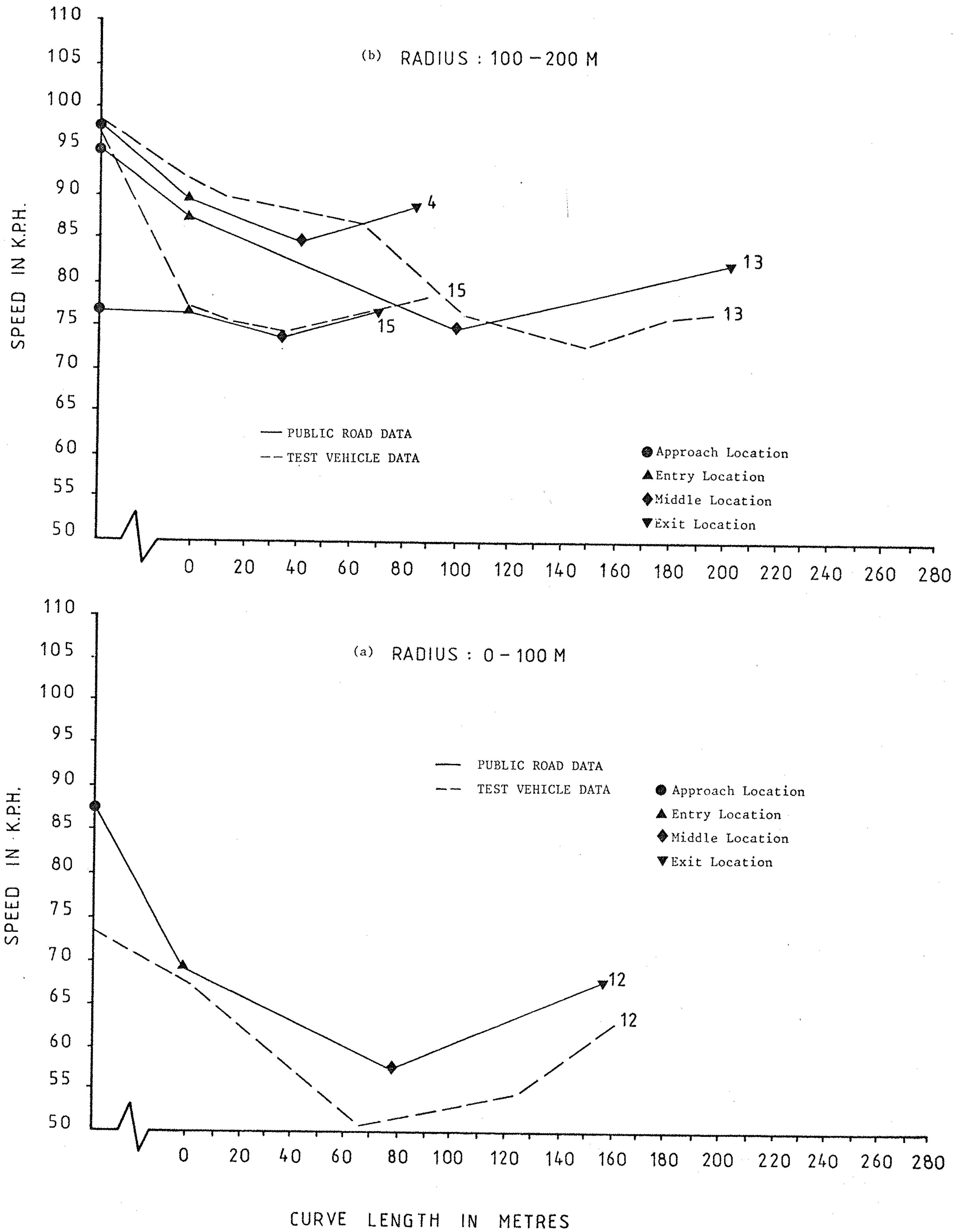
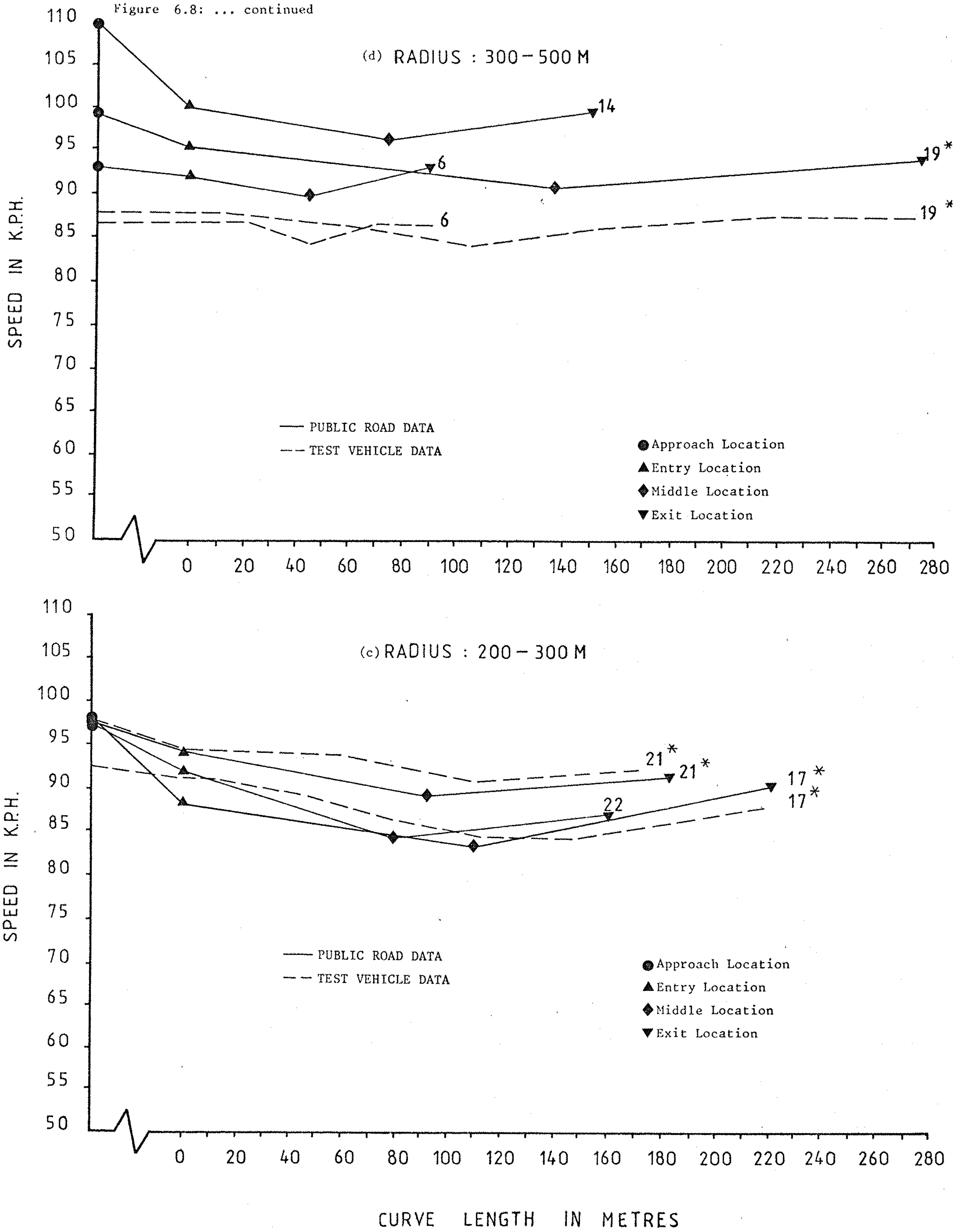
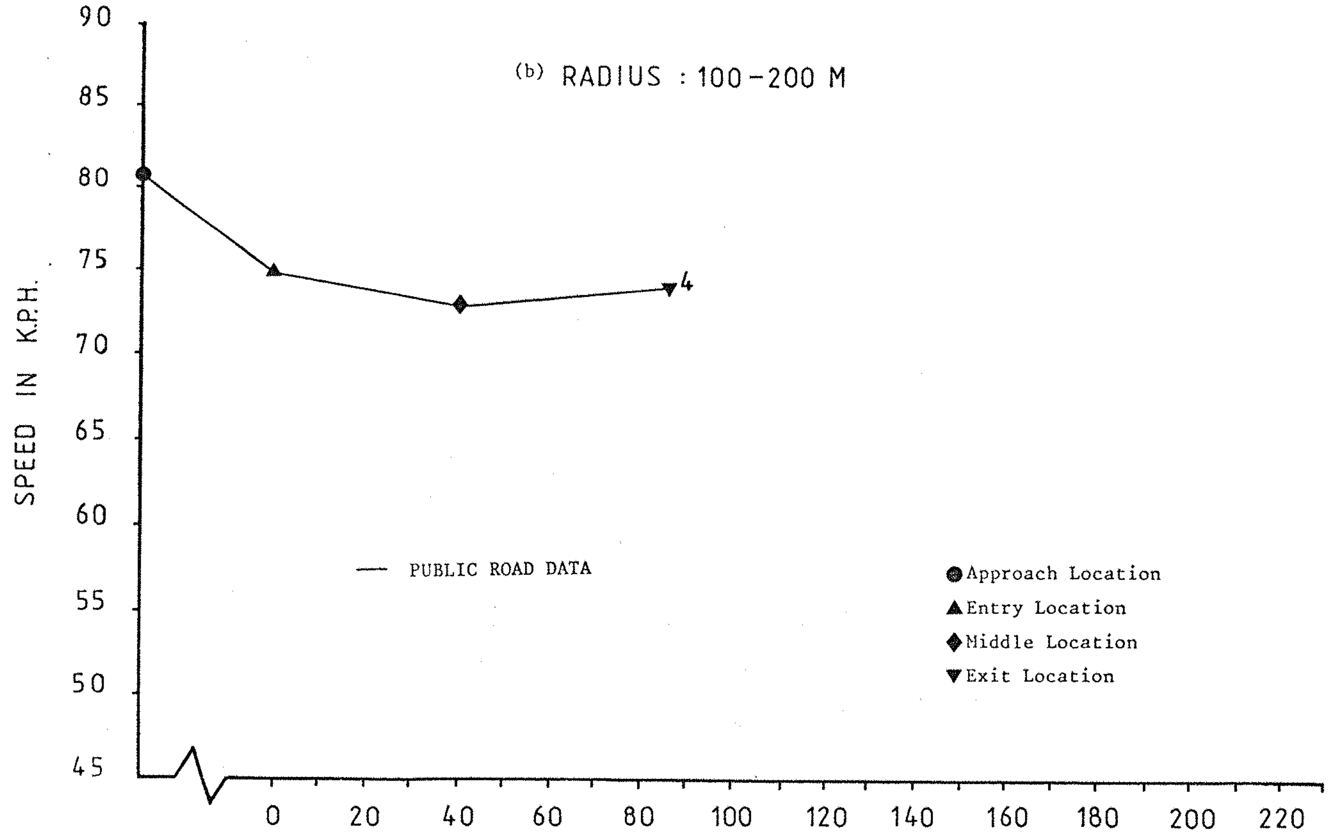


Figure 6.8: Speed/Distance Profiles for Public Road Drivers and Test Vehicle Driver (Dual Carriageways - Free Cars)

... continued

Figure 6.8: ... continued





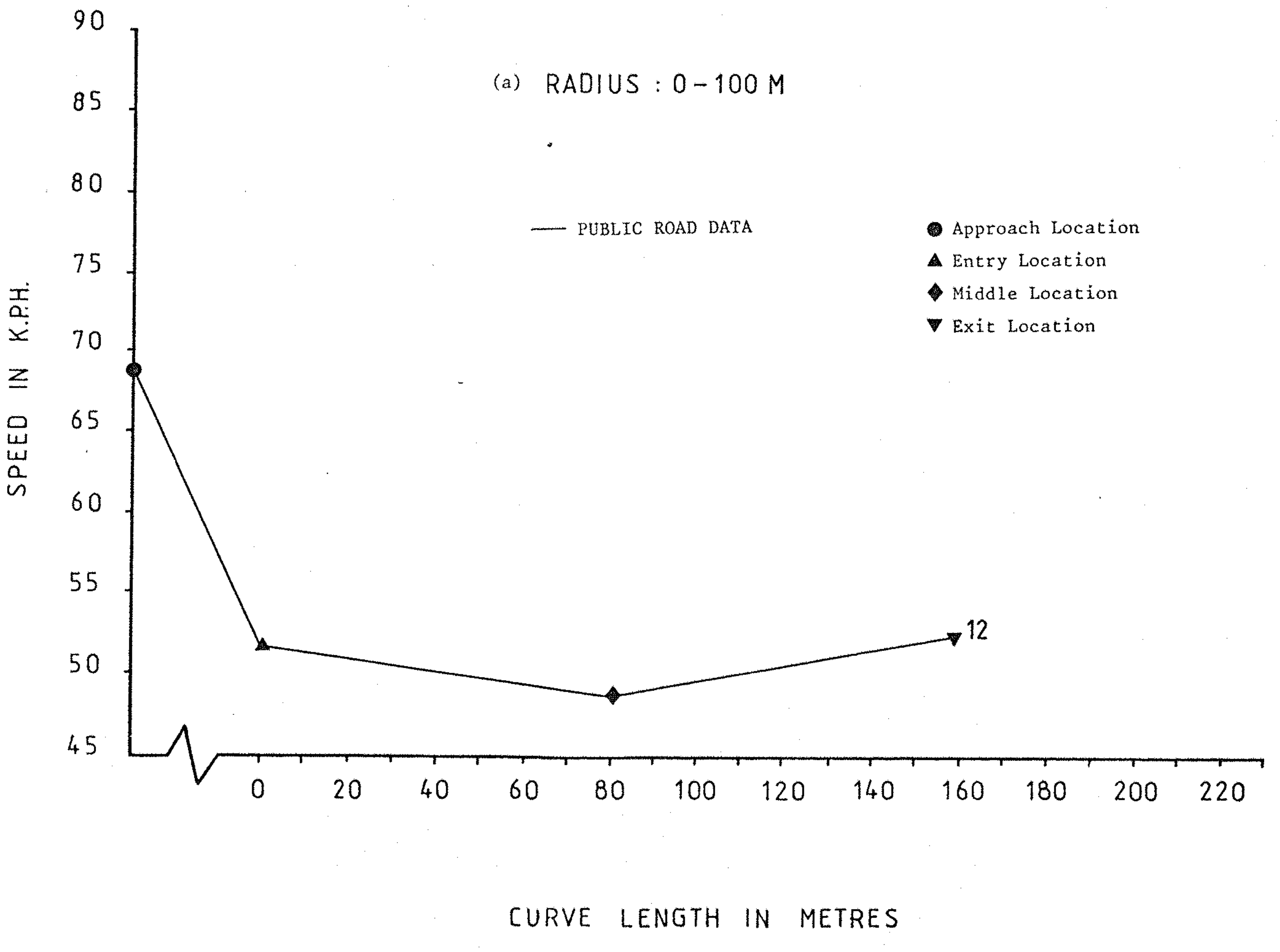
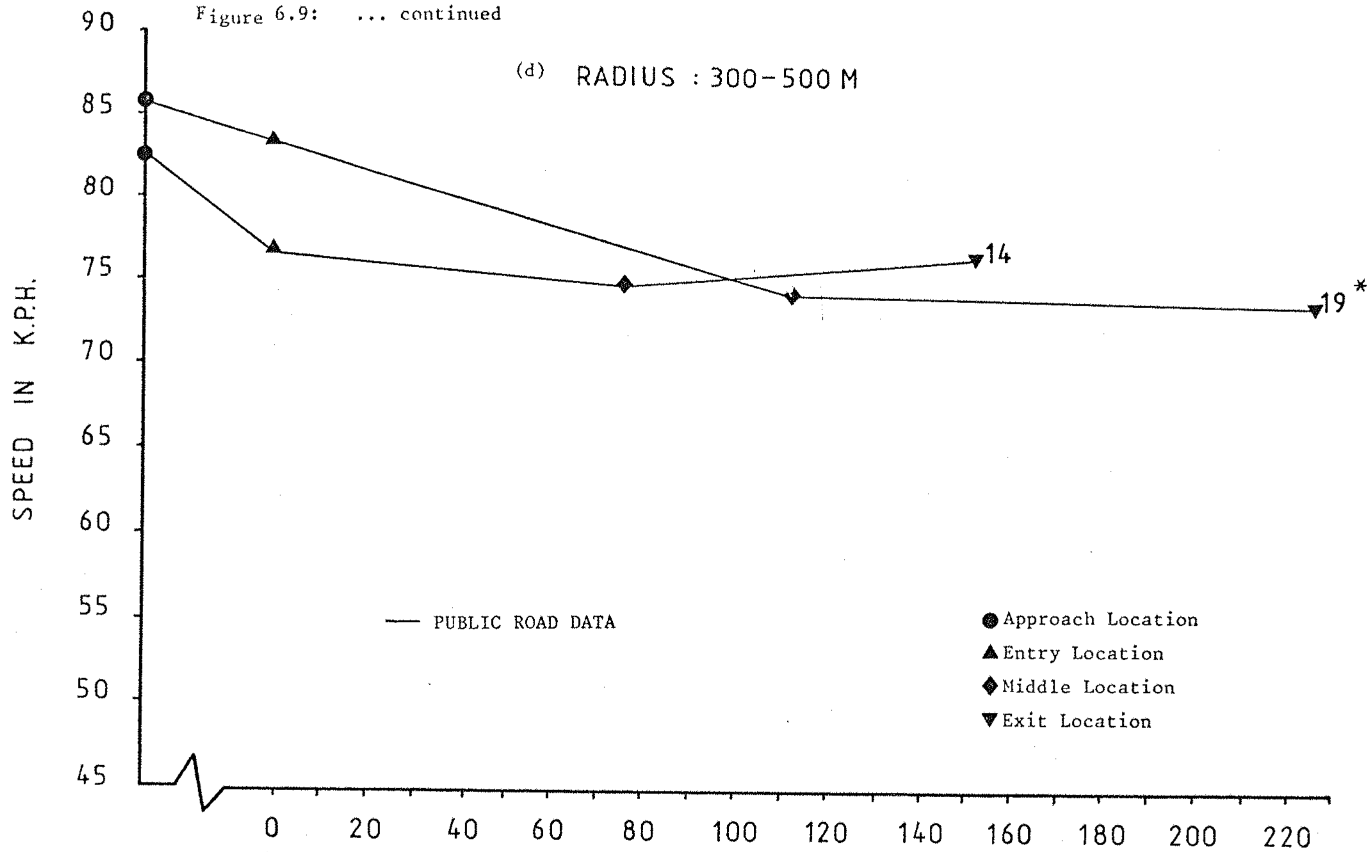
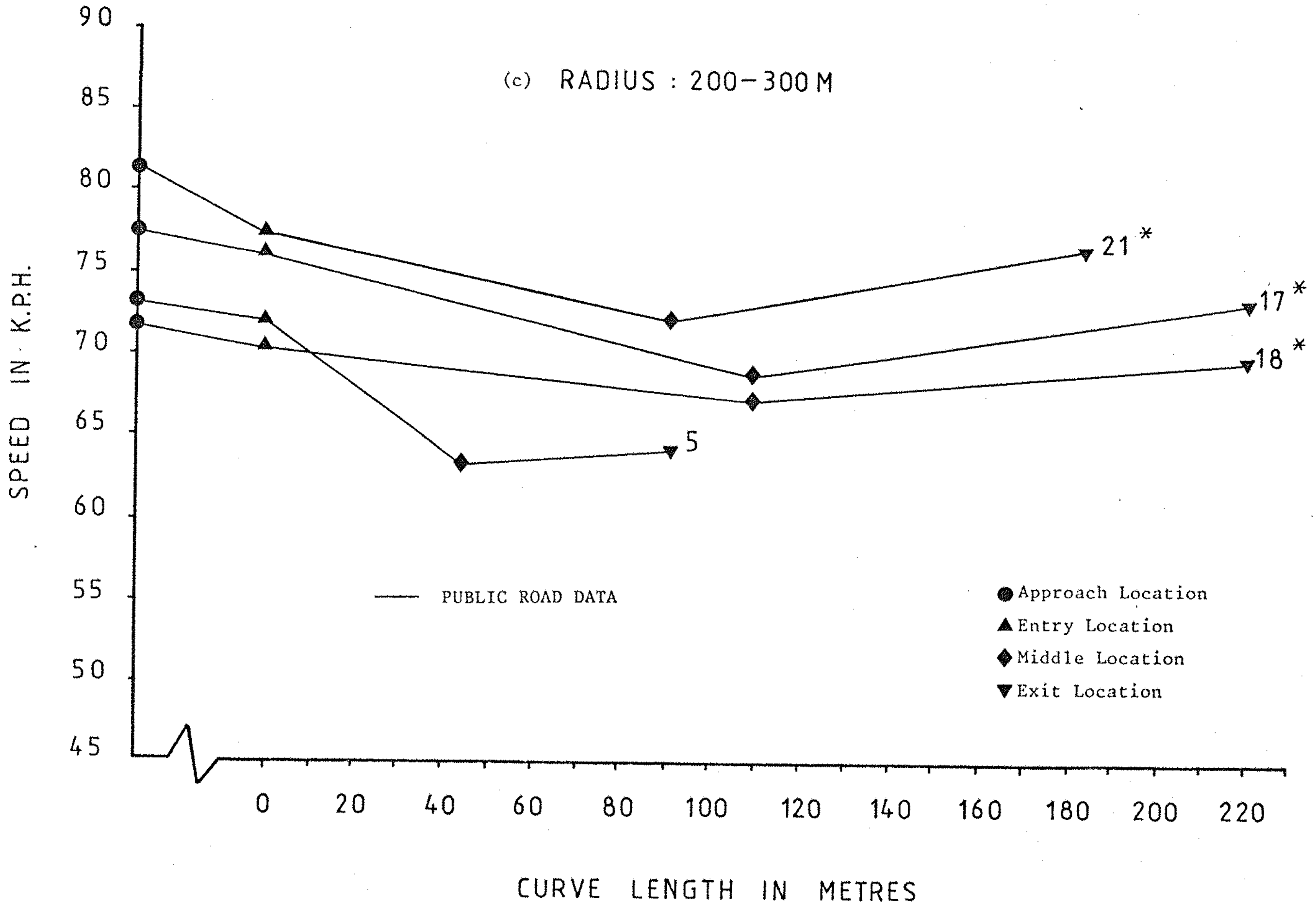


Figure 6.9: Speed/Distance Profiles for Public Road Drivers and Test Vehicle Driver (Dual Carriageways - Goods Vehicles)

... continued

Figure 6.9: ... continued





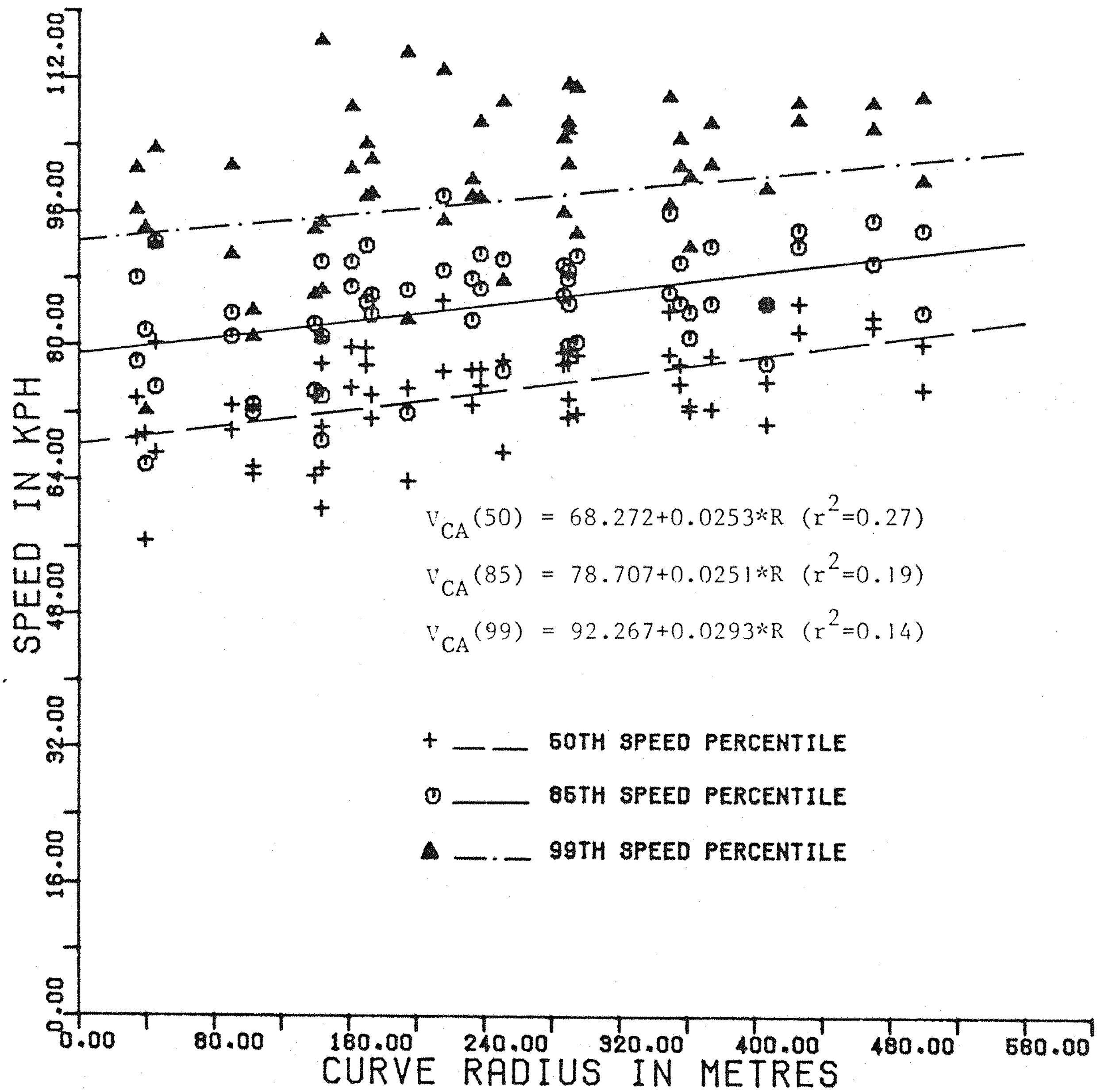


Figure 6.10 : Relationship between Approach Speed and Curve Radius (Single Carriageways - All Cars)

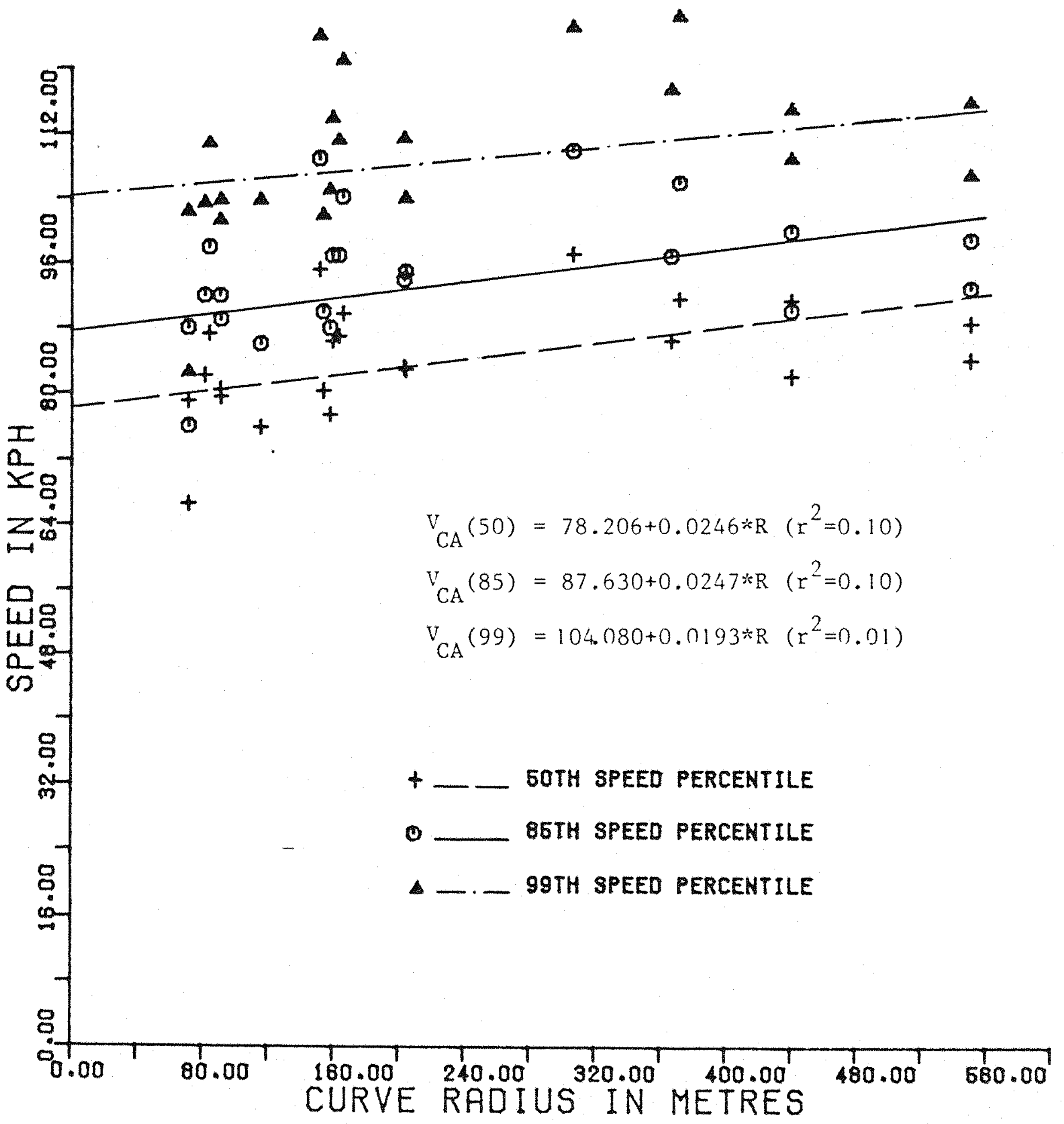


Figure 6.11 : Relationship between Approach Speed and Curve Radius
(Dual Carriageways - All Cars)

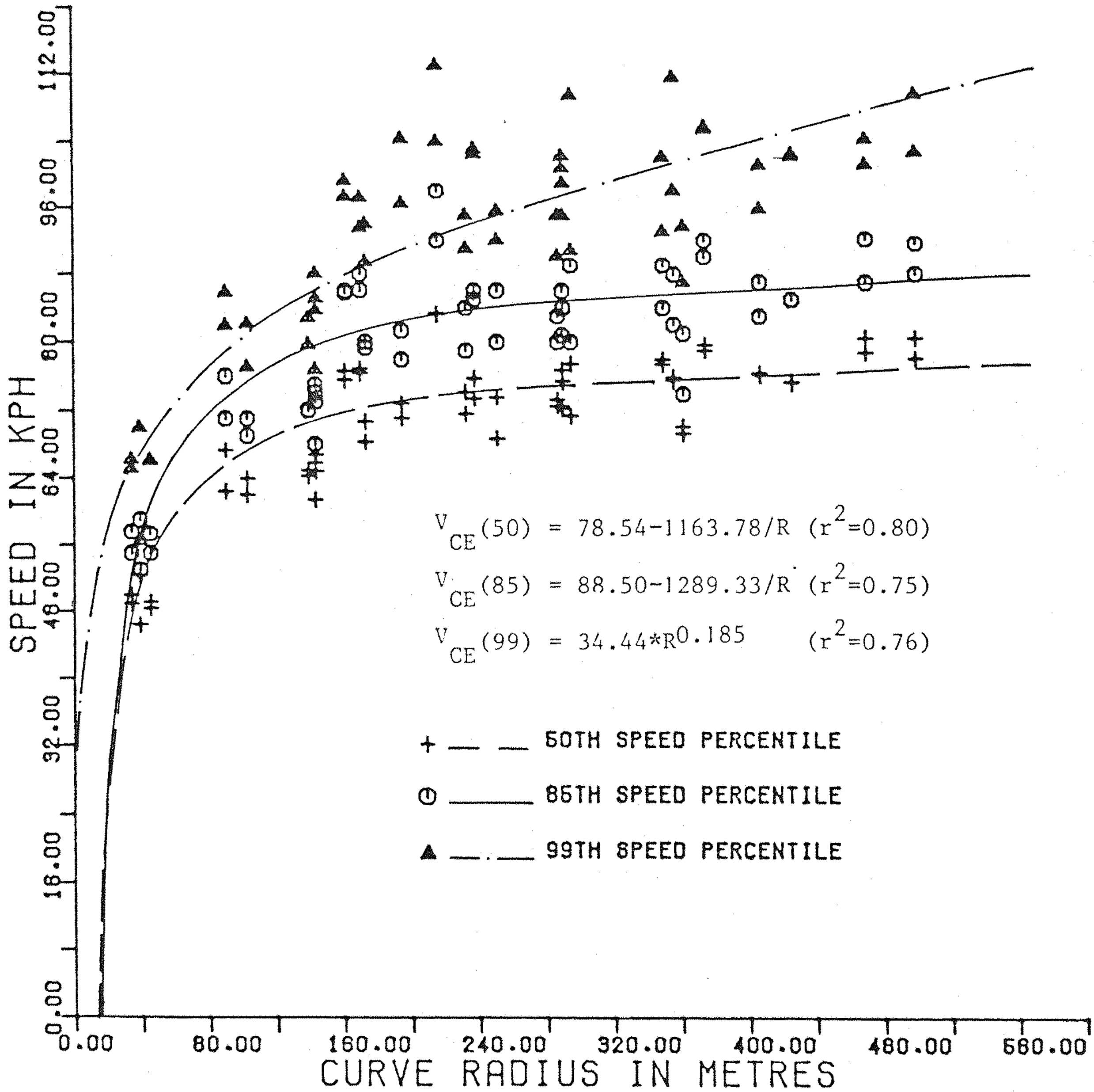


Figure 6.12 : Relationship between Entry Speed and Curve Radius
(Single Carriageways - All Cars)

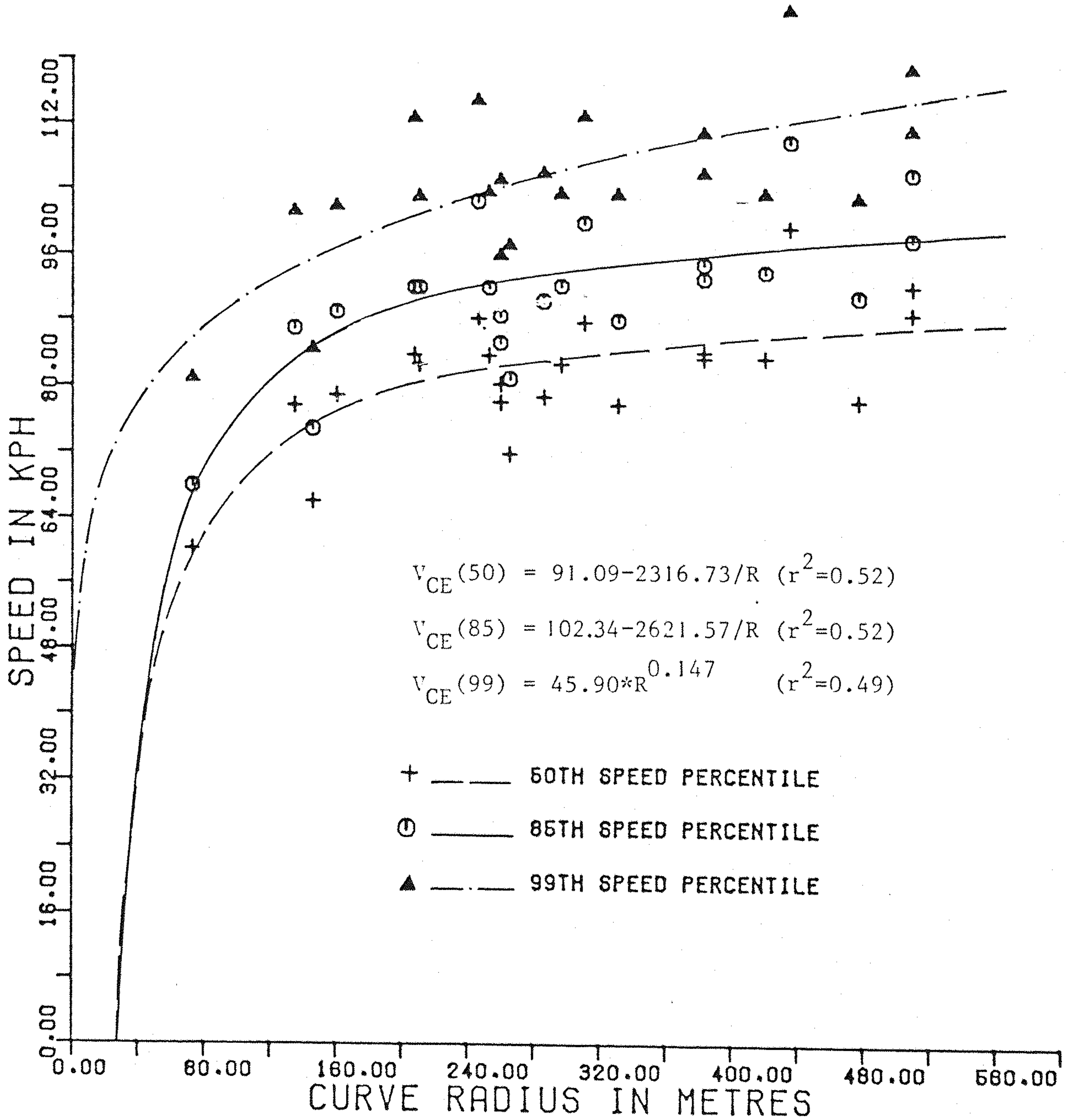


Figure 6.13 : Relationship between Entry Speed and Curve Radius (Dual Carriageways - All Cars)

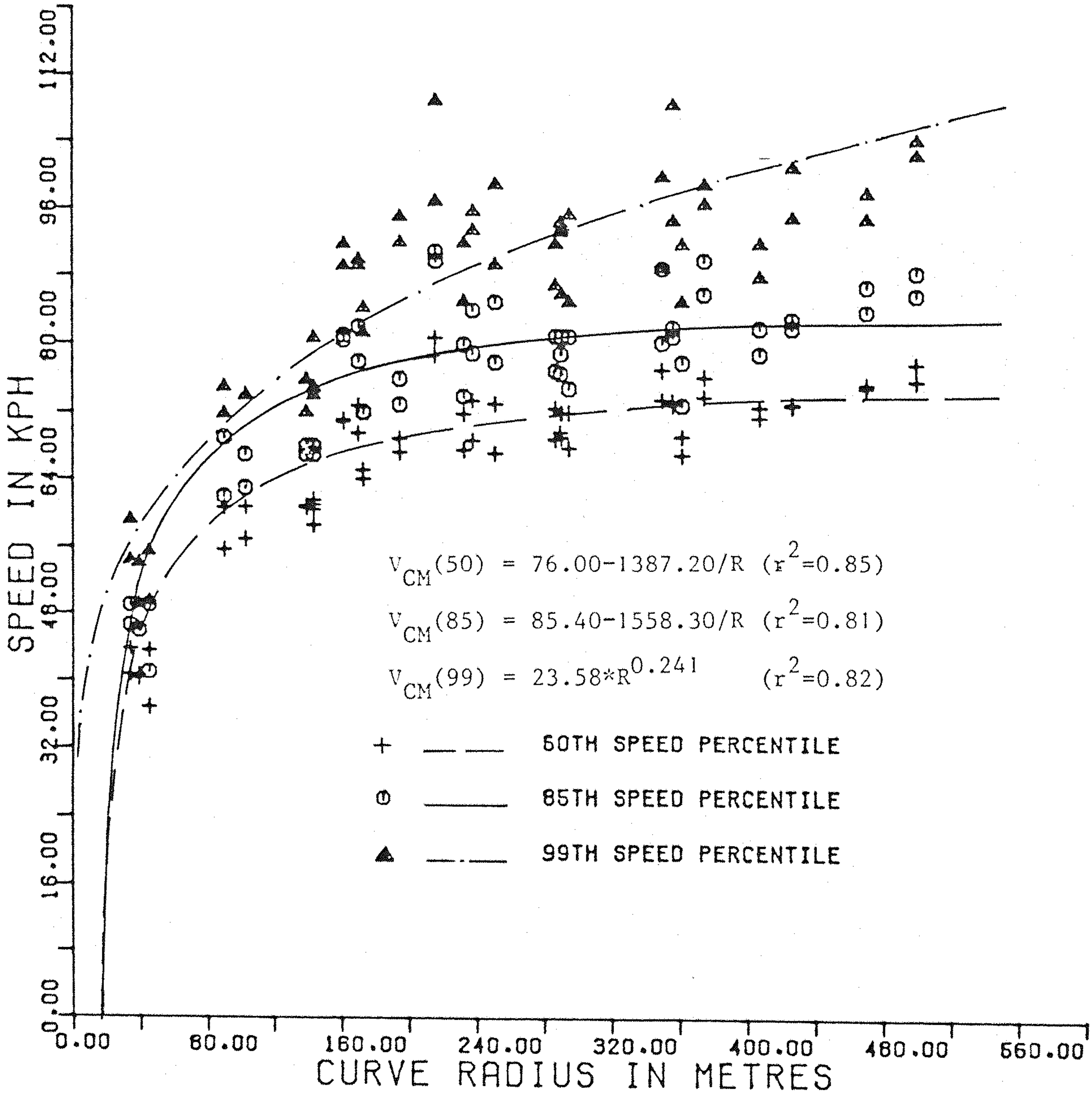


Figure 6.14: Relationship between Middle Speed and Curve Radius (Single Carriageways - All Cars)

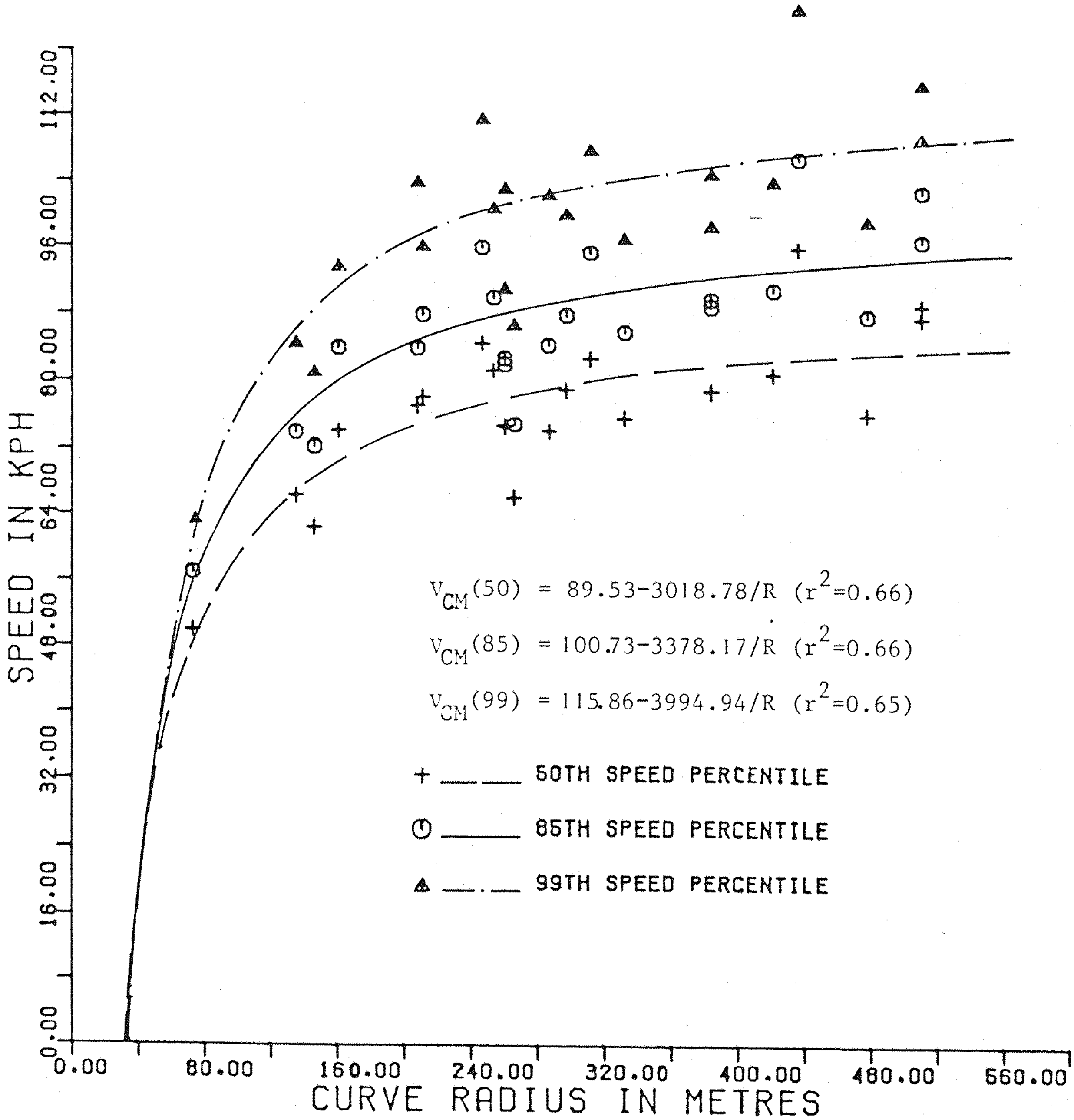


Figure 6.15 : Relationship between Middle Speed and Curve Radius (Dual Carriageways - All Cars)

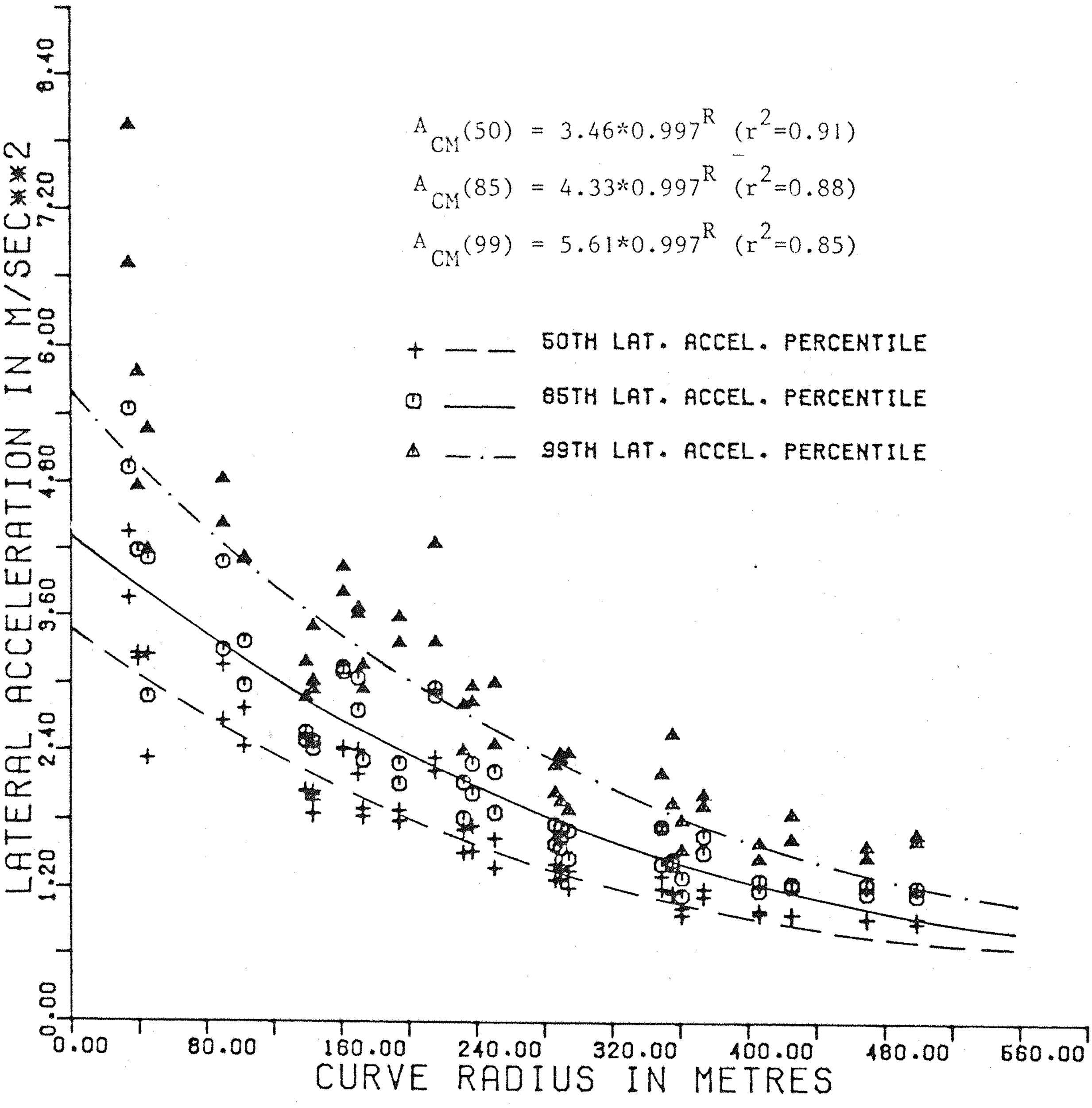


Figure 6.16 : Relationship between Middle Lateral Acceleration and Curve Radius
(Single Carriageways - All Cars)

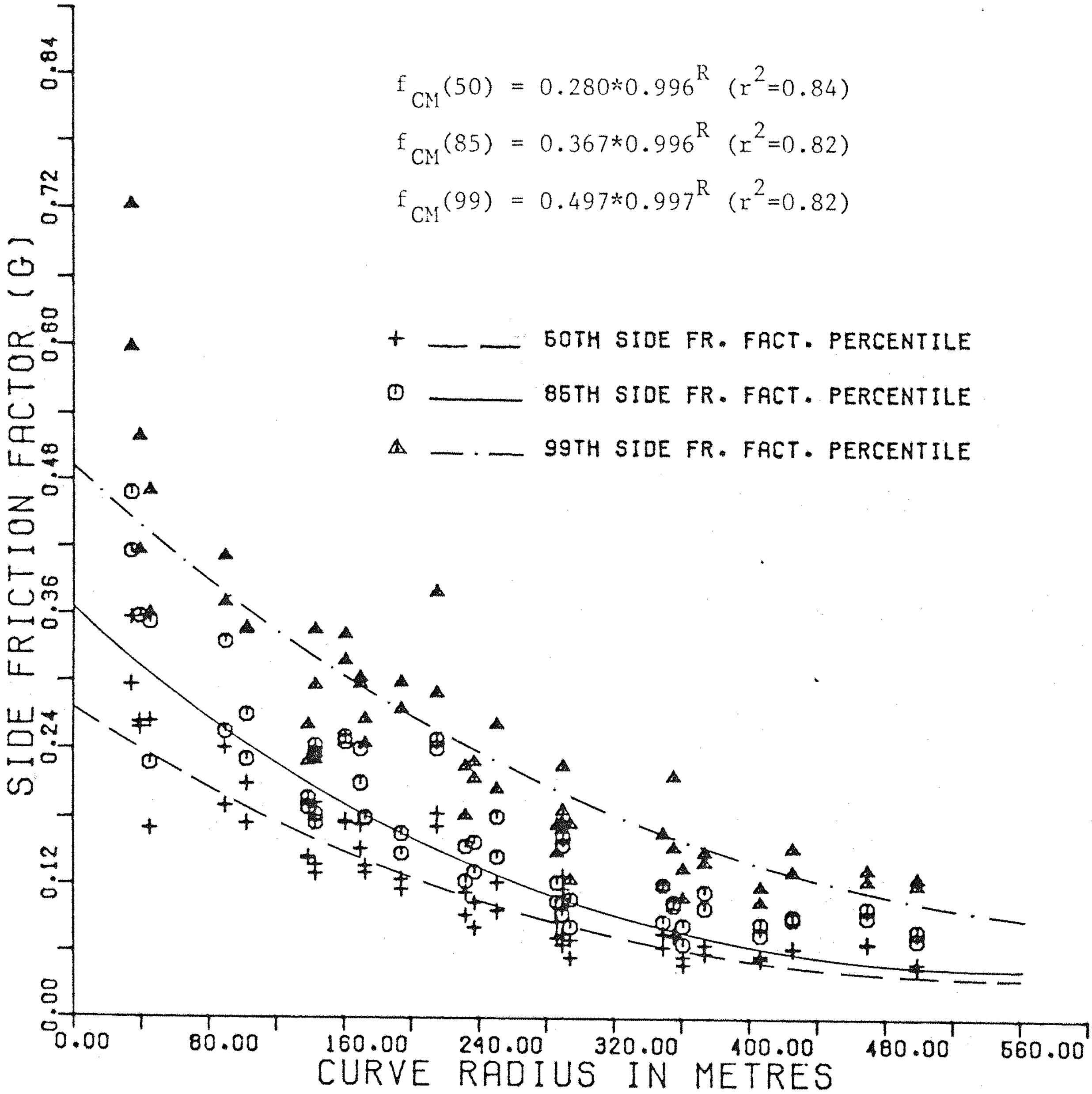


Figure 6.17: Relationship between Middle Side-Friction Factor and Curve Radius
(Single Carriageways - All Cars)

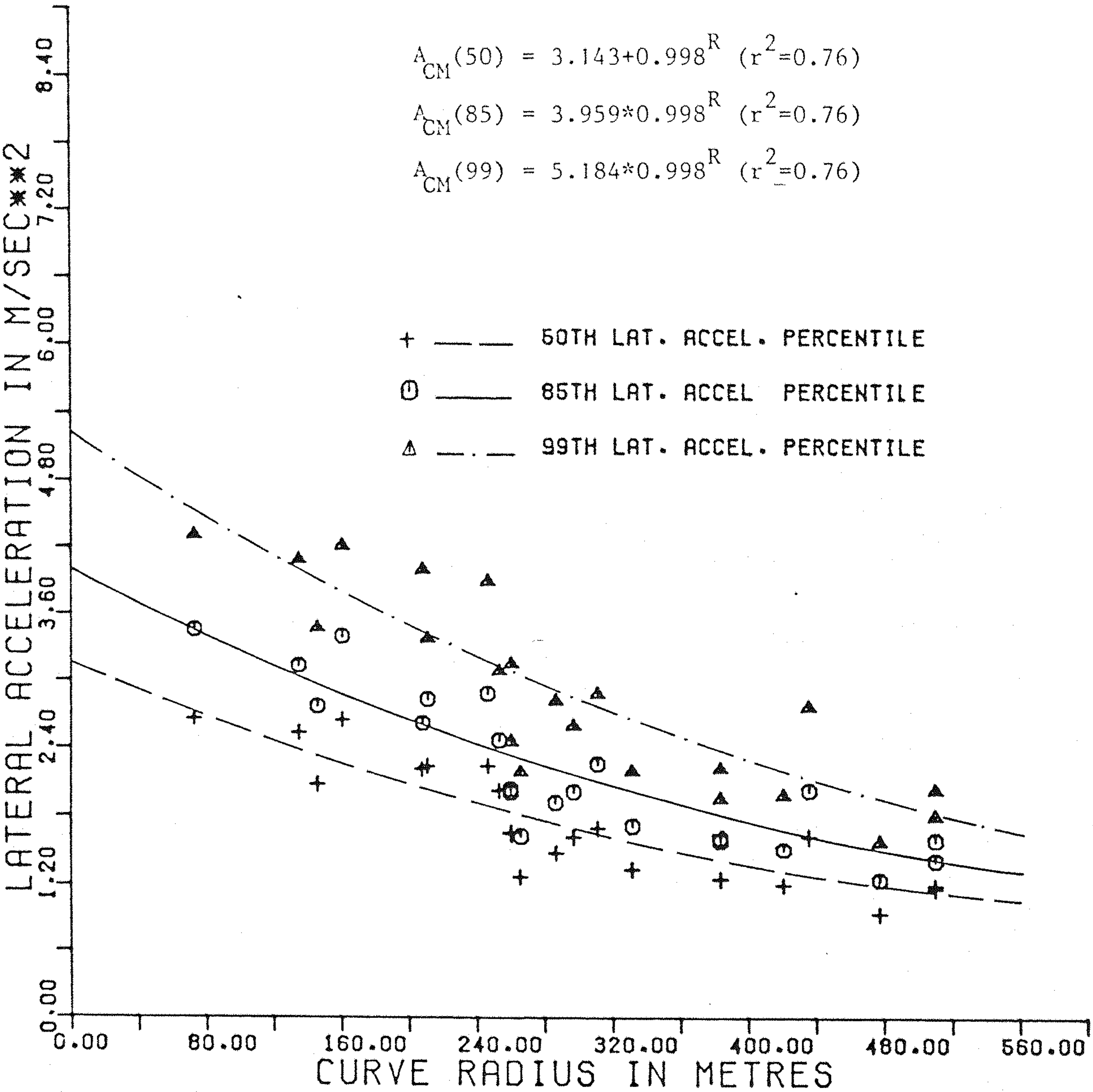


Figure 6.18 : Relationship between Middle Lateral Acceleration and Curve Radius
(Dual Carriageways - All Cars)

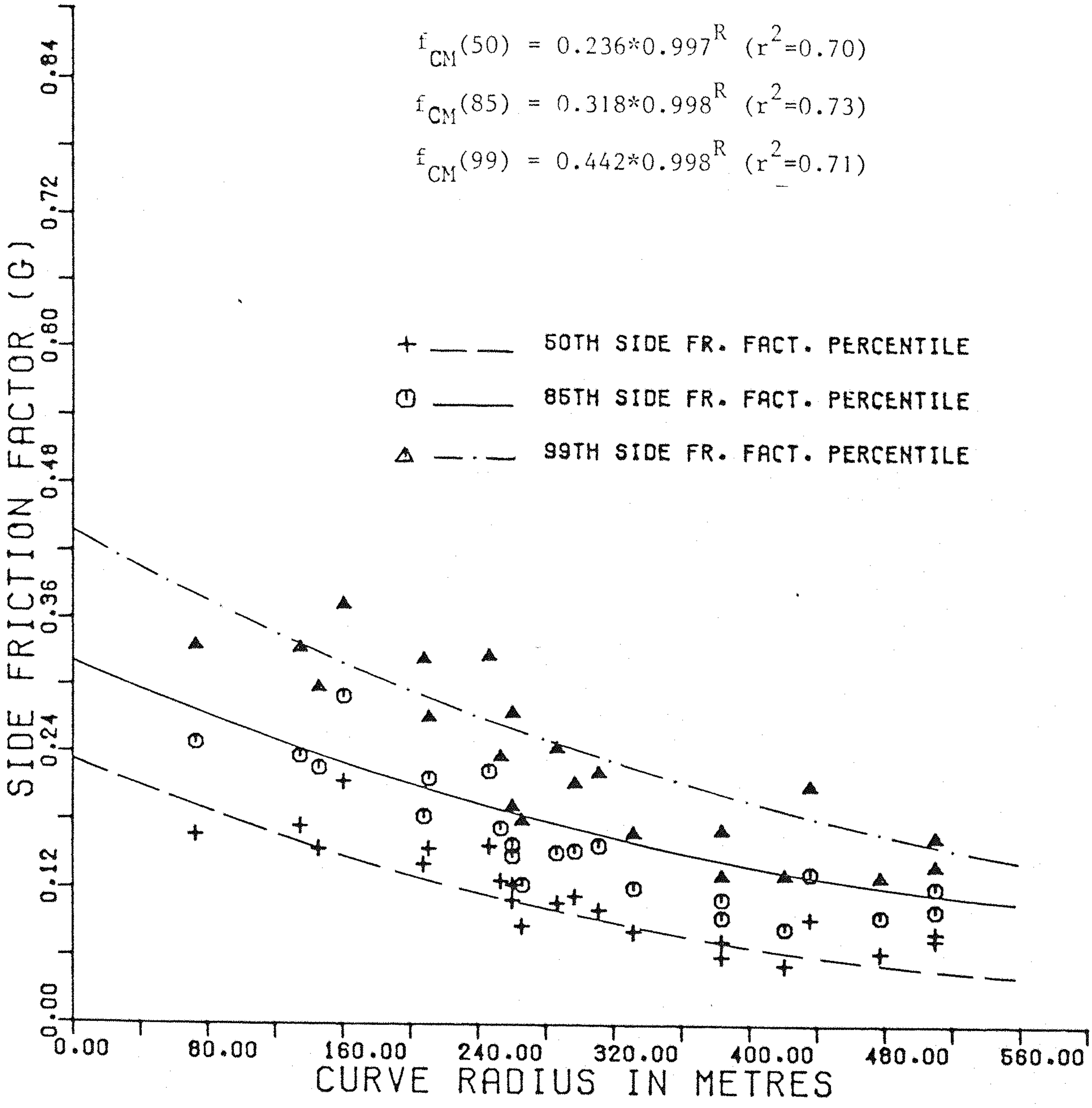


Figure 6.19 : Relationship between Middle Side-Friction Factor and Curve Radius
(Dual Carriageways - All Cars)

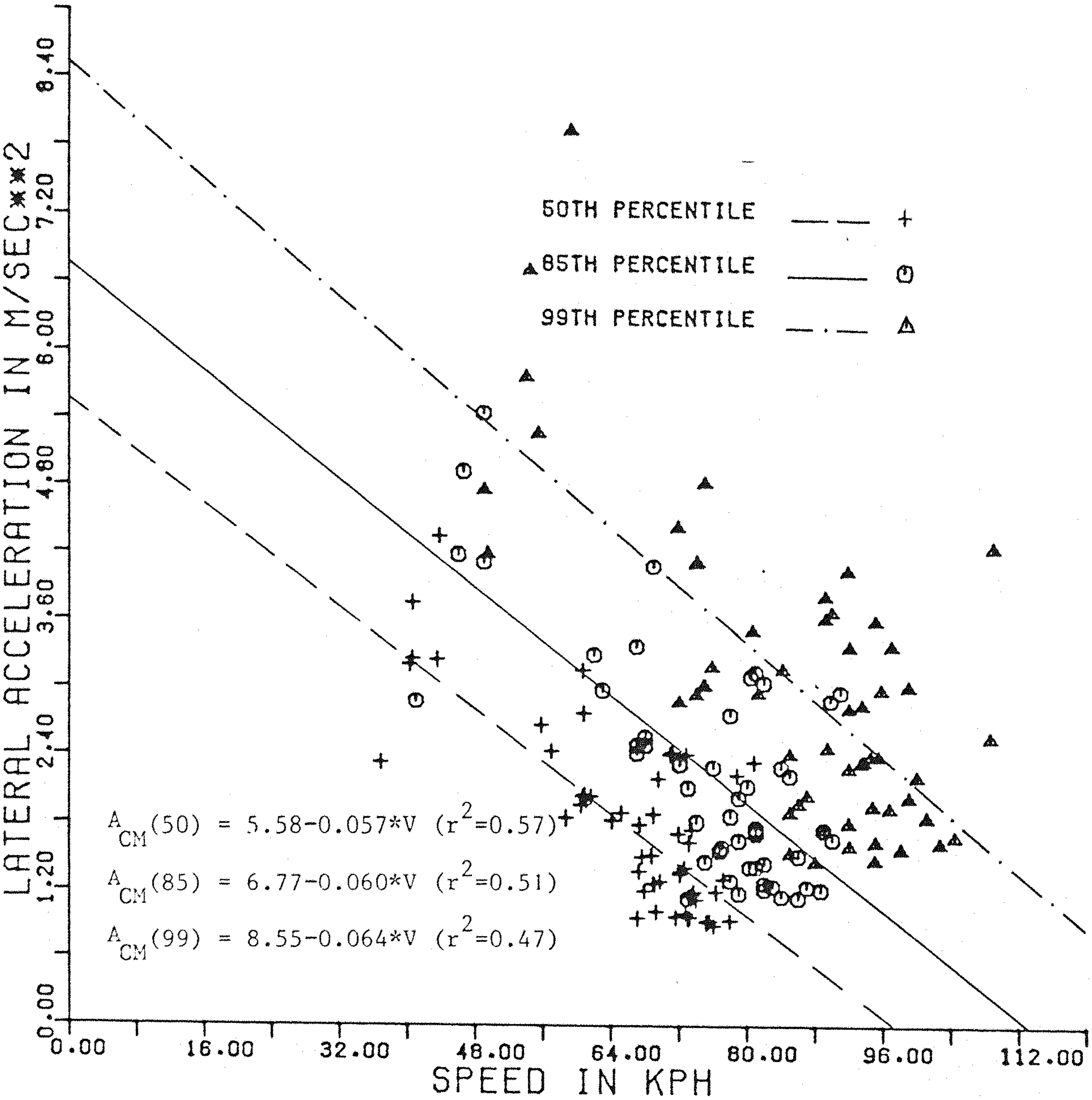


Figure 6.20 : Relationship between Middle Lateral Acceleration and Middle Speed
(Single Carriageways - All Cars)

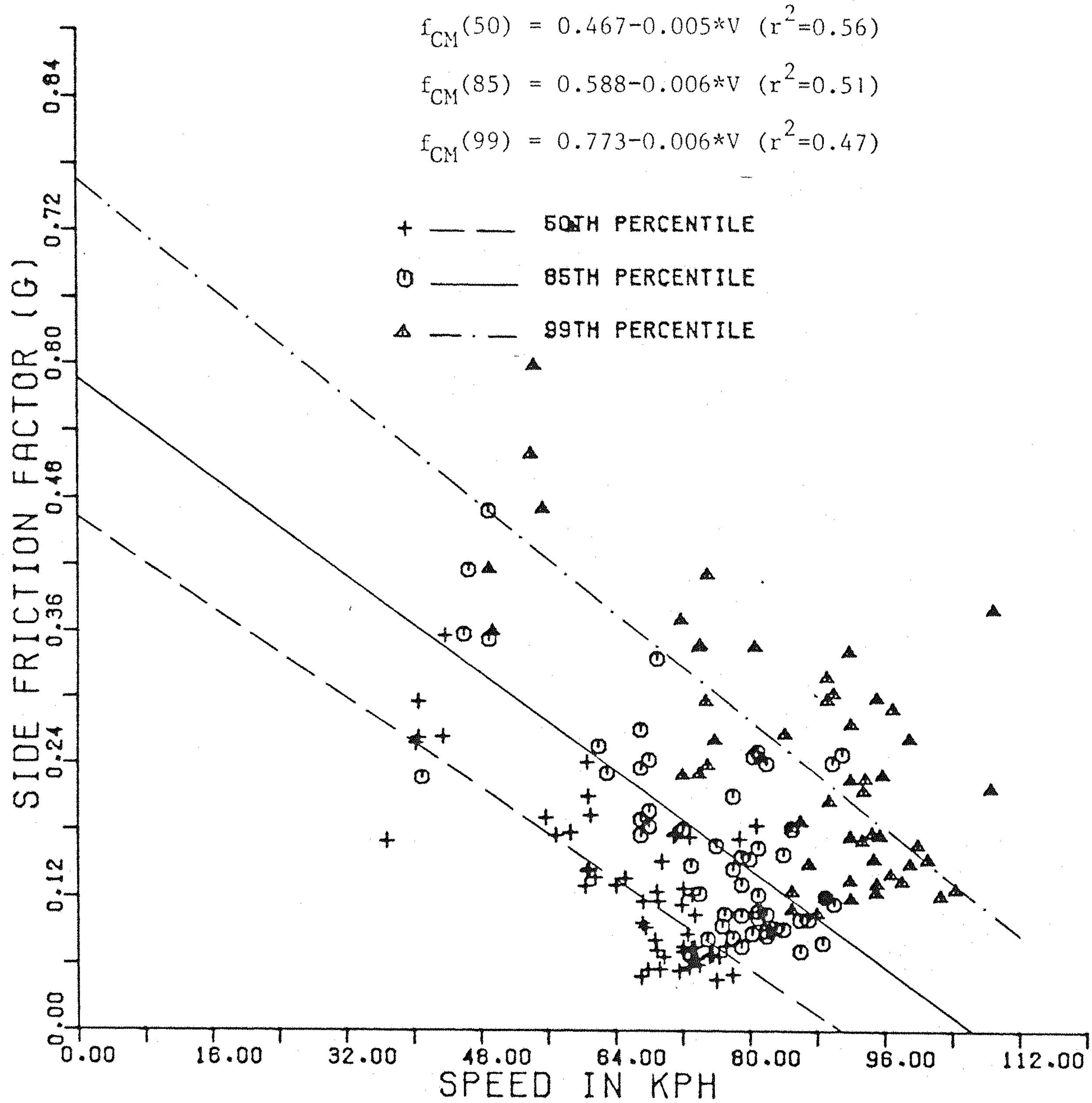


Figure 6.21 : Relationship between Middle Side-Friction Factor and Middle Speed
(Single Carriageways - All Cars)

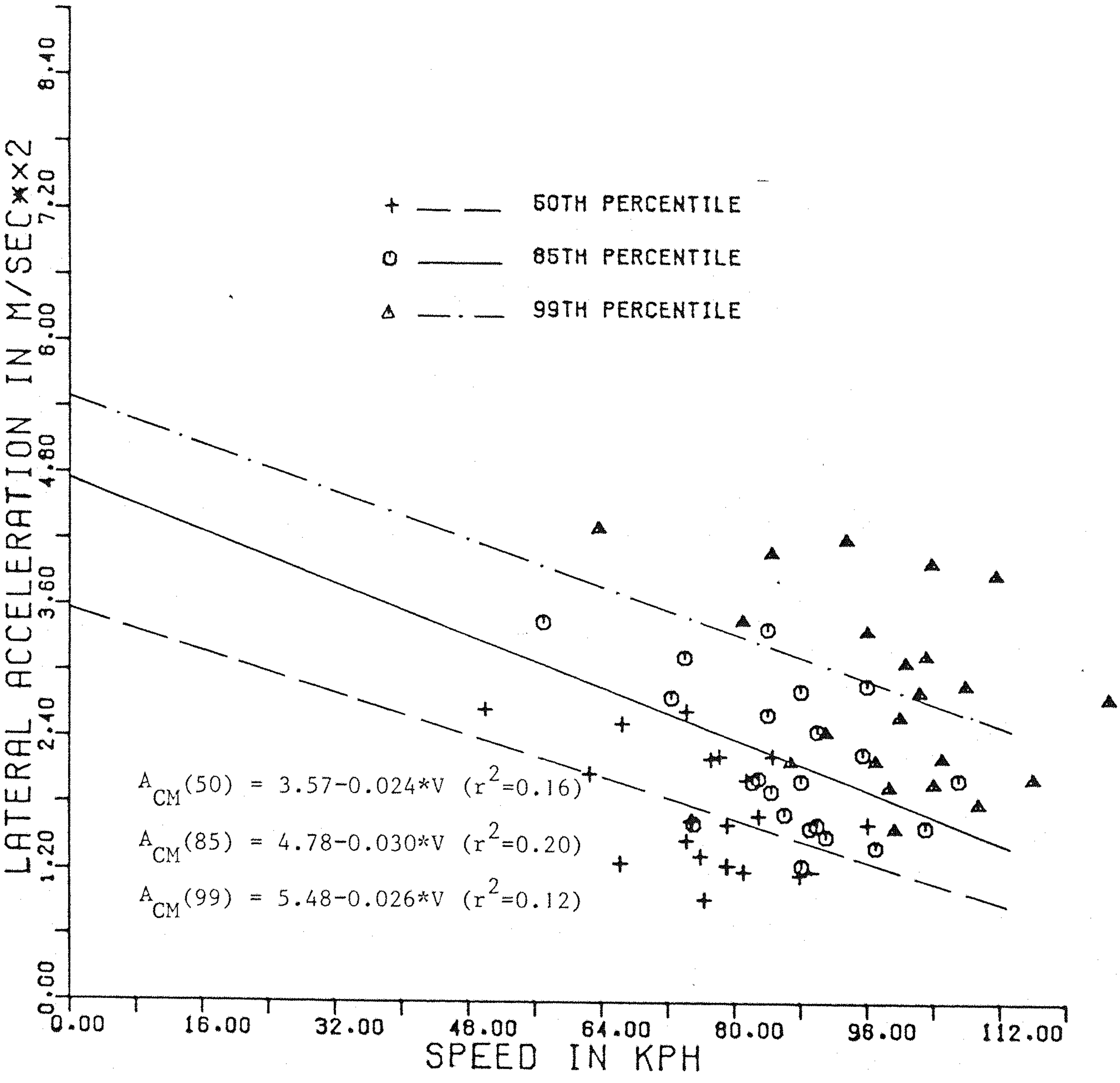


Figure 6.22 : Relationship between Middle Lateral Acceleration and Middle Speed (Dual Carriageways - All Cars)

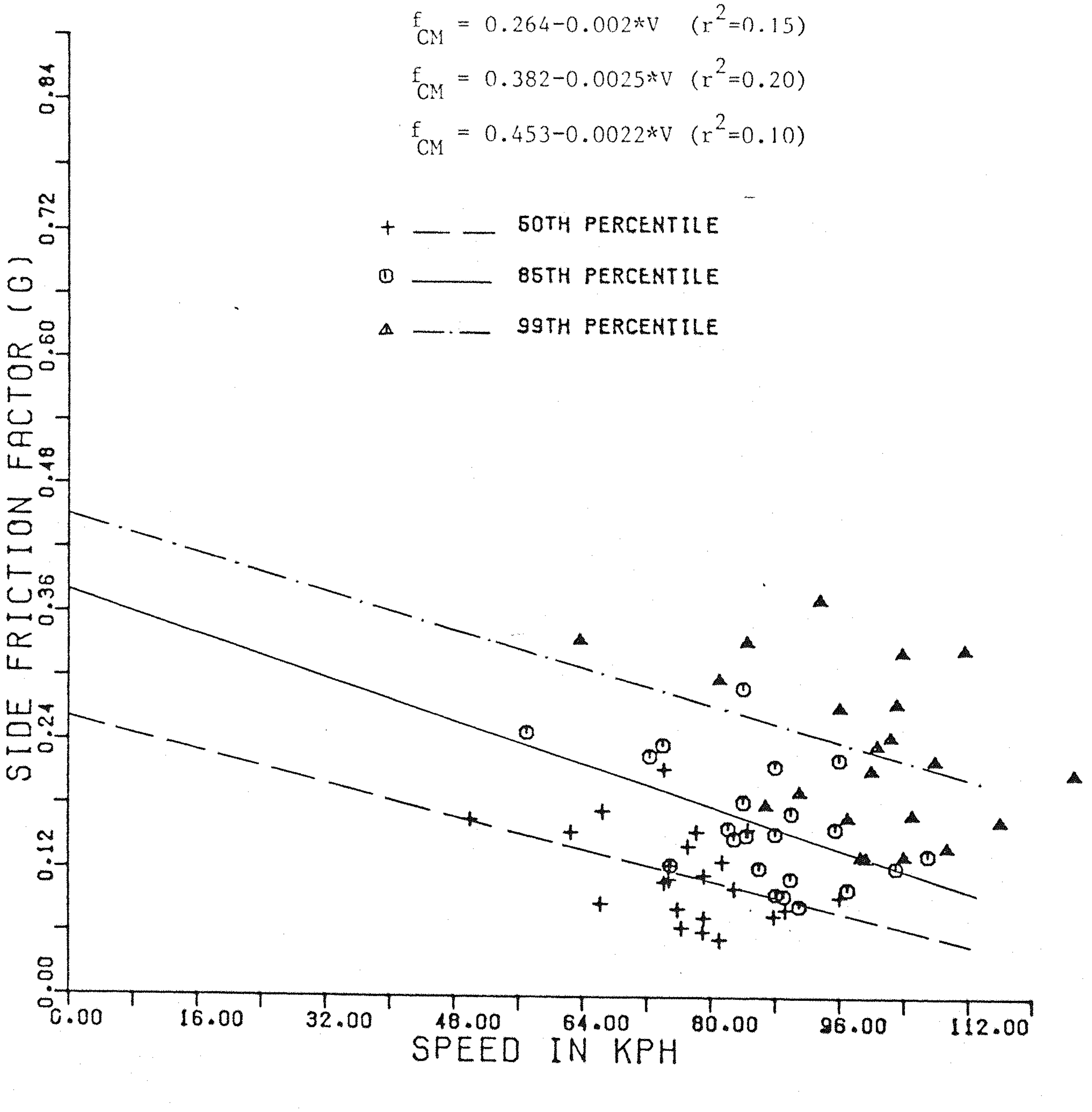


Figure 6.23 : Relationship between Middle Side-Friction Factor and Middle Speed
(Dual Carriageways - All Cars)

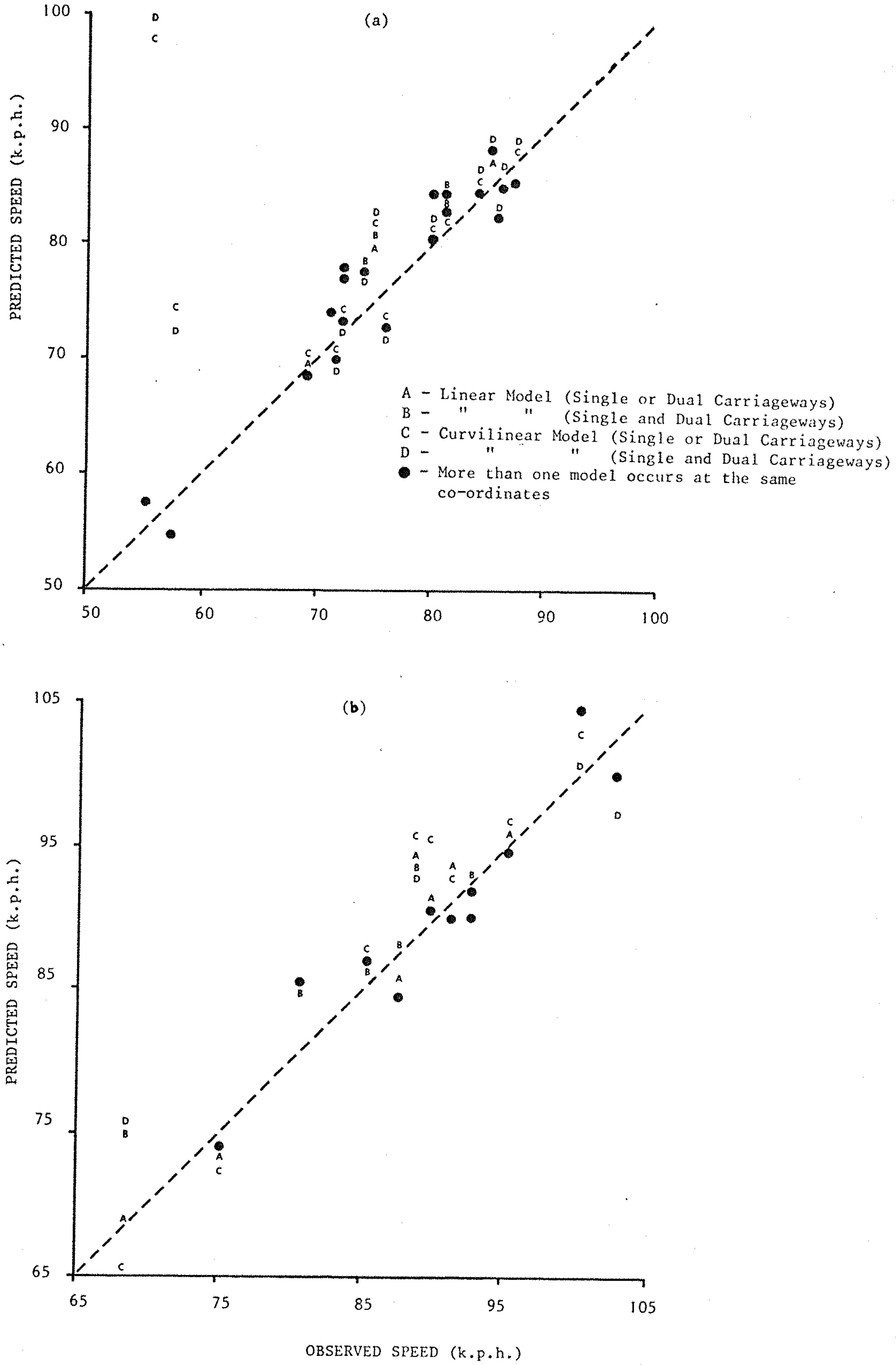


Figure 6.24: Plots of Observed Entry Speeds against Predicted Entry Speeds for various Regression Models
((a) Single Carriageways, (b) Dual Carriageways - All Cars)

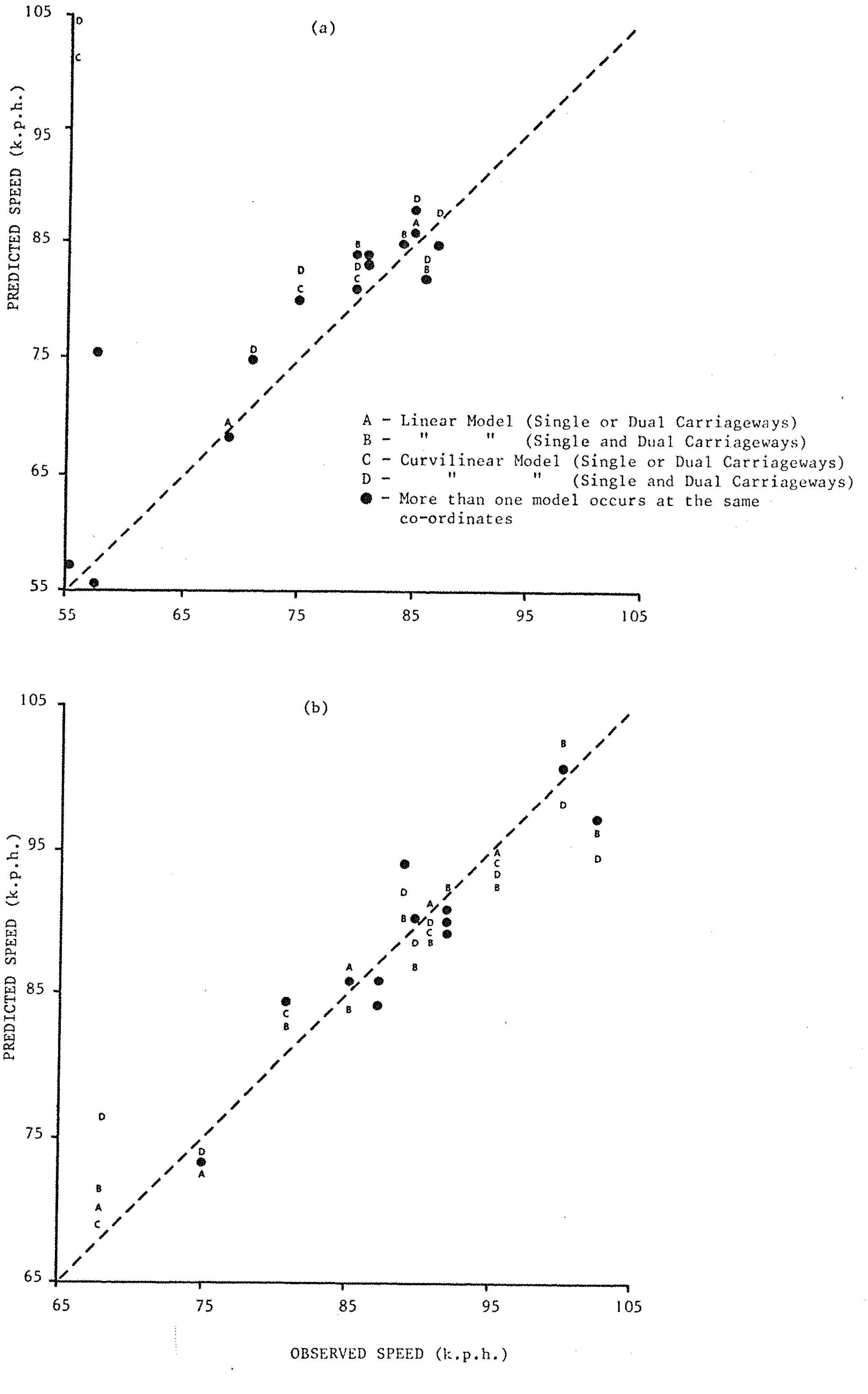
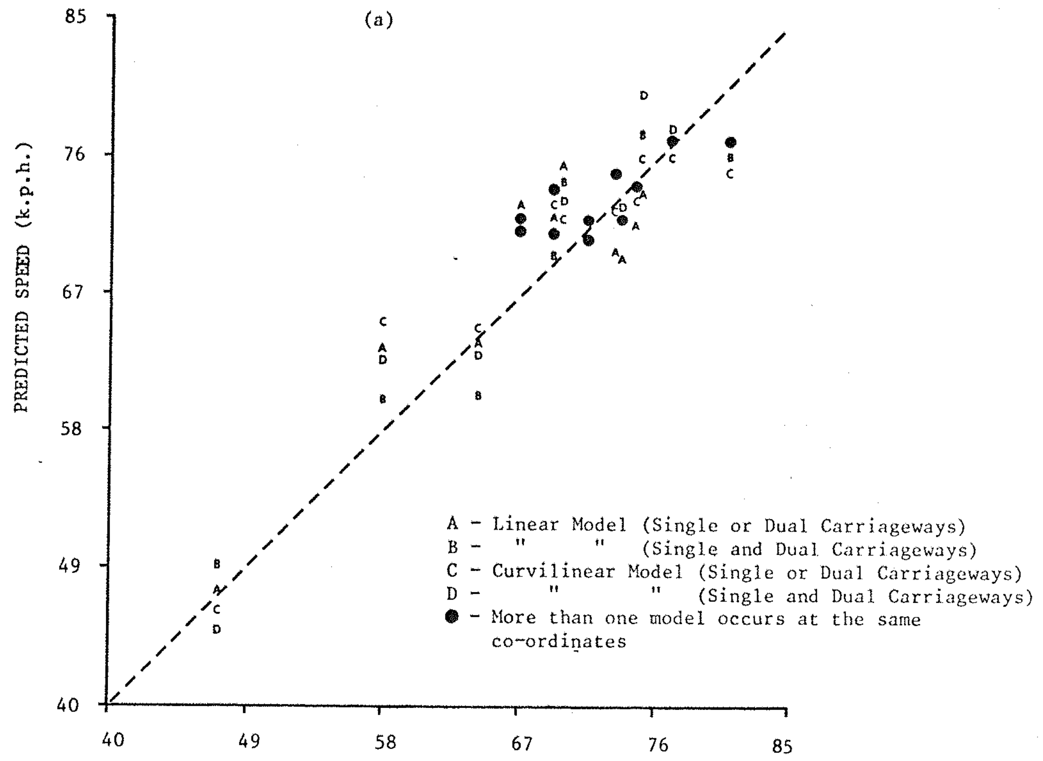


Figure 6.25: Plots of Observed Entry Speeds against Predicted Entry Speeds for various Regression Models
((a) Single Carriageways, (b) Dual Carriageways - Selected All Cars)



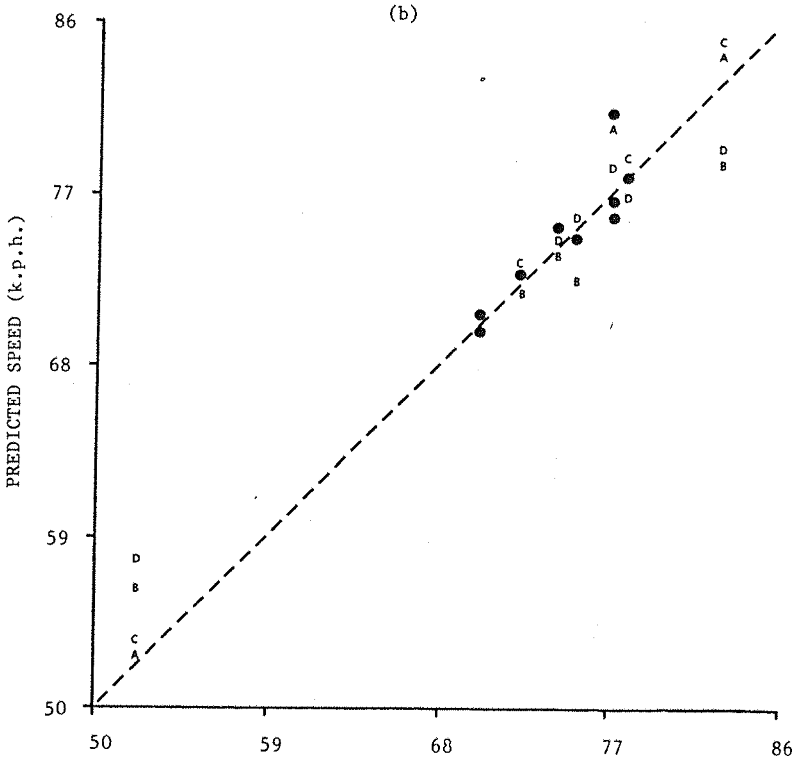


Figure 6.26 : Plots of Observed Entry Speeds against Predicted Entry Speeds for various Regression Models
((a) Single Carriageways, (b) Dual Carriageways - Goods Vehicles)

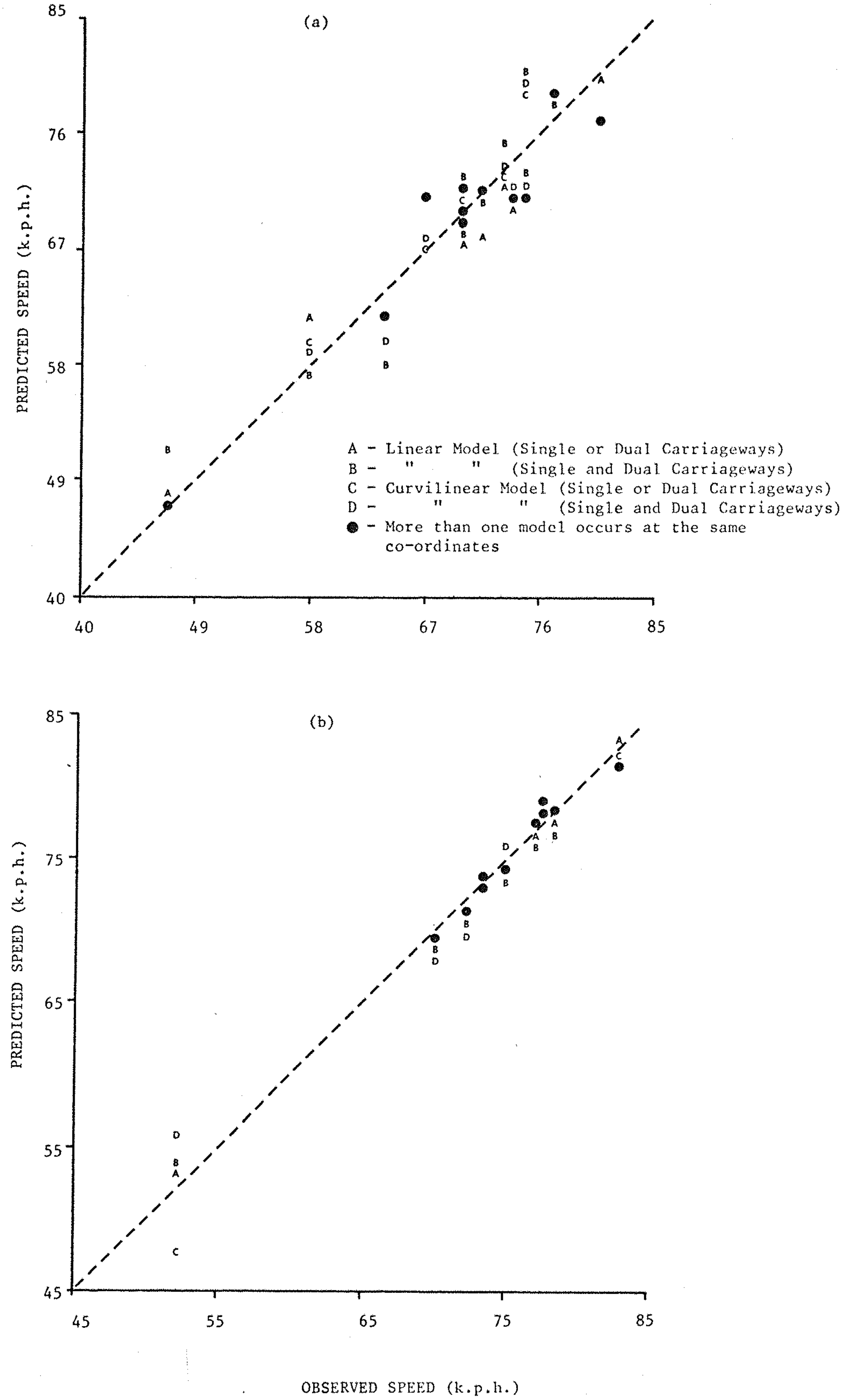


Figure 6.27 : Plots of Observed Entry Speeds against Predicted Entry Speeds for various Regression Models
((a) Single Carriageways, (b) Dual Carriageways - Selected Goods Vehicles)

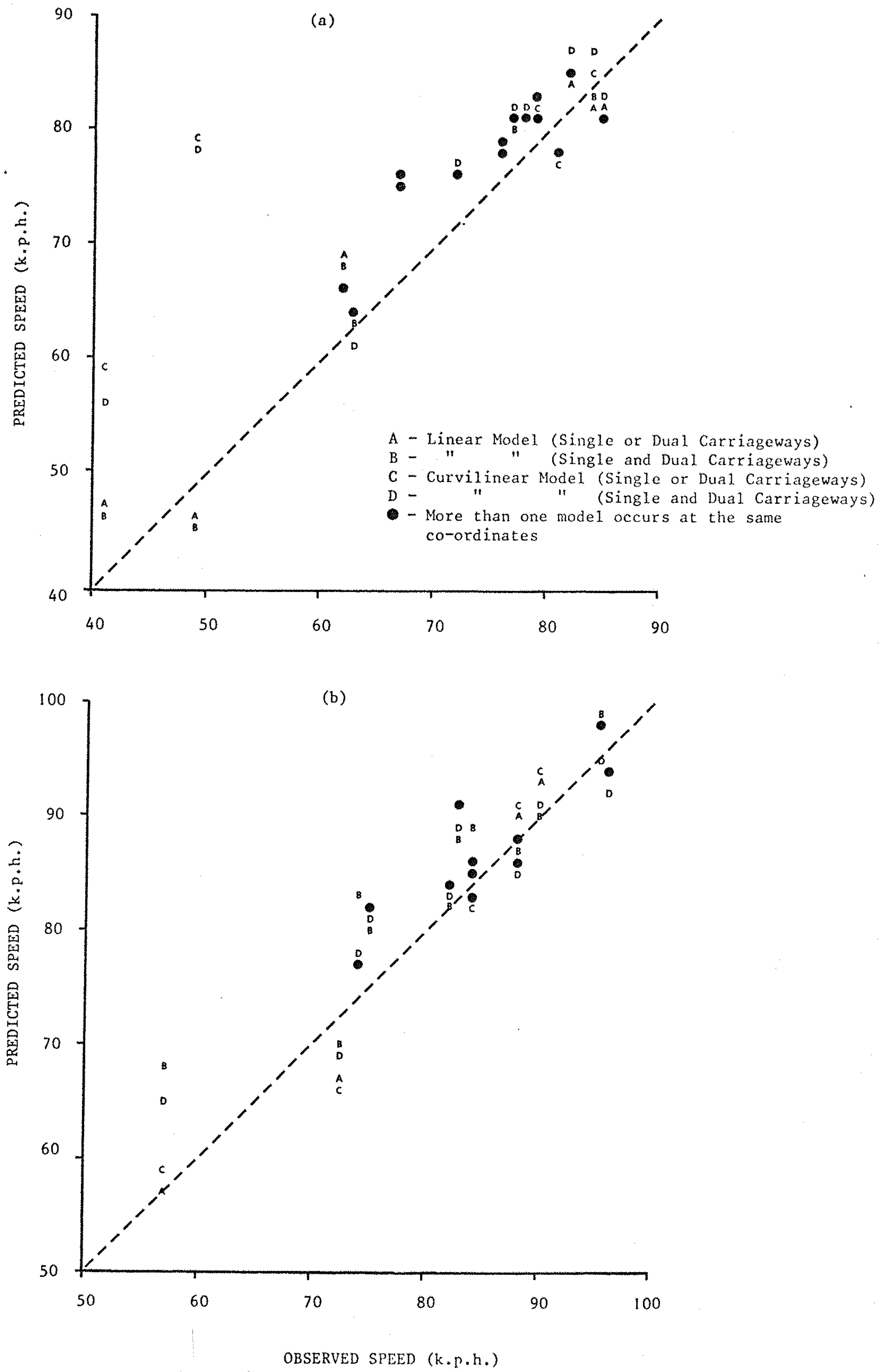


Figure 6.28 : Plots of Observed Middle Speeds against Predicted Middle Speeds for various Regression Models
((a) Single Carriageways, (b) Dual Carriageways - All Cars)

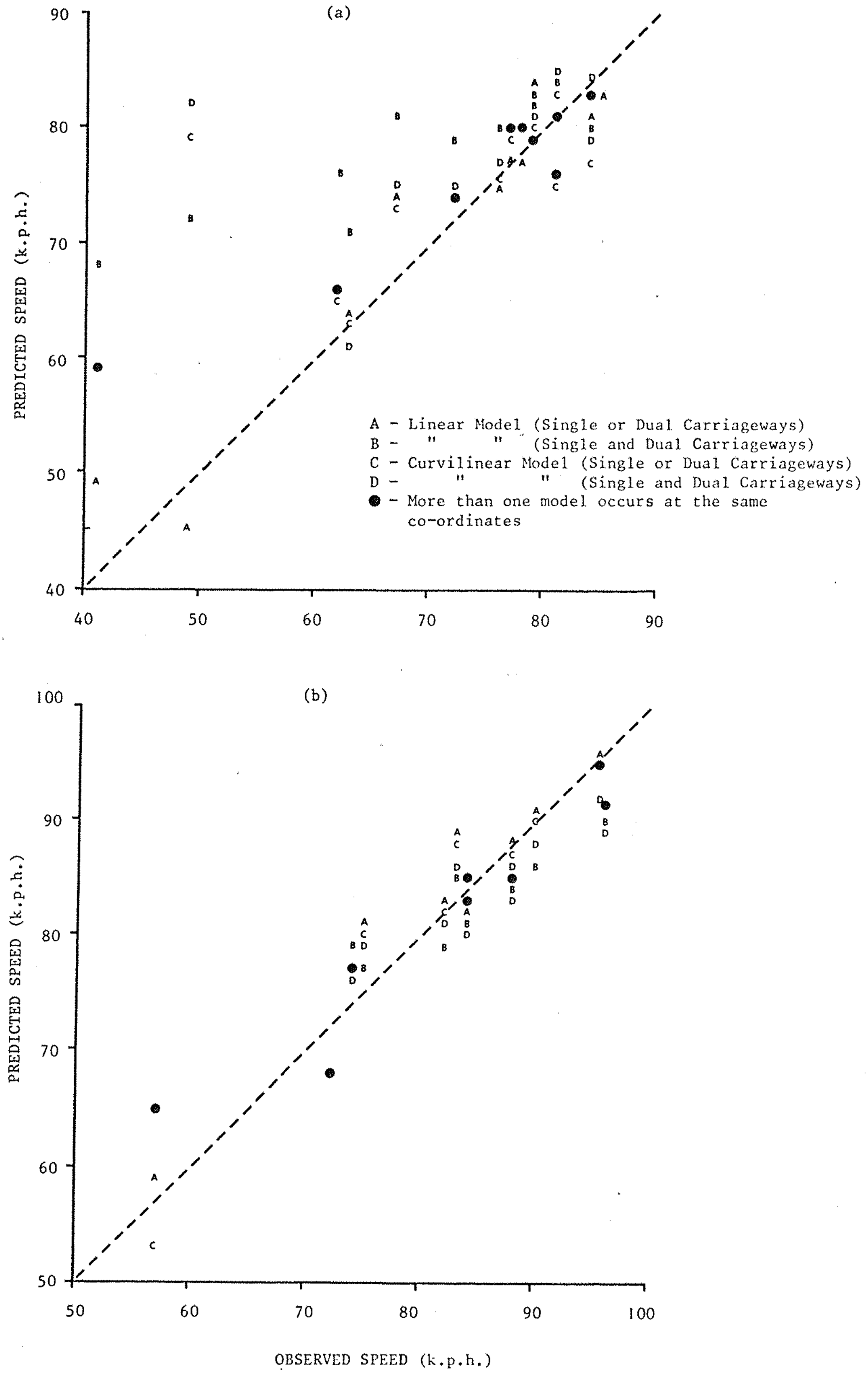


Figure 6.29: Plots of Observed Middle Speeds against Predicted Middle Speeds for various Regression Models
((a) Single Carriageways, (b) Dual Carriageways - Selected All Cars)

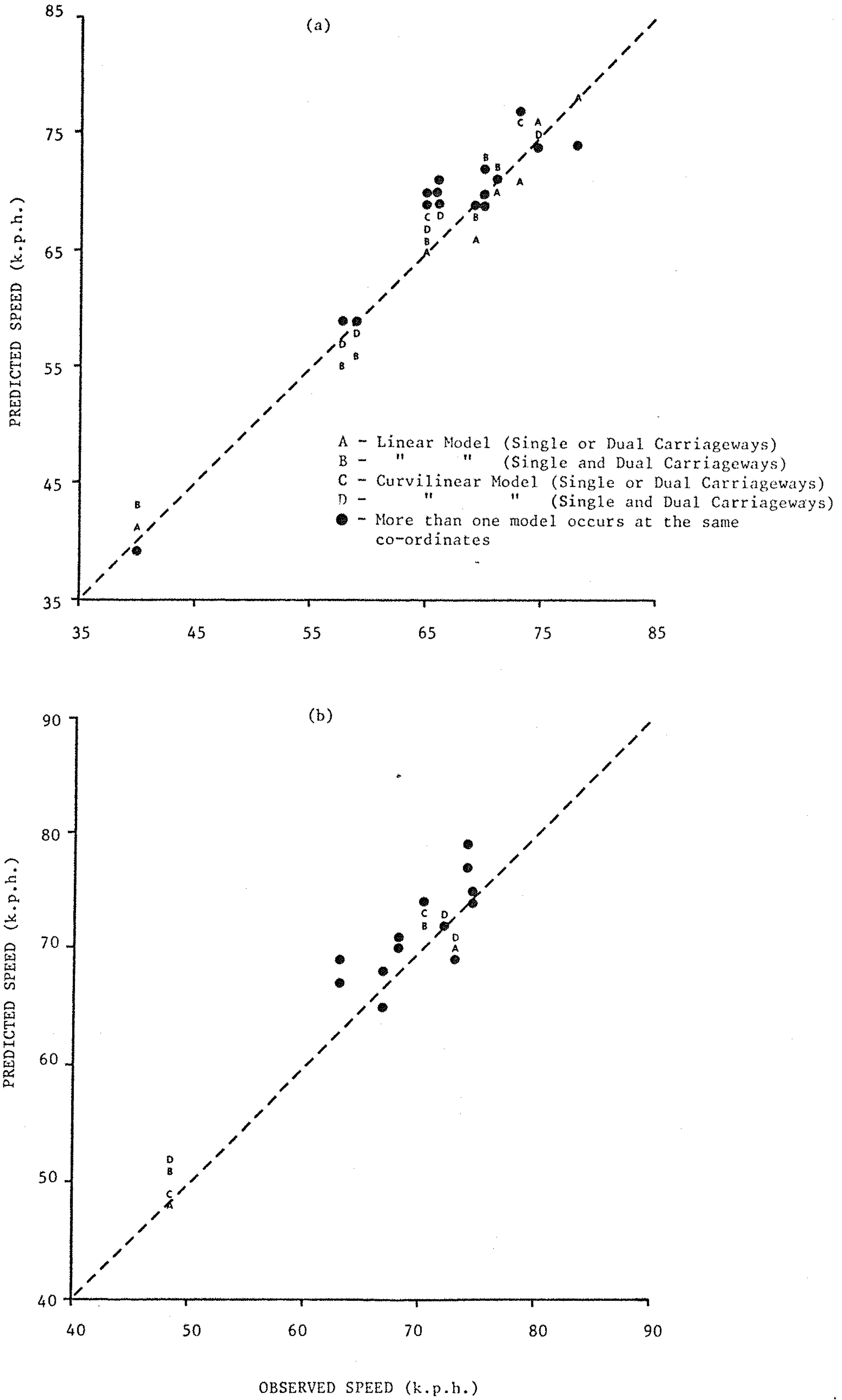
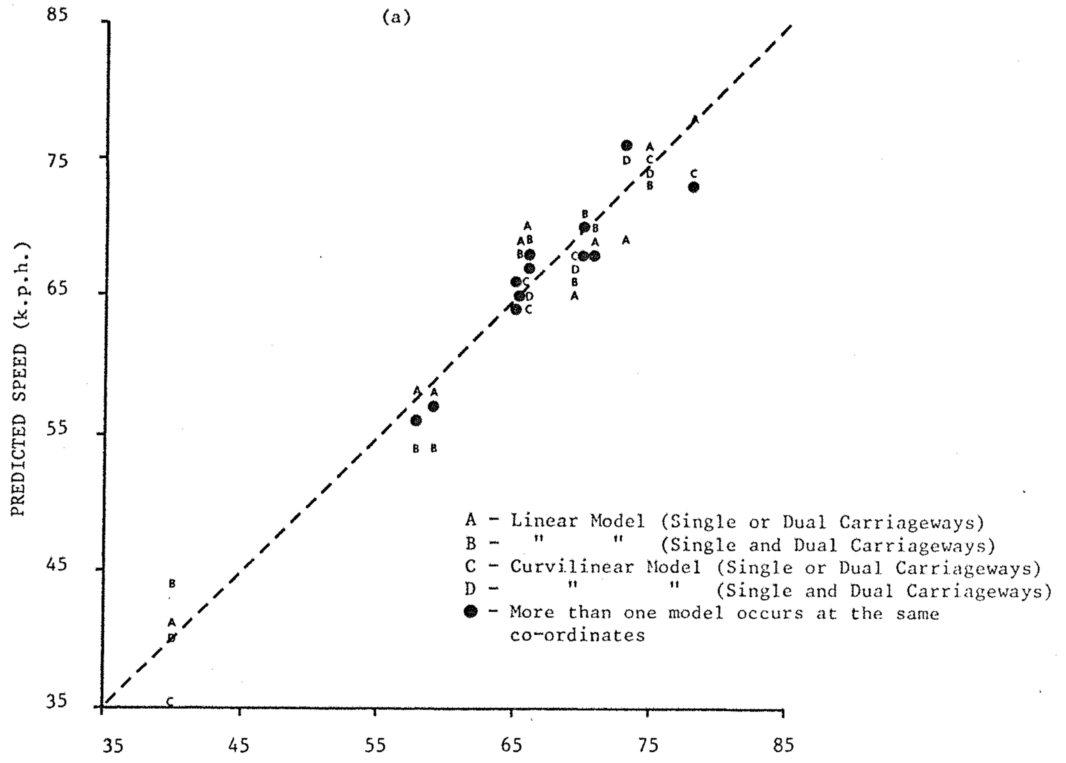


Figure 6.30 : Plots of Observed Middle Speeds against Predicted Middle Speeds for various Regression Models ((a) Single Carriageways, (b) Dual Carriageways - Goods Vehicles)



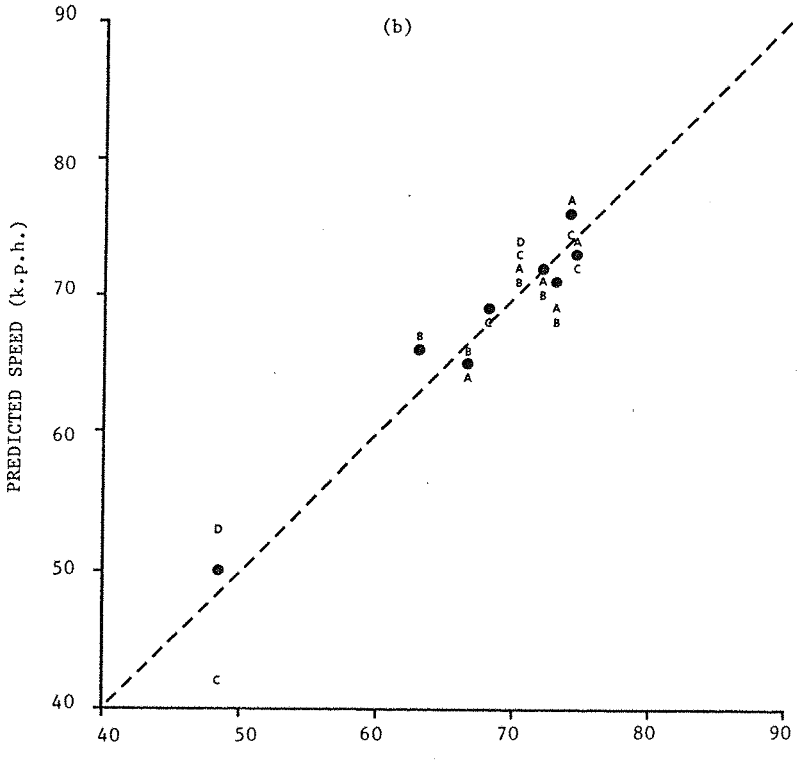


Figure 6.31: Plots of Observed Middle Speeds against Predicted Middle Speeds for various Regression Models ((a) Single Carriageways, (b) Dual Carriageways - Selected Goods Vehicles)

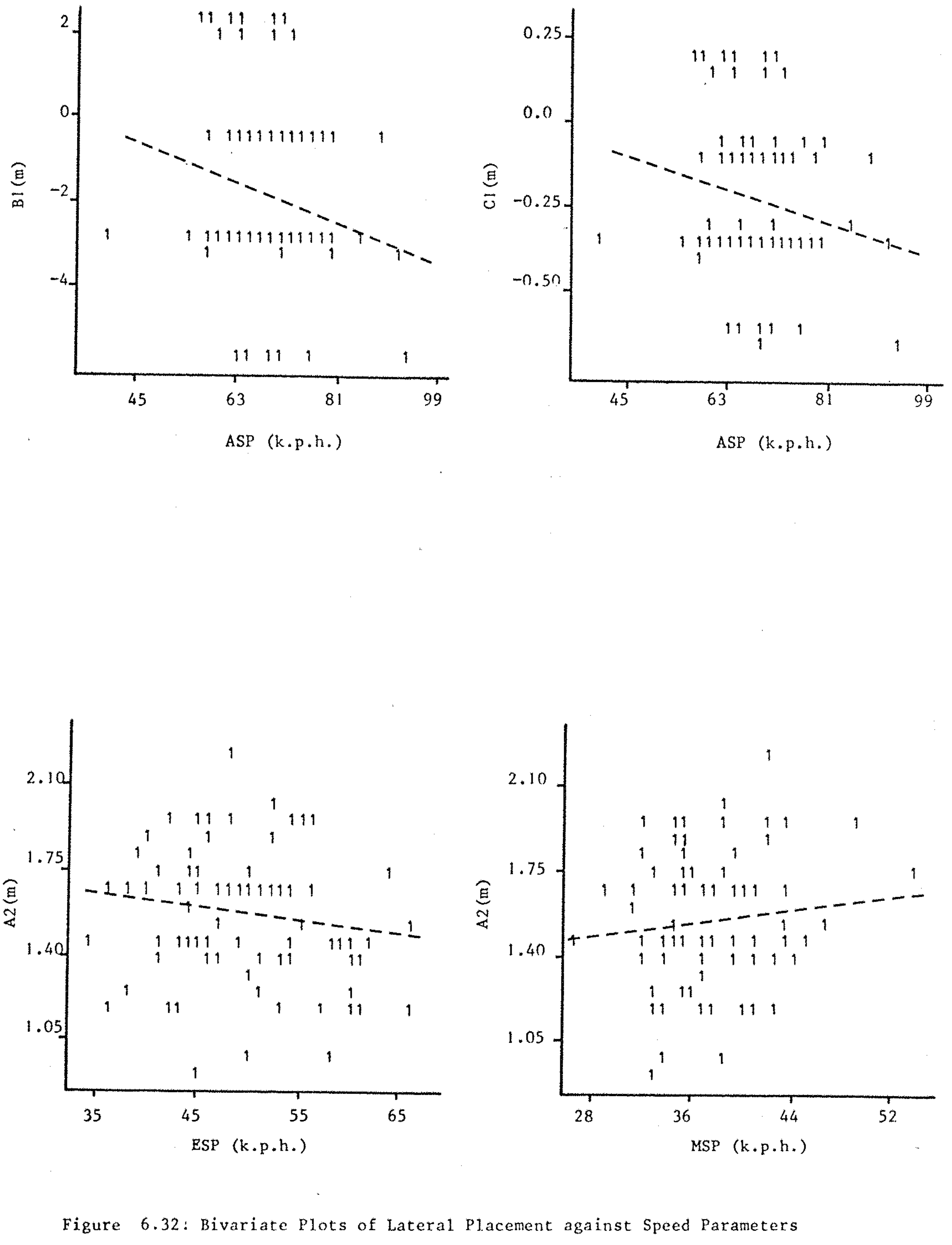


Figure 6.32: Bivariate Plots of Lateral Placement against Speed Parameters
(Single Carriageways - Free Car - Site Code 17 - Left Hand Curve)

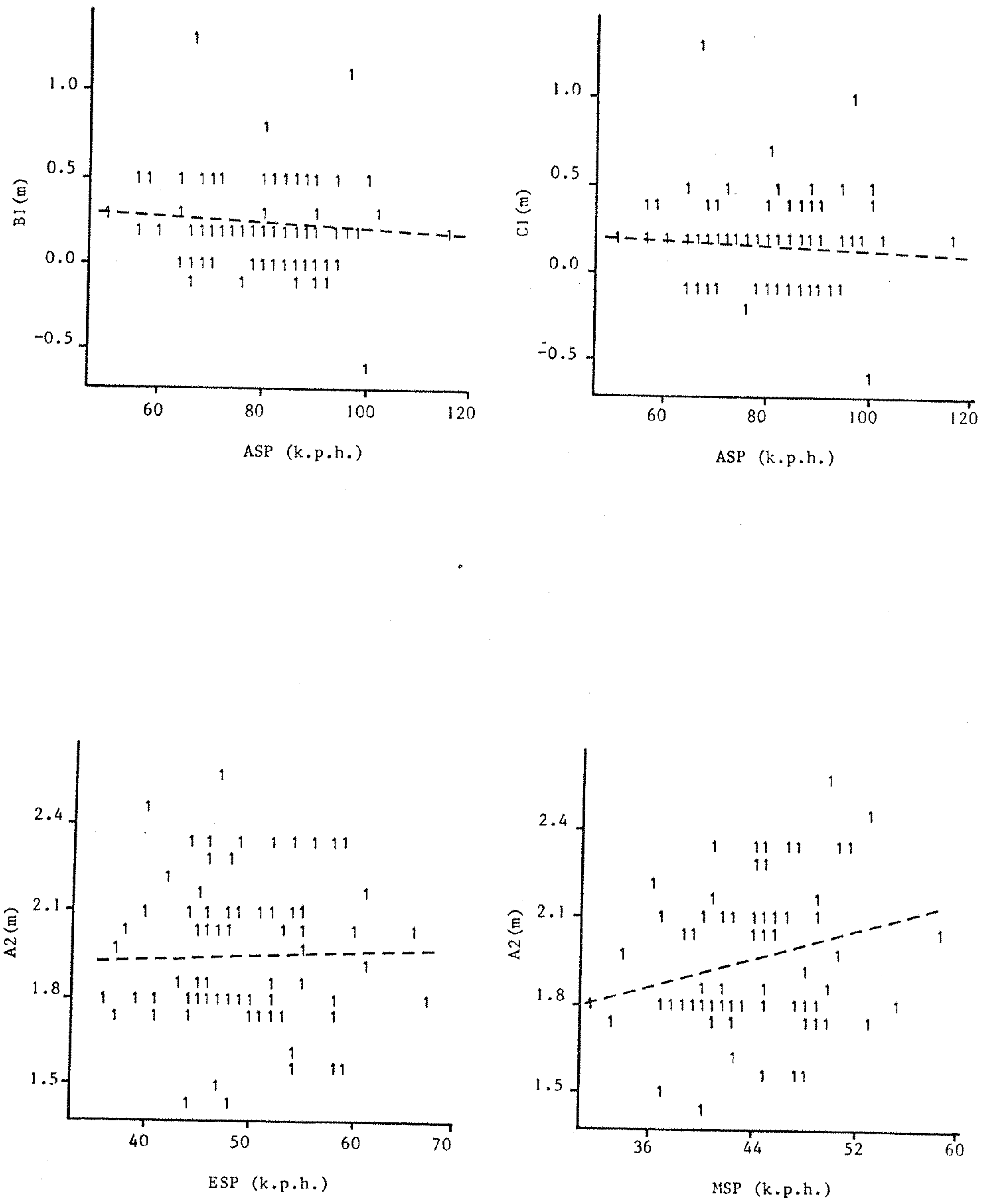


Figure 6.33 : Bivariate Plots of Lateral Placement against Speed Parameters
(Single Carriageways - Free Car - Site Code 8 - Right Hand Curve)

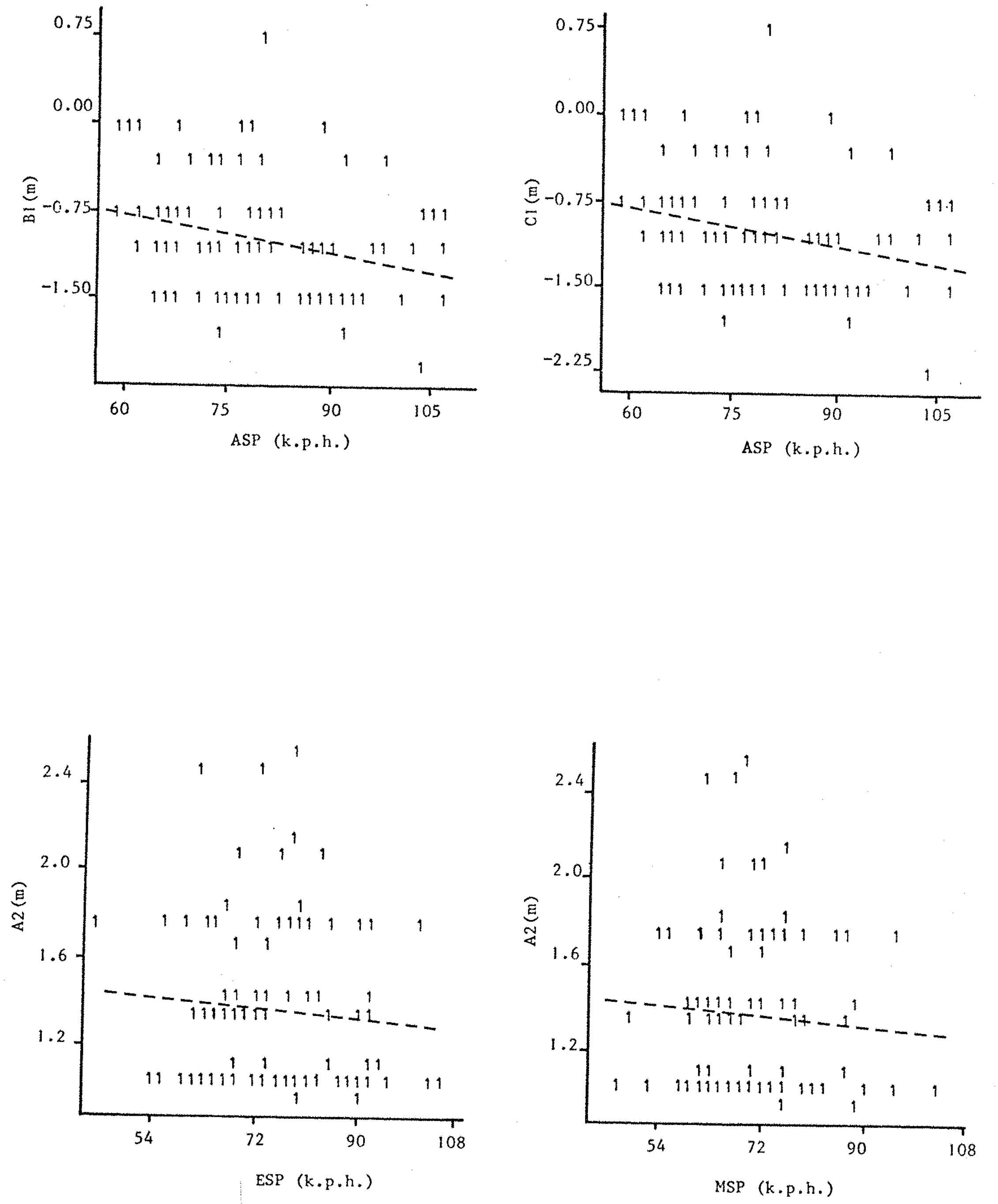


Figure 6.34: Bivariate Plots of Lateral Placement against Speed Parameters
(Single Carriageways - Free Car - Site Code 29 - Left Hand Curve)

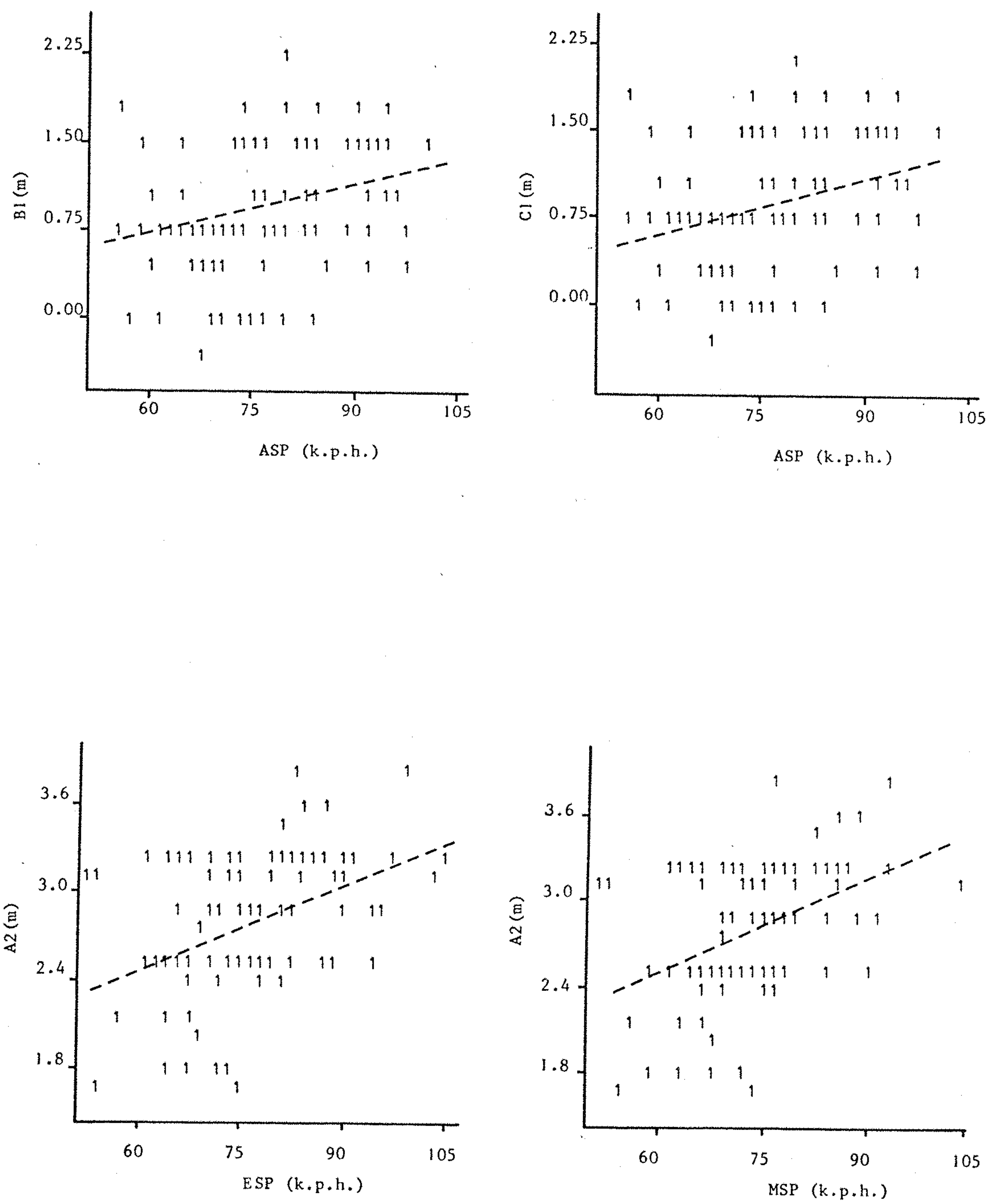


Figure 6.35: Bivariate Plots of Lateral Placement against Speed Parameters (Single Carriageways - Free Car - Site Code 30 - Right Hand Curve)

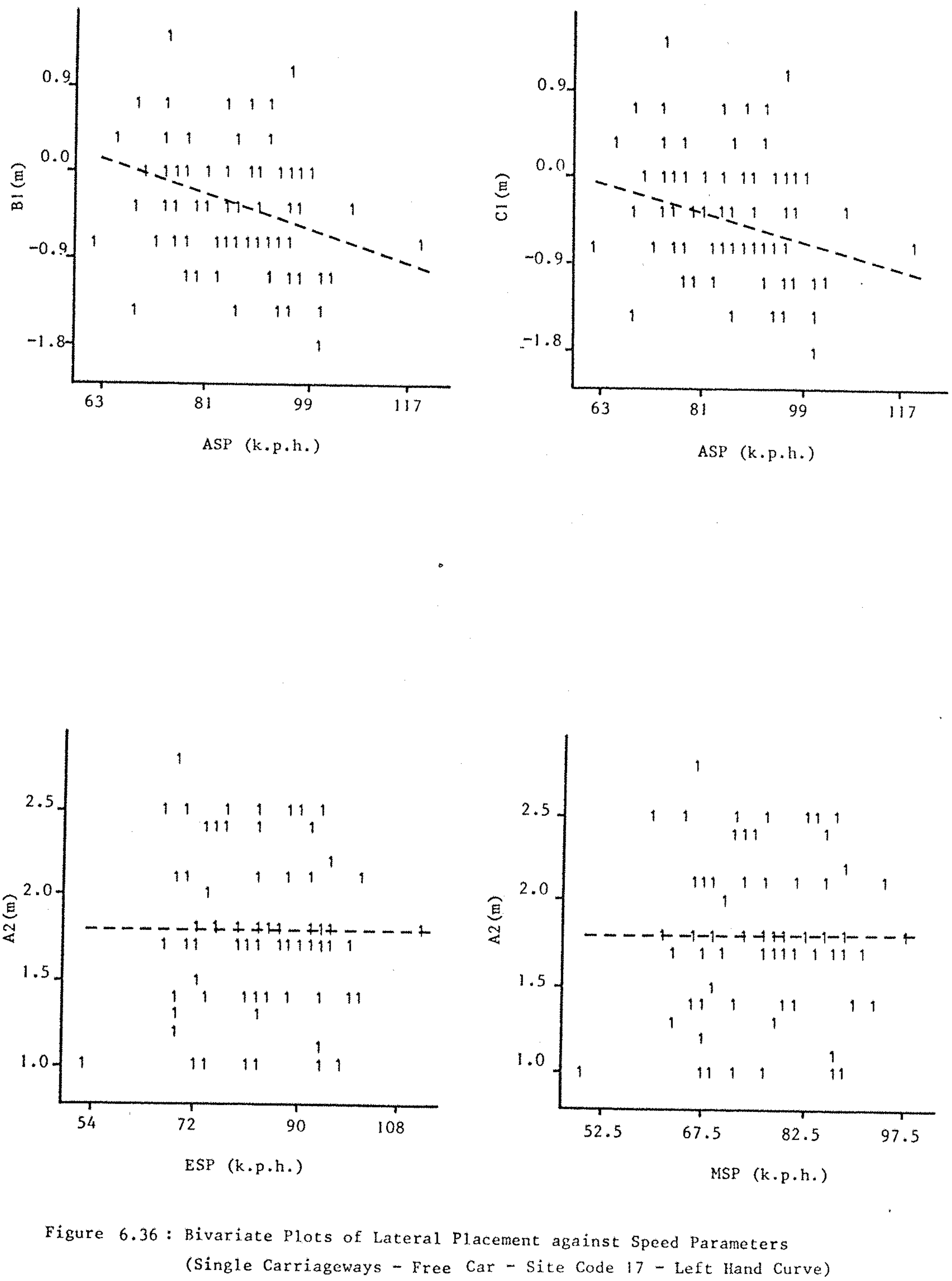


Figure 6.36 : Bivariate Plots of Lateral Placement against Speed Parameters
(Single Carriageways - Free Car - Site Code 17 - Left Hand Curve)

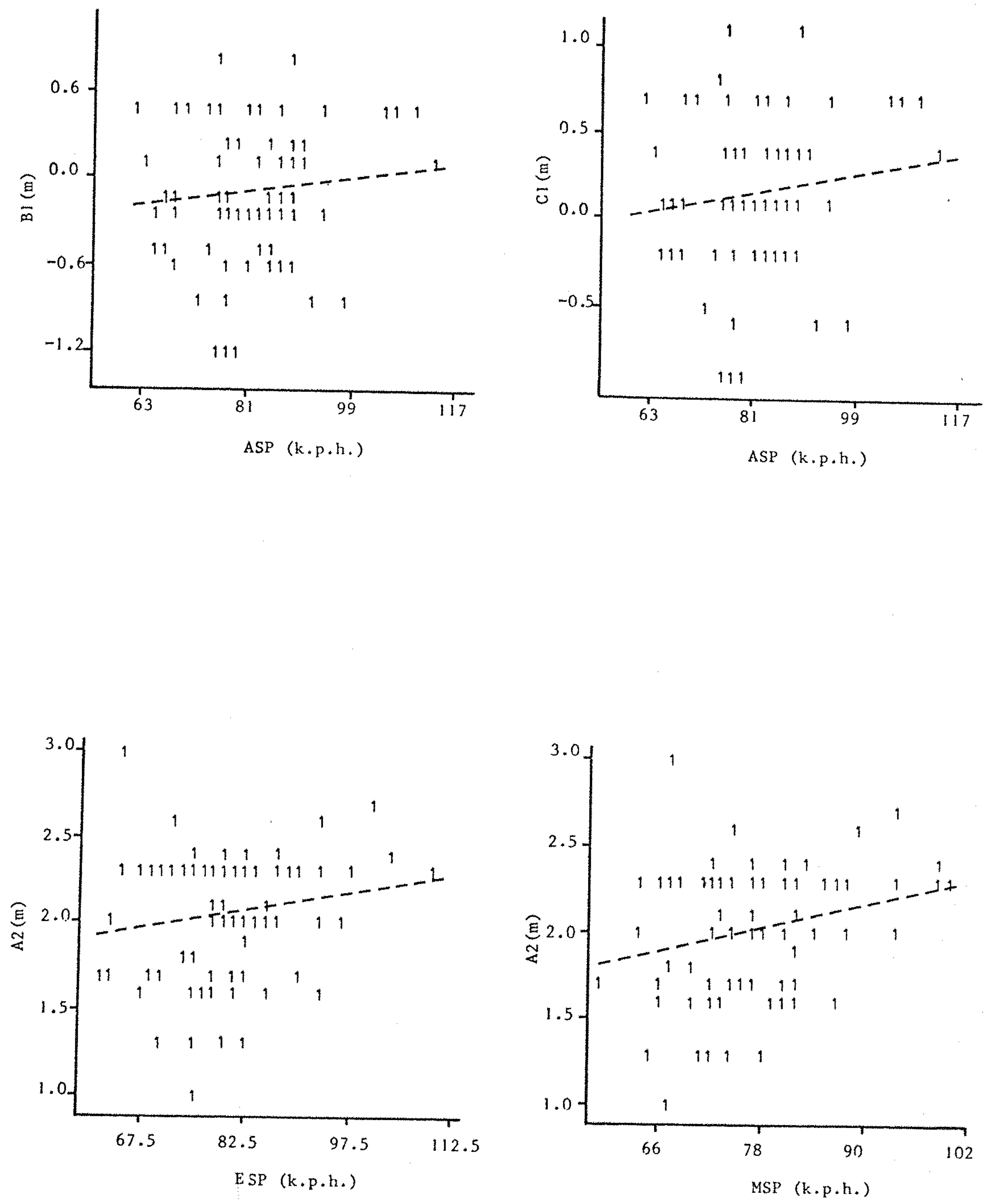


Figure 6.37 : Bivariate Plots of Lateral Placement against Speed Parameters (Single Carriageways - Free Car - Site Code 18 - Right Hand Curve)

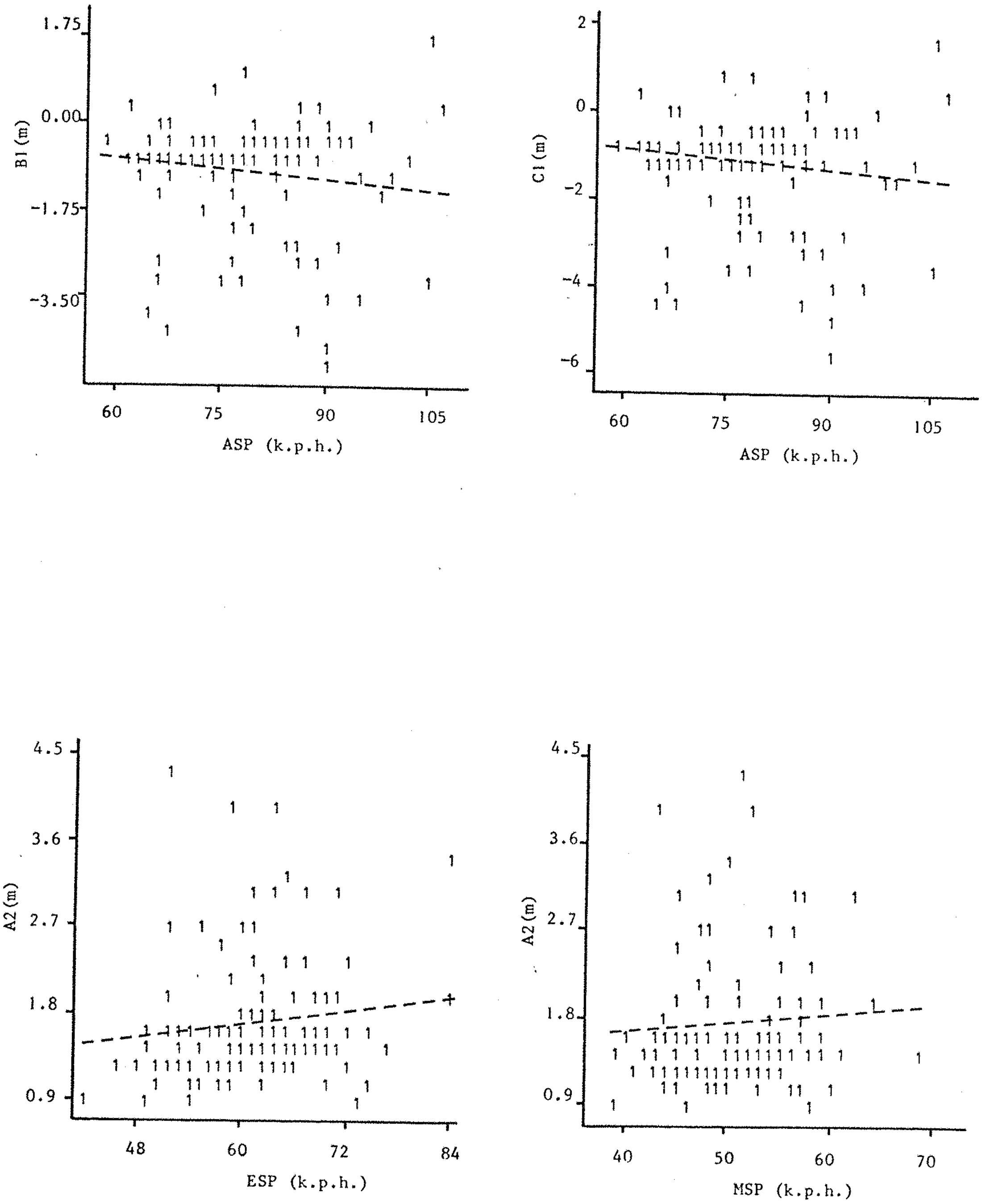


Figure 6.38: Bivariate Plots of Lateral Placement against Speed Parameters (Dual Carriageways - Free Car - Site Code 12 - Left Hand Curve)

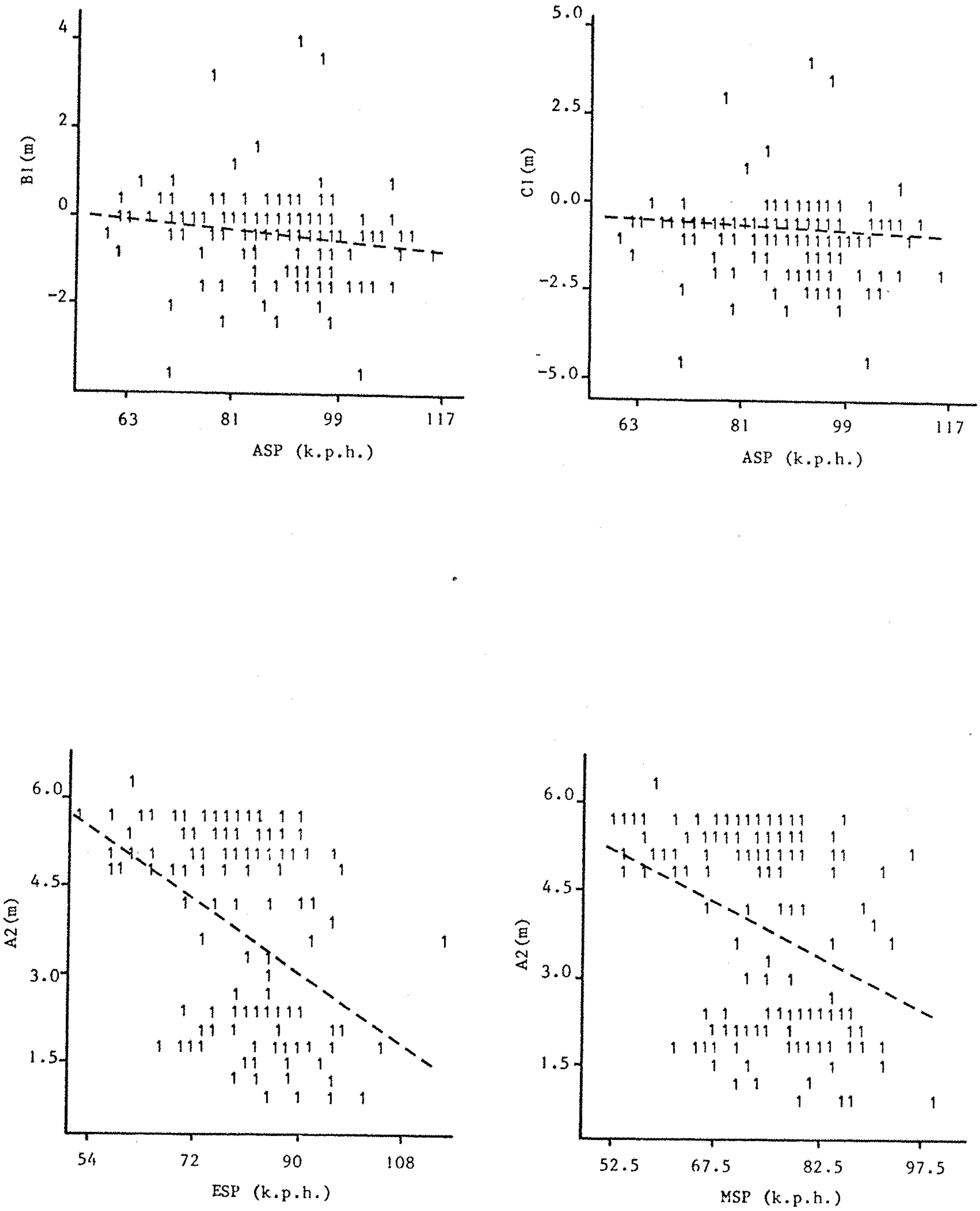


Figure 6.39 : Bivariate Plots of Lateral Placement against Speed Parameters
(Dual Carriageways - Free Car - Site Code 4 - Right Hand Curve)

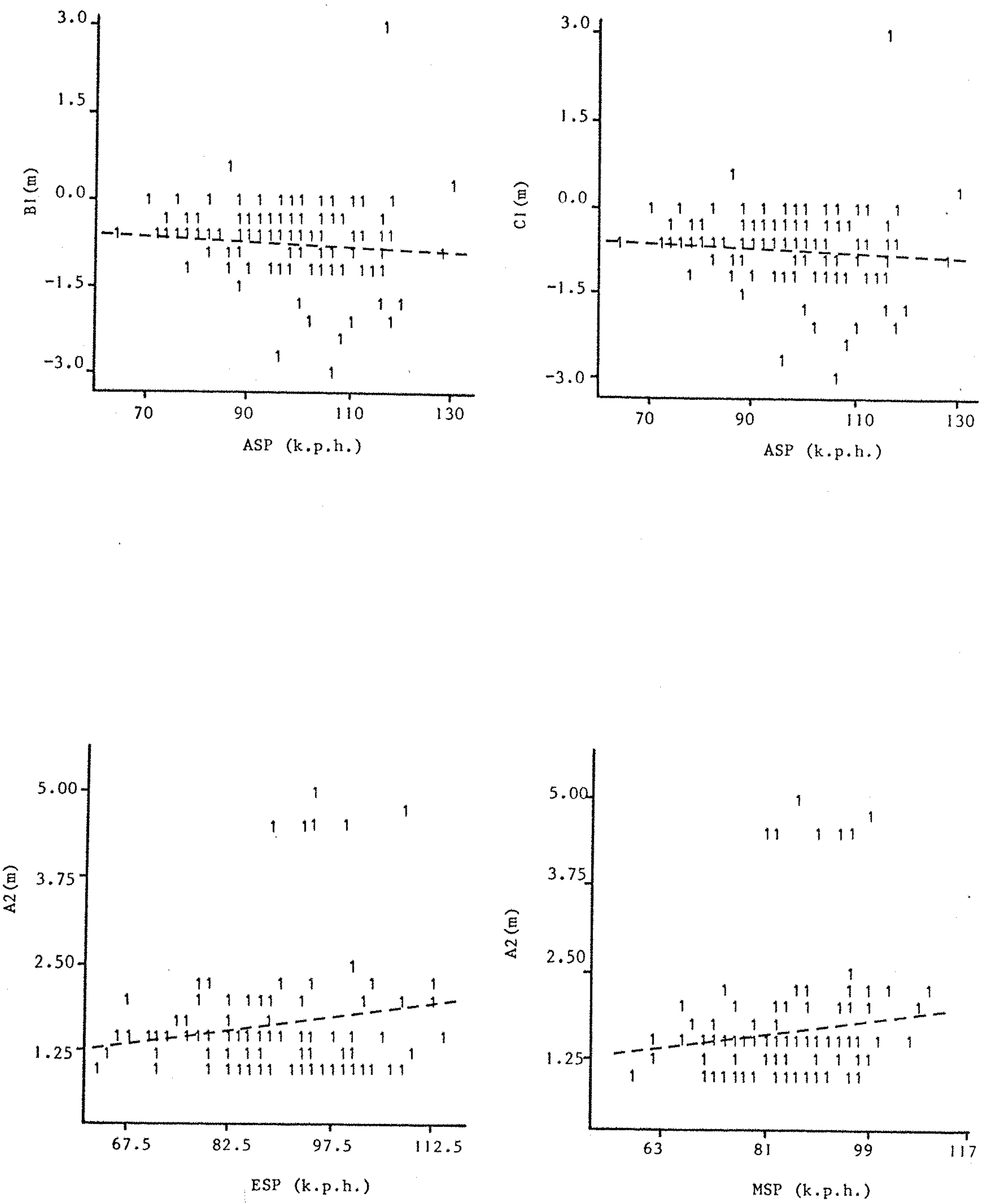


Figure 6.40 : Bivariate Plots of Lateral Placement against Speed Parameters (Dual Carriageways - Free Car - Site Code 14 - Left Hand Curve)

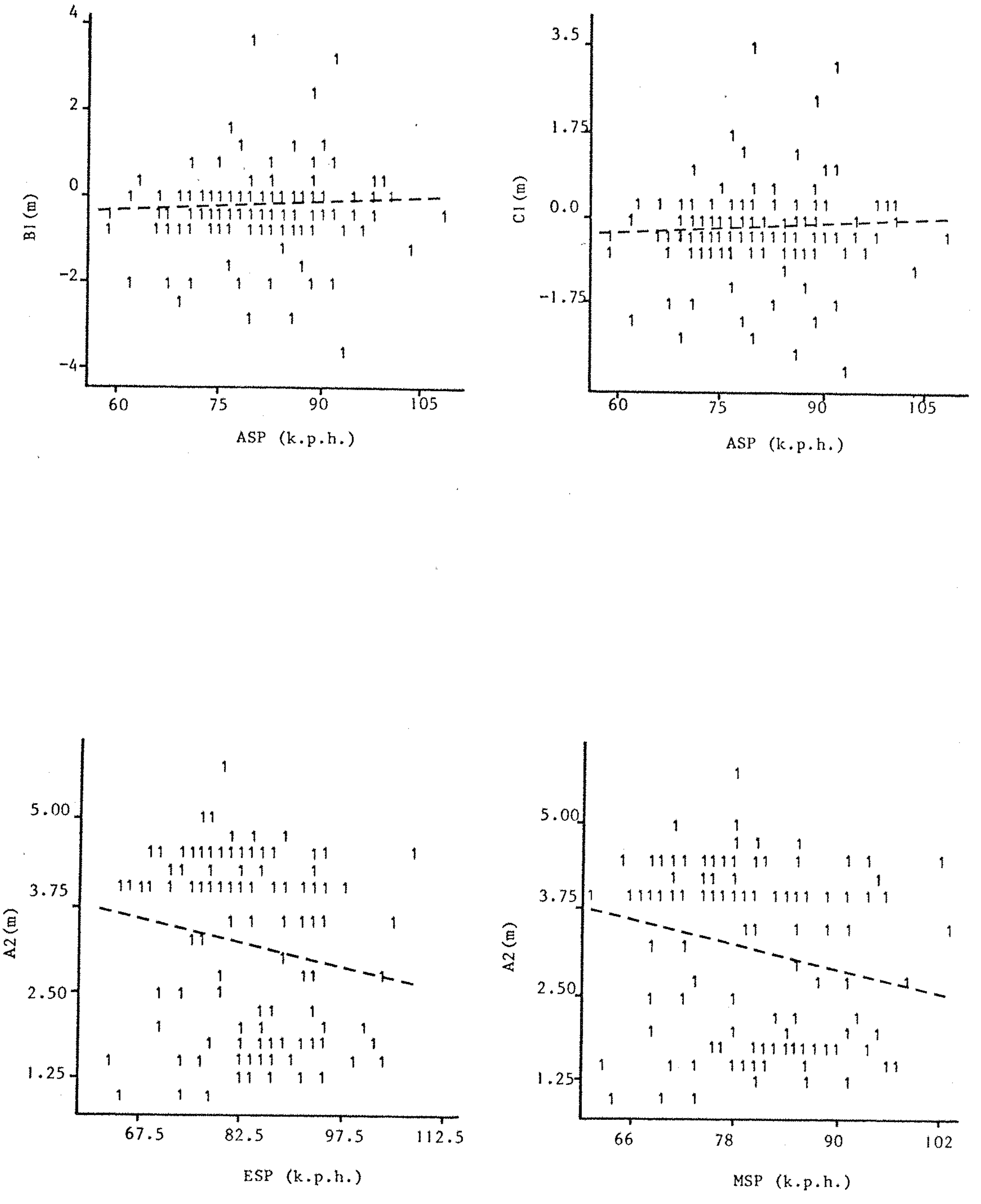


Figure 6.41 : Bivariate Plots of Lateral Placement against Speed Parameters
(Dual Carriageways - Free Car - Site Code 10 - Right Hand Curve)

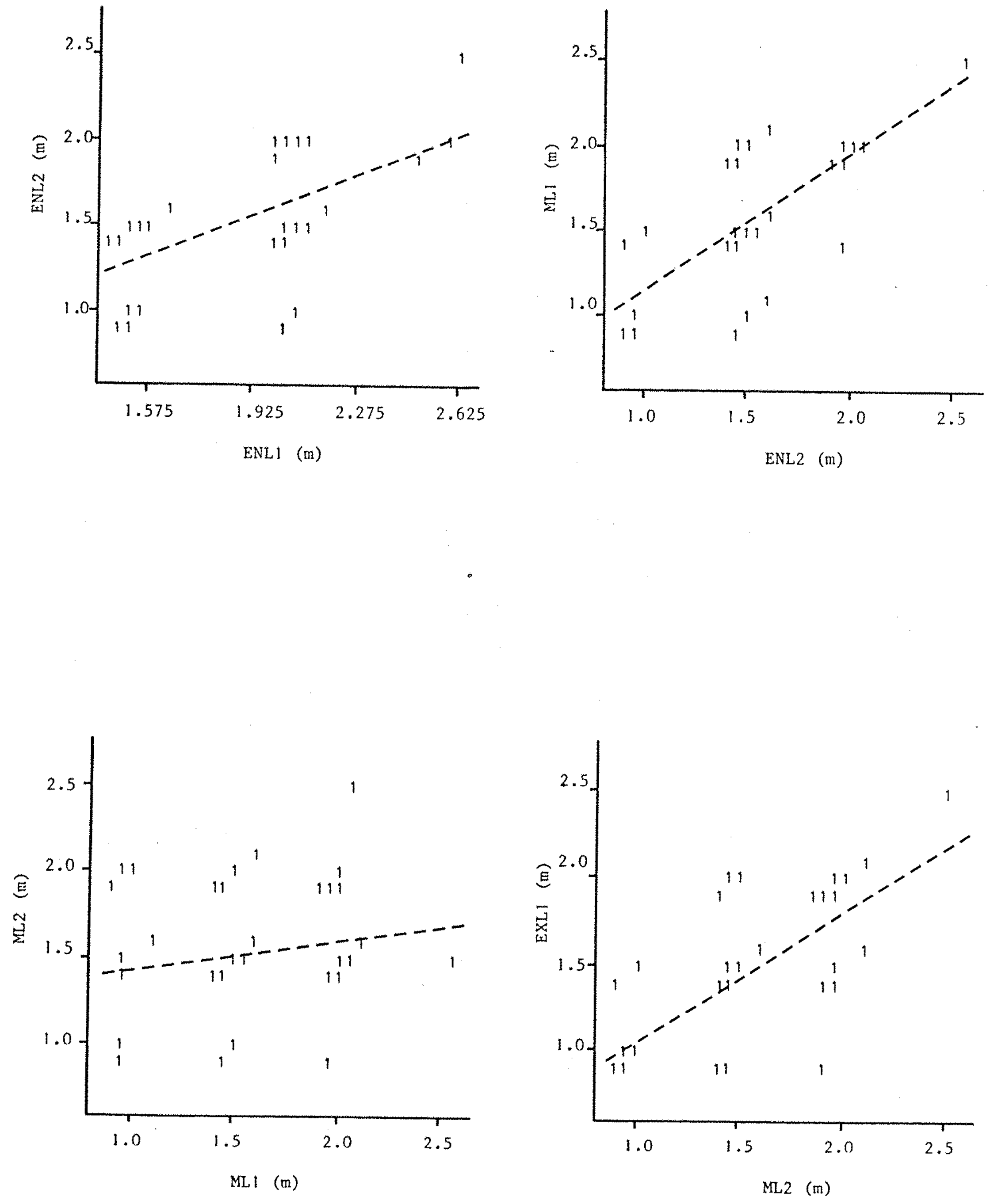


Figure 6.42 : Plots of Lateral Placement for Various Locations around the Curve (Single Carriageway - Free Car - Site Code 7 - Left Hand Curve)

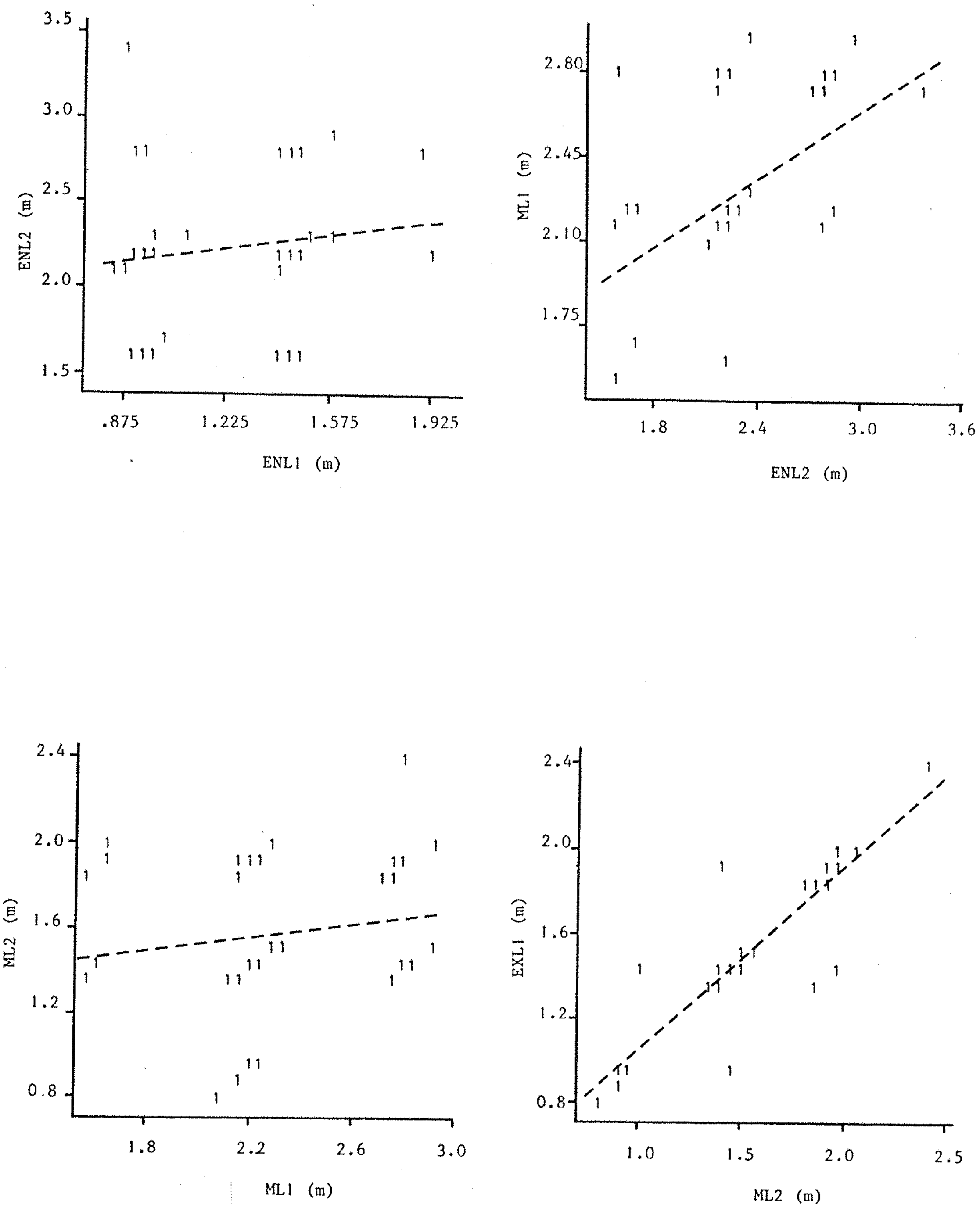


Figure 6.43 : Plots of Lateral Placement for Various Locations around the Curve
(Single Carriageway - Free Car - Site Code 8 - Right Hand Curve)

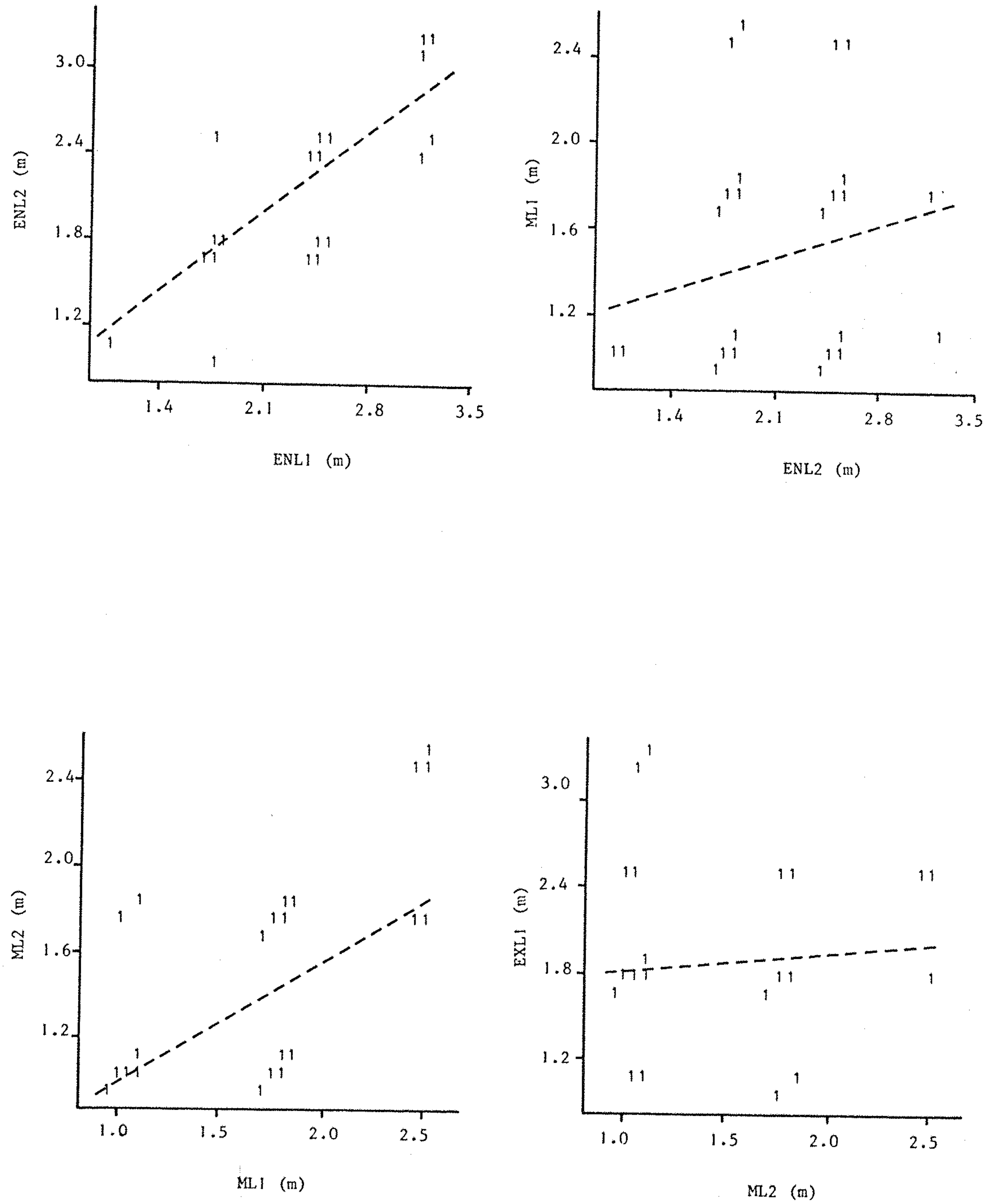


Figure 6.44 : Plots of Lateral Placement for Various Locations around the Curve
(Single Carriageway - Free Car - Site Code 29 - Left Hand Curve)

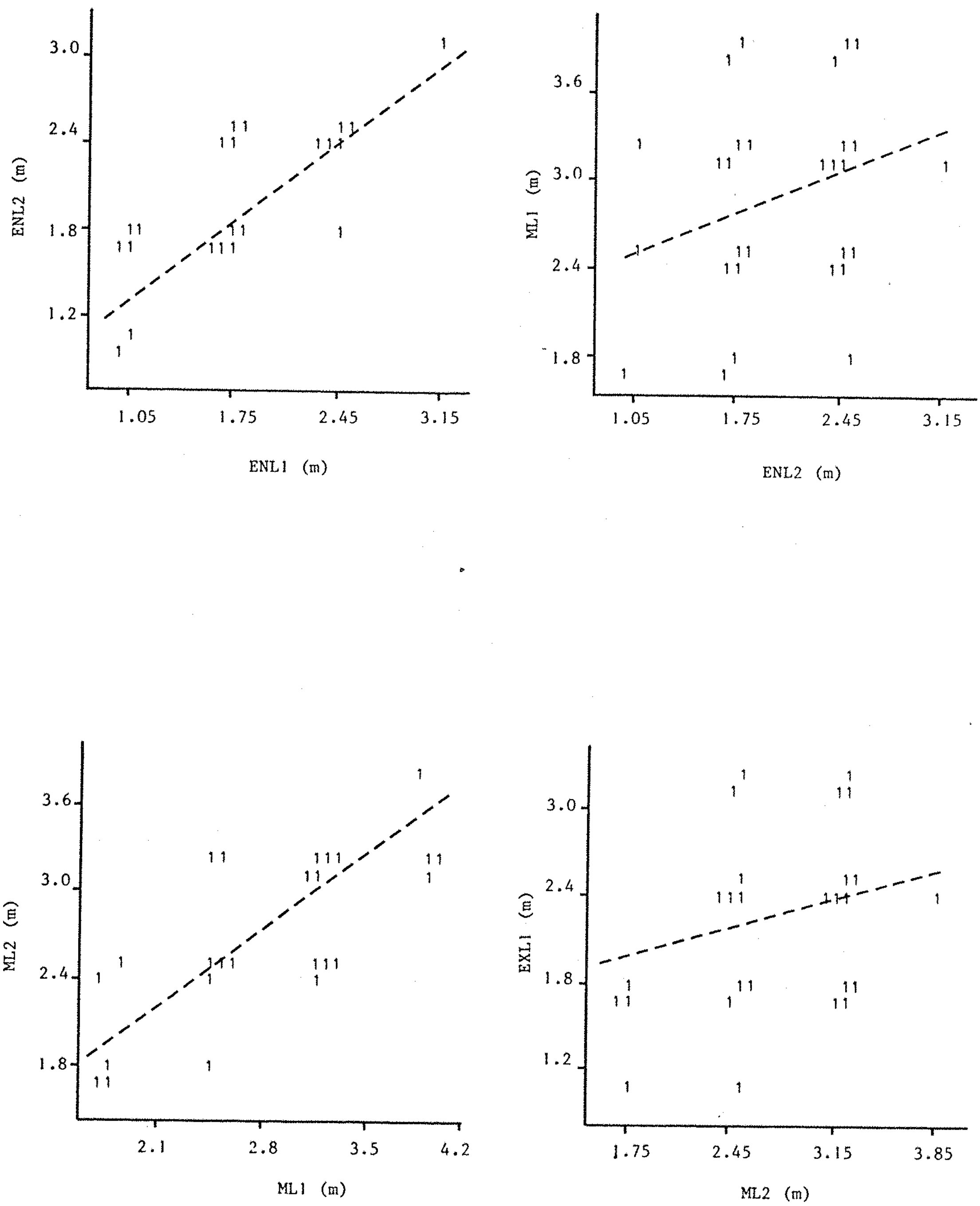


Figure 6.45 : Plots of Lateral Placement for Various Locations around the Curve
(Single Carriageway - Free Car - Site Code 30 - Right Hand Curve)

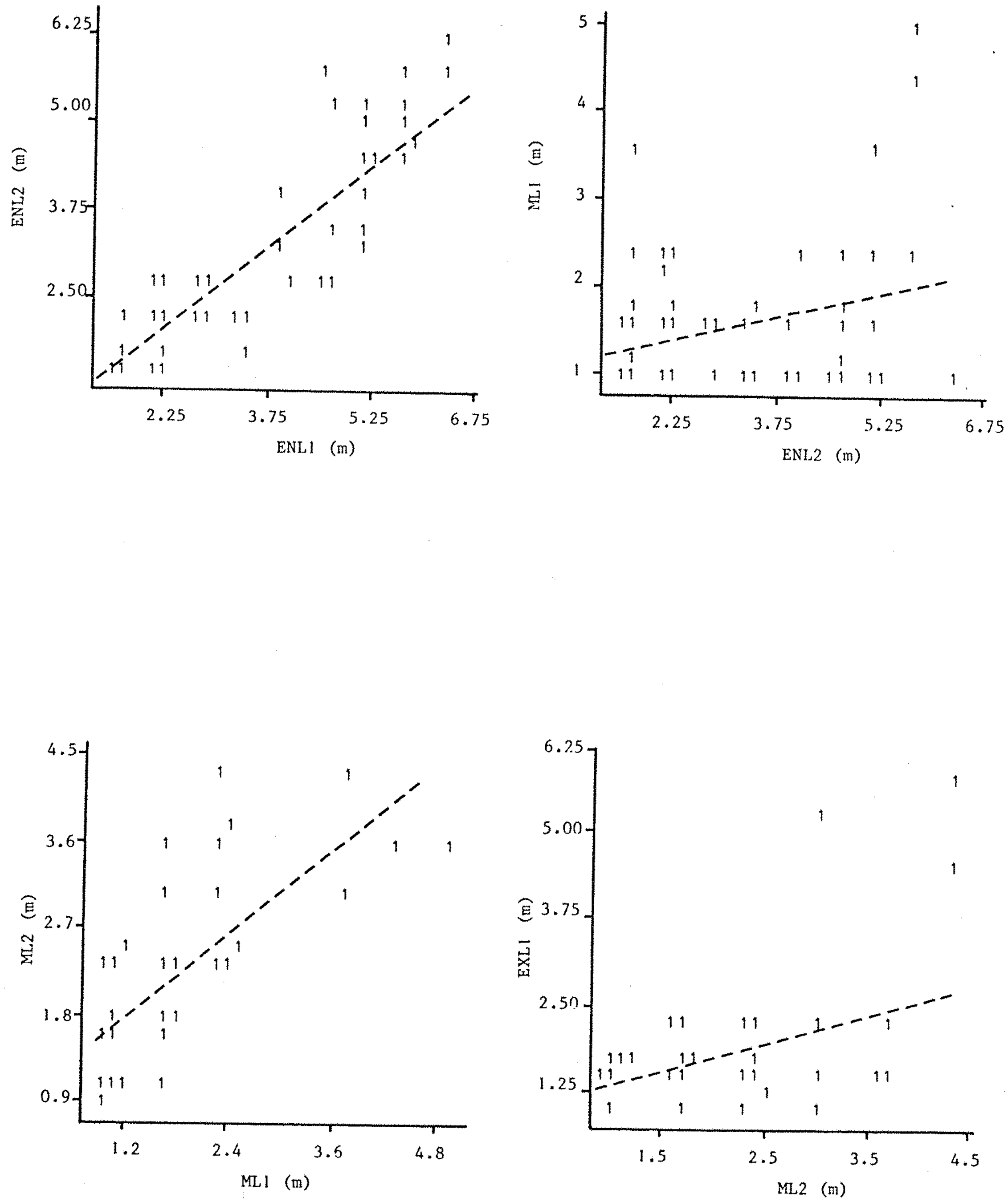
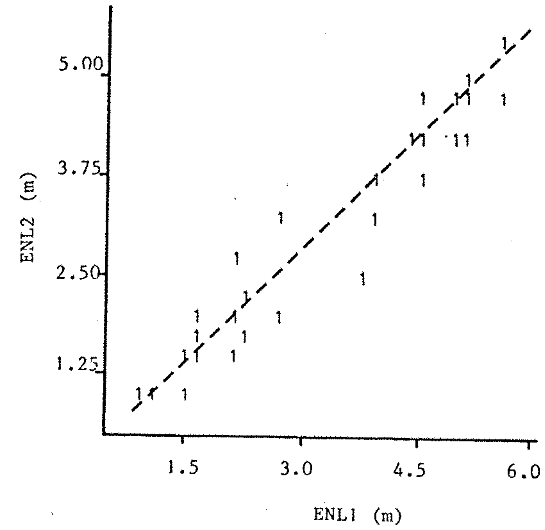
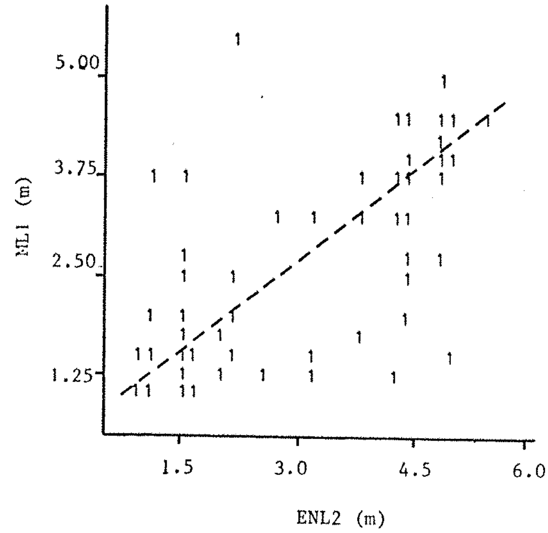
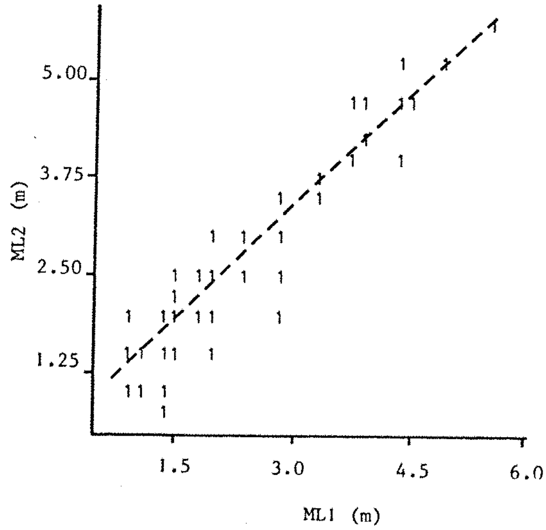


Figure 6.46 : Plots of Lateral Placement for Various Locations around the Curve (Dual Carriageway - Free Car - Site 12 - Left Hand Curve)







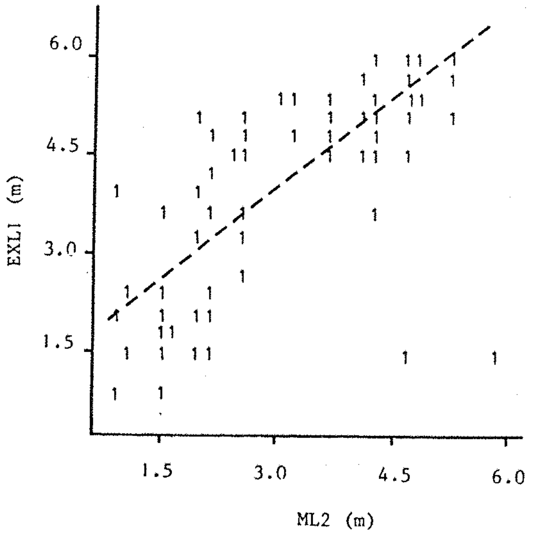


Figure 6.47 : Plots of Lateral Placement for Various Locations around the Curve
(Dual Carriageway - Free Car - Site Code 4 - Right Hand Curve)

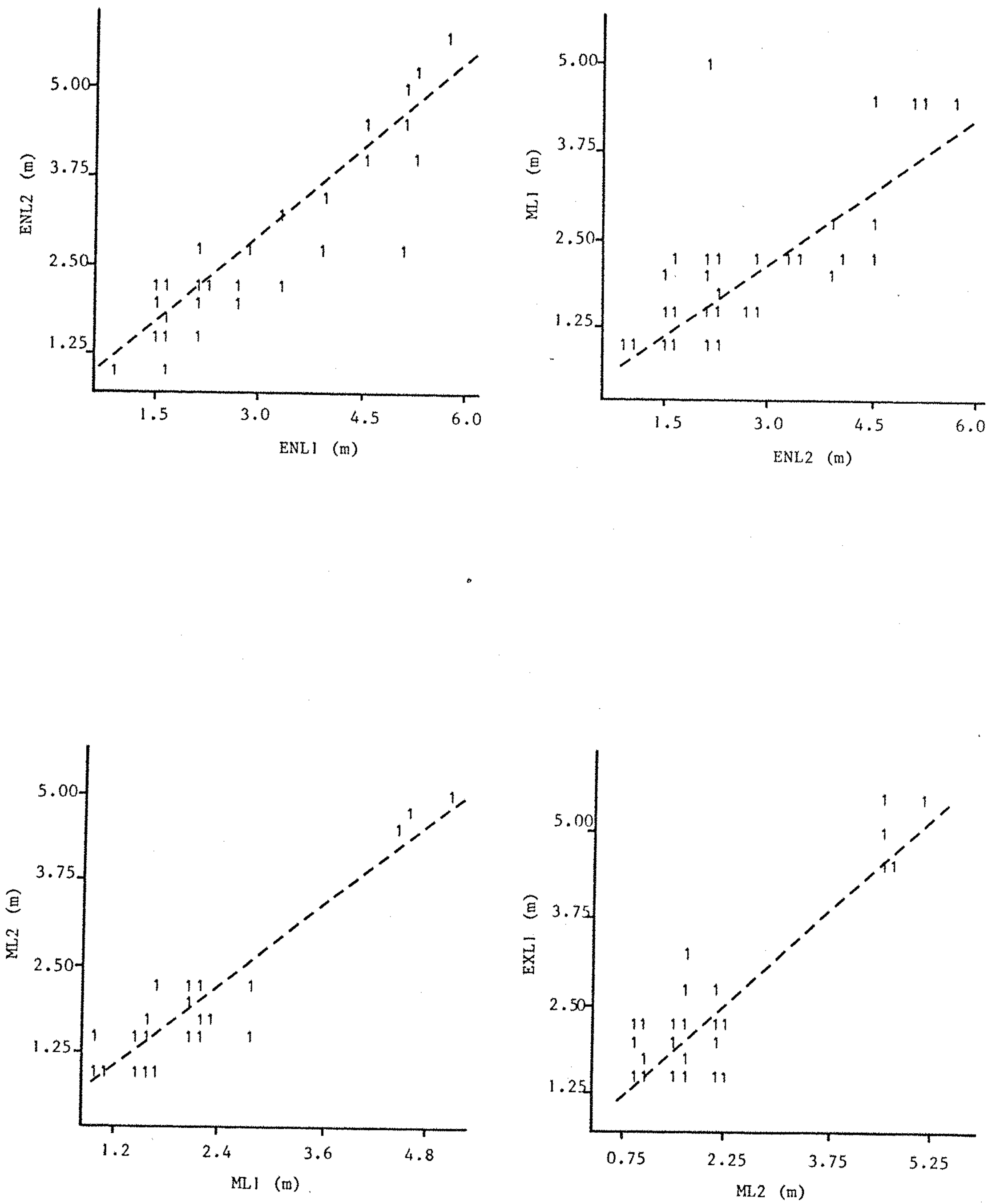


Figure 6.48 : Plots of Lateral Placement for Various Locations around the Curve (Dual Carriageways - Free Car - Site Code 14 - Left Hand Curve)

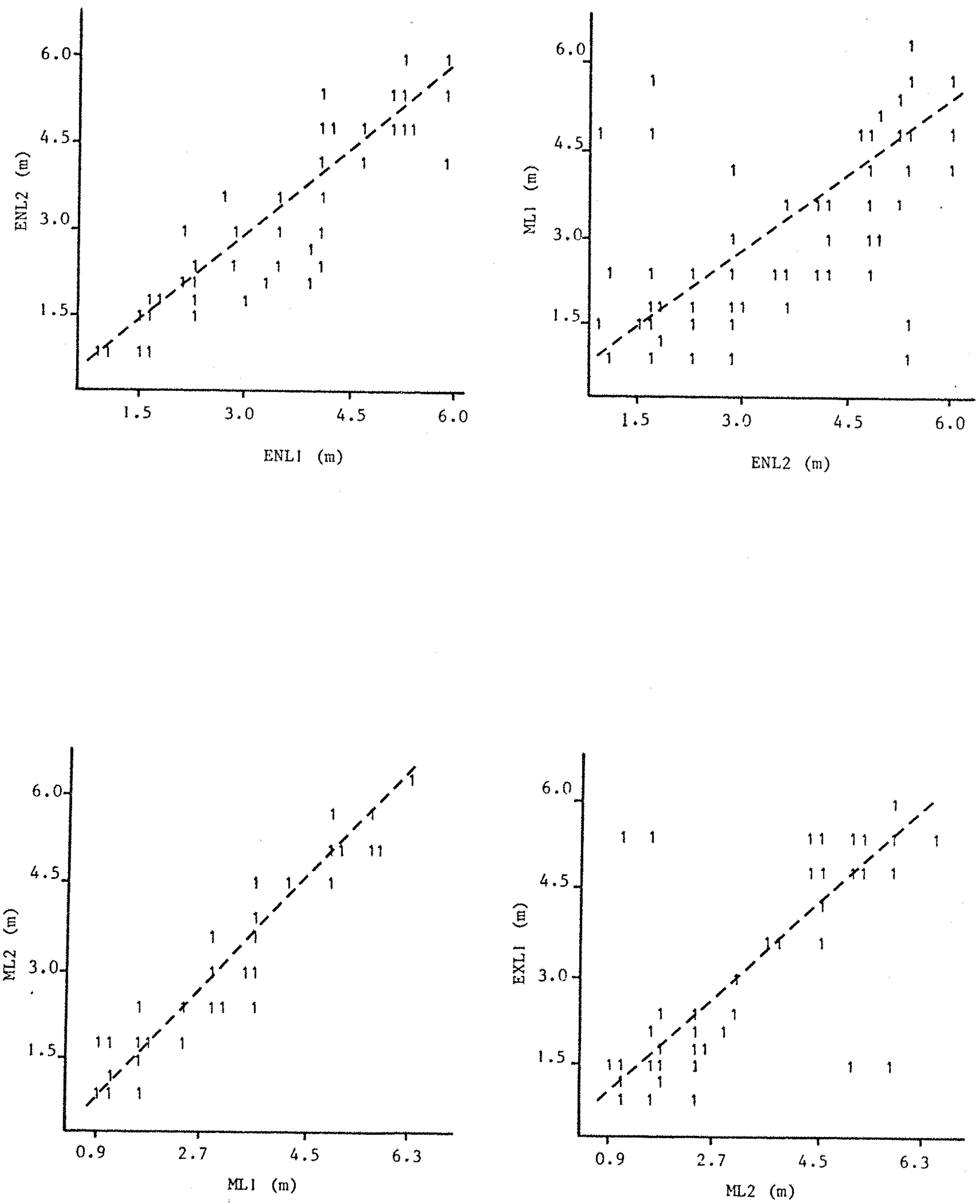


Figure 6.49 : Plots of Lateral Placement for Various Locations around the Curve
(Dual Carriageway - Free Car - Site Code 10 - Right Hand Curve)

CHAPTER SEVEN

DISCUSSION OF CURRENT HORIZONTAL ALIGNMENT POLICIES

7.1 INTRODUCTION

As described previously (see Chapter 2), some lack of uniformity has been found to exist between the various current British, American, Australian and German Design Policies. There is some evidence that current Design Policies do not completely represent public drivers' preference.

One of the most important design aspects is that of minimum horizontal curve radius, especially on low speed roads. Foreign evidence[22,41,57] suggests that on low radius single carriageway curves car drivers tend to develop higher lateral acceleration values than those assumed in the Design Policies. However, on larger radius curves speeds are generally less than the adopted safe curve speeds.

The following two comparison tests were performed to investigate the adequacy of some of the outstanding Design Policies and especially of the new Highway Link Design Departmental Standard[17].

a. Relationships between minimum design elements such as design speed, minimum curve radius and maximum lateral acceleration assumed by Design Policies were compared to the corresponding relationships observed for the 85th percentile public driver for all cars and goods vehicles.

b. The 85th percentile curve middle speeds for all cars and goods vehicles were compared to the curve safe speeds as defined by the British Design Policies[17].

Single and dual carriageways were treated separately.

The curve safe speed is regarded as the maximum speed at which a vehicle can negotiate a curve without exceeding the Department of Transport lateral acceleration criterion according to the centripetal equation:

$$E+f=\frac{V^2}{127R}$$

7.2 BRITISH DESIGN POLICY

In the new British Design Standard for Highway Link Design[17] minimum design elements are determined on the basis of the Design Speed which is taken as the 85th percentile speed of travel for light vehicles under wet road surface conditions. There are also three different minimum levels of design defined as Desirable, Absolute and Limiting Radius which correspond to different levels of comfort and safety. For each of these minimum levels of design a constant distribution of lateral acceleration is assumed for the determination of the maximum design curvatures.

In Figure 7.1 the relationships between the Design speed and the minimum curve radius for the three different minimum levels of design are compared with the relationships observed between the 85th percentile curve middle speed and curve radius. All car data on single and dual carriageways, as well as goods vehicle data on single carriageways are treated separately.

It can be seen that observed 85th percentile car speeds are generally in excess of the assumed Design speeds for curves with radii ranging from about 230m for the Limiting Radius minimum to 330m for the Absolute minimum and to 500m for the Desirable minimum design level. The corresponding figures for goods vehicles are about 180m, 250m and 350m for the three design levels respectively. It must be noted here that whereas design speed is a travel speed (space-mean speed), the observed speed is a time-mean speed and thus theoretically higher than the first. However, the design assumption that the design speed must not be exceeded at any point along the road section certifies the validity of the comparison test.

Figure 7.2 is very similar to Figure 7.1 with the speed variable having been replaced by the lateral acceleration. The difference in the overall form between the design and the observed relationships can clearly be seen. Drivers appear to accept higher lateral acceleration values on both single and dual carriageway lower radius curves than on the larger radius curves. This function is in contrast with the assumption of a single value lateral acceleration/curve radius relationship used for design.

The linearly decreasing relationship between the observed 85th percentile lateral acceleration and speed values for both vehicle classes and road types, shown in Figure 7.3, is found not to be reflected by the current Standards. Drivers were found to develop considerably higher lateral accelerations at low speed/radius curves than the constant safe values assumed by the Design Policy. Thus for 85th percentile curve speeds of about 85 k.p.h. for cars and 60 k.p.h. for goods vehicles a surprisingly high safety margin is assumed by the Standards. It thus seems that the reality of driver behaviour is such that many drivers operate with a smaller friction safety margin on low standard curves than that assumed by the Design Policy. Unfortunately, since no recent data of the sideways skid resistance was available at the study sites, a direct study of the actual friction safety margins adopted by the drivers sampled could not be carried out.

Sideways skid resistance values recommended or measured by various road authorities or researchers around the world are superimposed on Figure 7.3. This illustrates the range of road surface friction which can be anticipated for well maintained rural roads. The differences between these values can be attributed partly to the measurement technique and partly to the surface texture and maintenance level. The Kummer and Meyer's[47] recommended minimum values for U.S. rural highways appear to be significantly lower than the recommended British value[48] of f = 0.50 at 50 k.p.h., the measured County Roads Board[22] values and the Russian[49] friction measurements on smooth, wet concrete pavements. They may, therefore, be regarded as lower bounds of sideways skid resistance values on well maintained road surfaces. The lateral acceleration values adopted by drivers may be seen to be well below Kummer and Meyer's lower level. However, the friction safety margins adopted on roads are much lower than those assumed by the Design Policy on low radius curves (V<85.0 k.p.h. or R<230.0m). On higher radius faster curves, however, drivers seem to be hesitant in developing the proposed lateral acceleration values.

A reduction of the Design Standards for low radius or low speed curves would therefore seem feasible. At a superficial level, it might appear that the proposed reduction in the Standards for the lower design speed band would produce alignments which are less safe than those based on current Standards, due to the apparent reduction in friction safety margins. However, this is not the case as the currently proposed values are far from those which are actually being utilised on current alignments Furthermore, a reduction of the lower end of current Standards will not only produce alignments according to drivers' preference but may result in substantial economic benefits in construction terms. It must be emphasised, however, that reduction of design values for low standard curve designs should account for extreme cases such as simultaneous cornering and braking, and cornering under extremely slippery road surface conditions. In the first case the resulting friction force would be higher than the simple cornering force and a higher skid resistance value would be needed to keep the vehicle on the road. In the second case pavement skid resistance would be lower resulting in less safe friction margins necessary for steady and safe travel around the curves. Consideration should also be given to accident risk.

The 'overdriving' by public drivers of low standard curves on rural single and dual carriageways is again illustrated in Figures 7.4 to 7.7 where the 85th percentile curve middle speed is plotted against the curve safe speed determined according to the design f values. By superimposing a 45 degree line on the Figures it can be seen for curves with safe speed greater than about 85.0 k.p.h., that 85th percentile vehicle speeds tend to be less than the curve safe speed, while for curves of lower standard, 85th percentile vehicle speeds tend to be in excess of the curve safe speed.

7.3 OTHER POLICIES

There has been considerable criticism in the past of Design Policies in other countries[4,22,68,69,77]. Some of them have been shown to be based on not fully justified or relevant driver behaviour data.

The current AASHO[15], NAASRA[18], DMR[36] and German[37] Design Policies are compared to the observed driving behaviour (85th percentile values) in Figures 7.8 to 7.10.

In Figure 7.8 the AASHO recommended design speed/minimum curve radius relationships for different maximum superelevations (E = 0.06 and E = 0.10) are shown together with the observed 85th percentile car curve middle speed/curve radius relationships for both single and dual carriageways. It can be seen again that drivers travel faster on single carriageways than recommended by the Standards for curve radii below about 200m for E = 0.06 and 250m for E = 0.10. The corresponding figures for dual carriageways are about 260m and 330m. The same comments apply for NAASRA Design Policy (Figure 7.9) which is largely modelled on the AASHO Policy.

The German (RAL-L) Policy, shown in Figure 7.10, seems to be more conservative than the other two with 'overdriving' occurring below curve radii of about 340m and 470m for single and dual carriageways respectively.

It must be noted that the validity of such comparisons is limited since our data has been collected for British conditions.

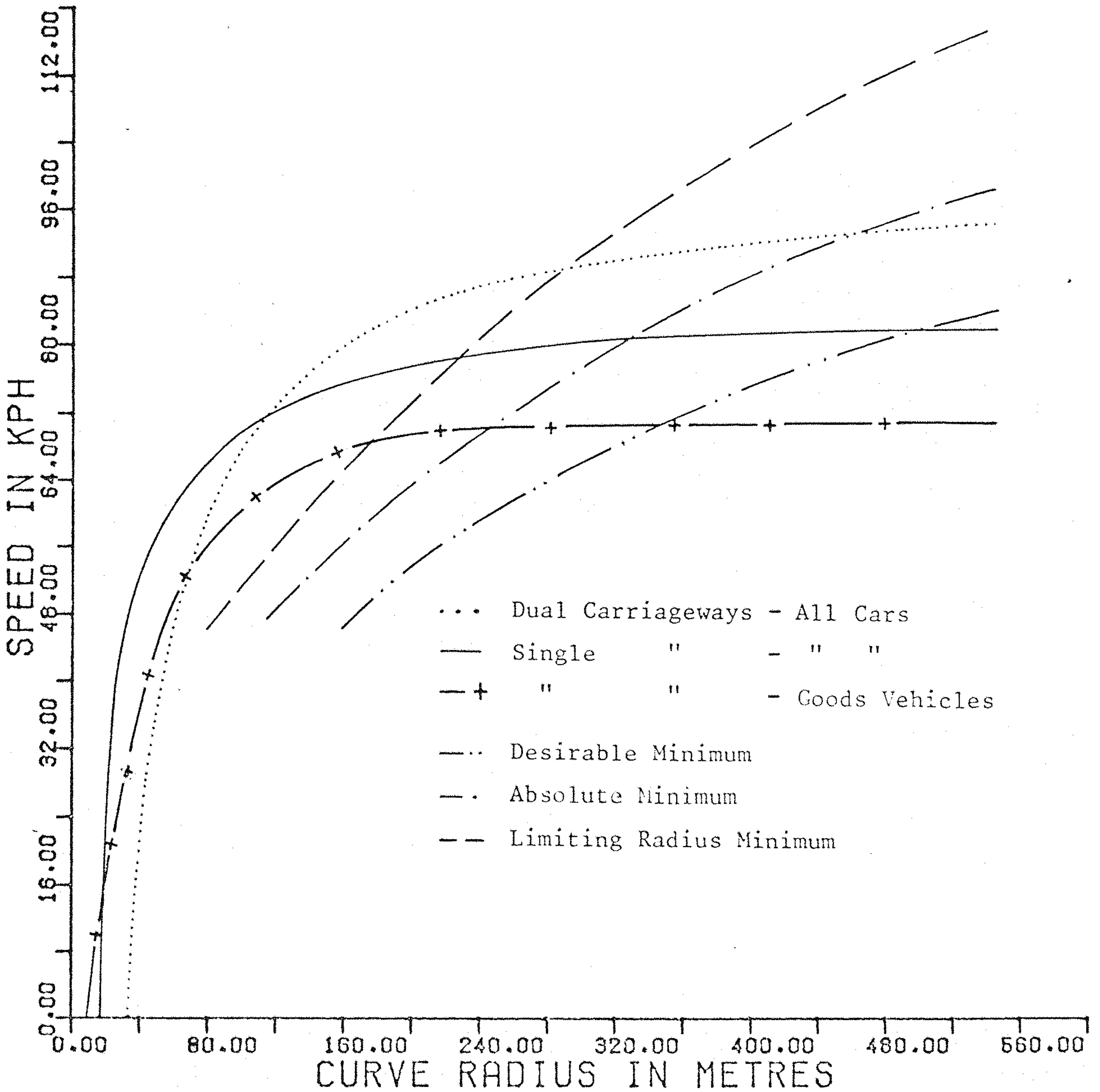


Figure 7.1: Observed 85th Percentile Middle Speed/Curve Radius Relationships compared with Current British Design Standards

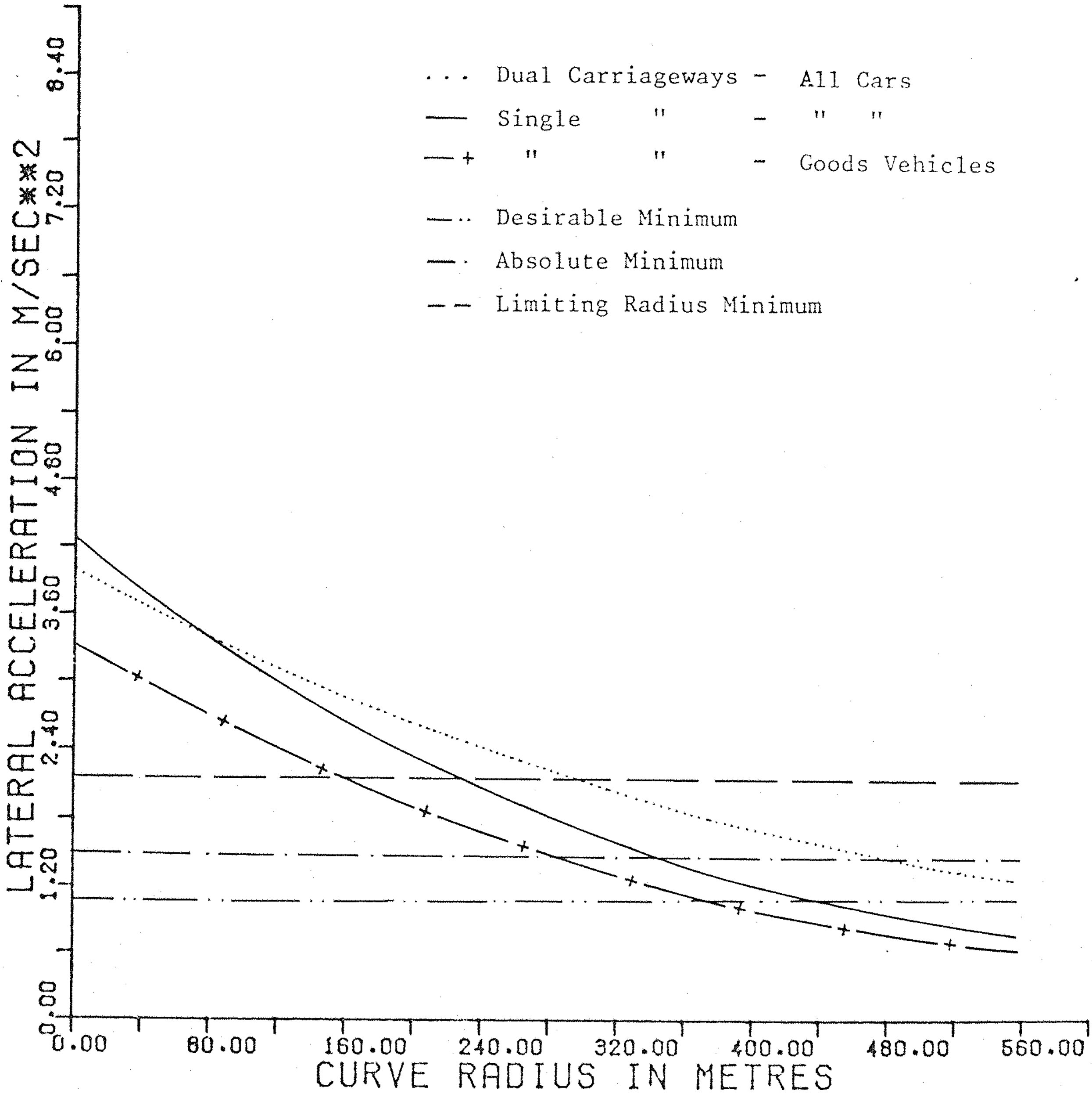


Figure 7.2: Observed 85th Percentile Middle Lateral Acceleration/Curve Radius Relationships compared with Current British Design Standards

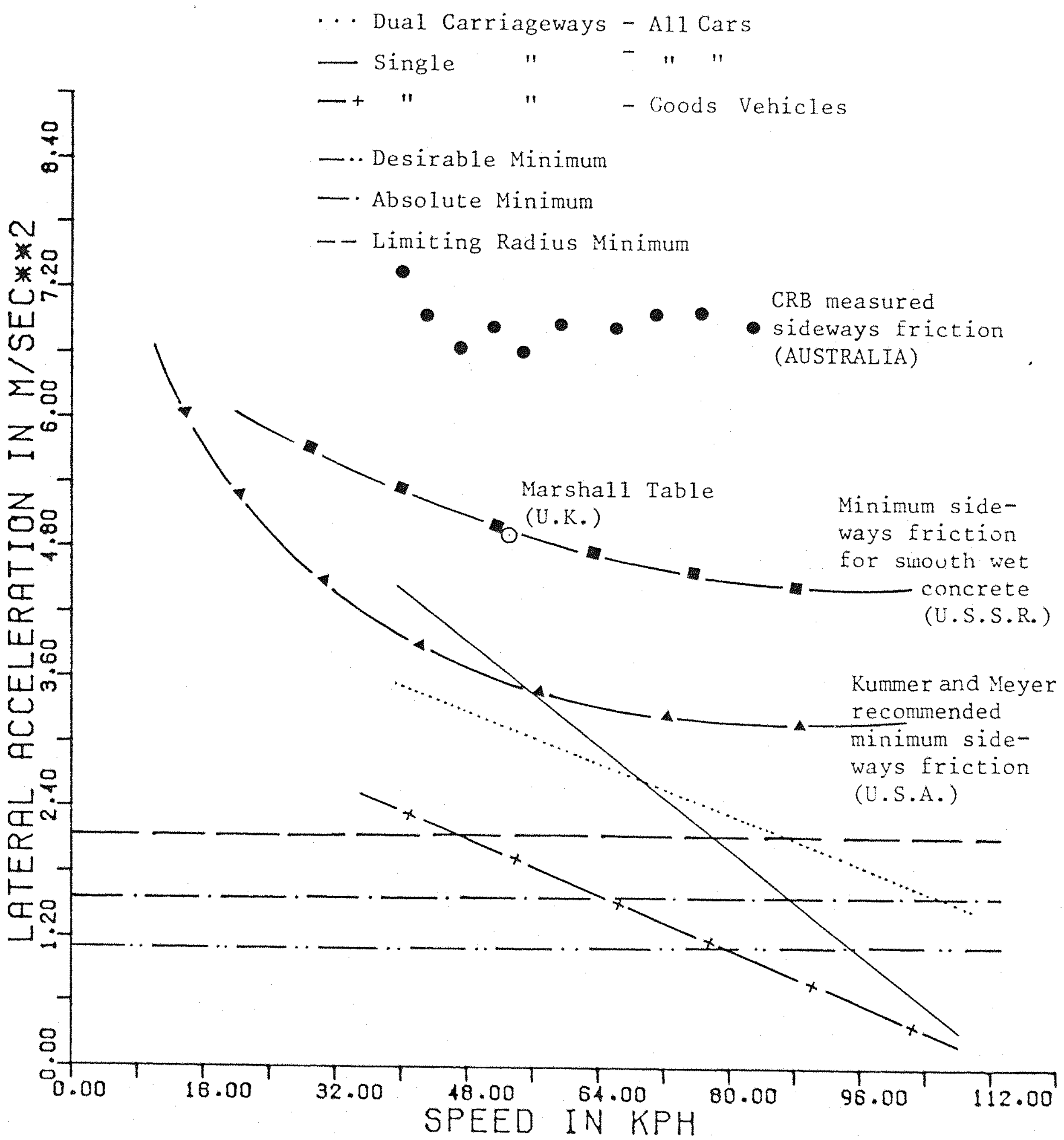


Figure 7.3: Observed 85th Percentile Middle Acceleration/Speed Relationships compared with Current British Design Standards and Sideways Skid Resistance Relationships

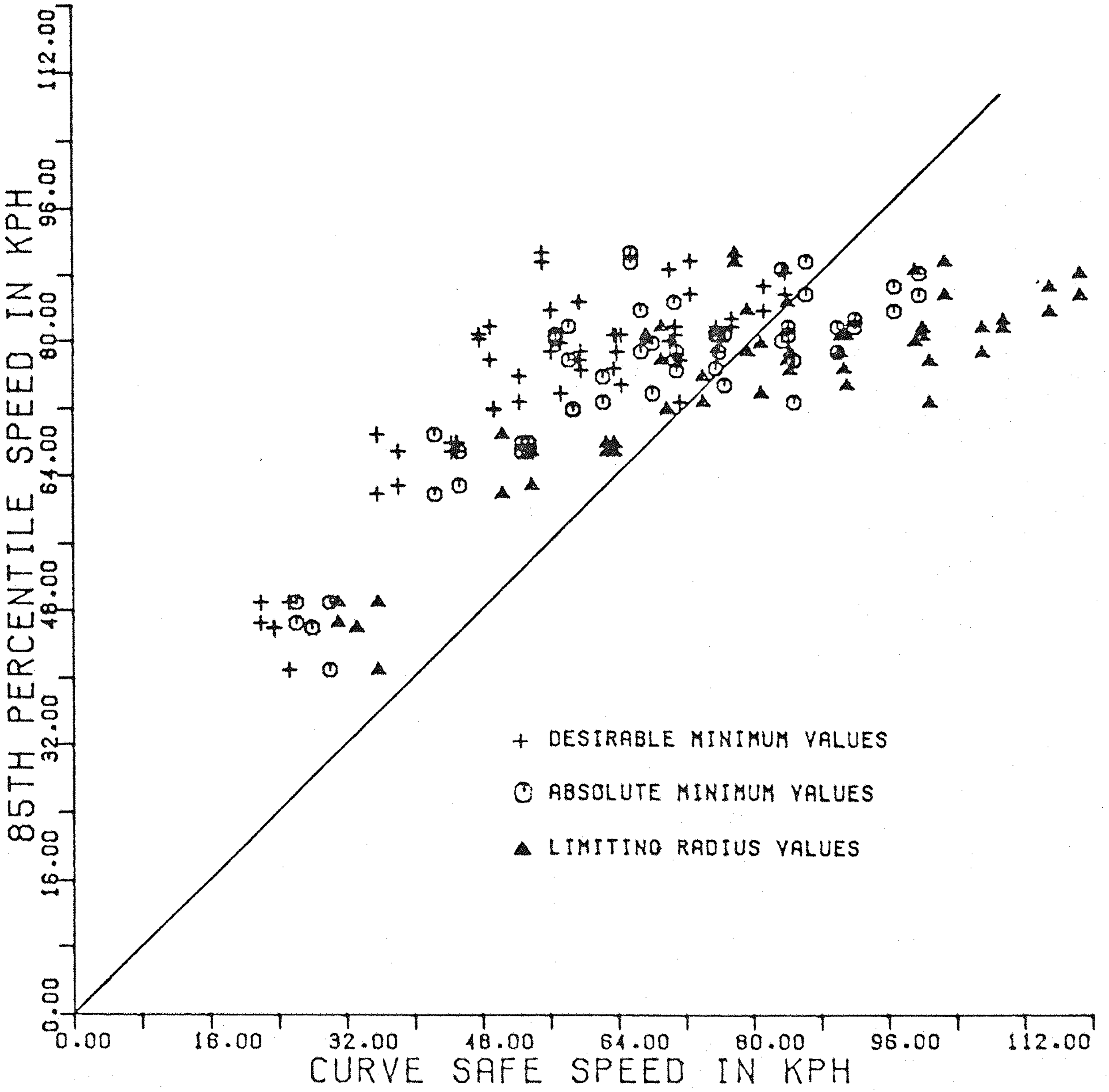


Figure 7.4: Relationship between Observed Curve Middle Speed and the Curve Safe Speed
(Single Carriageways - All Cars)

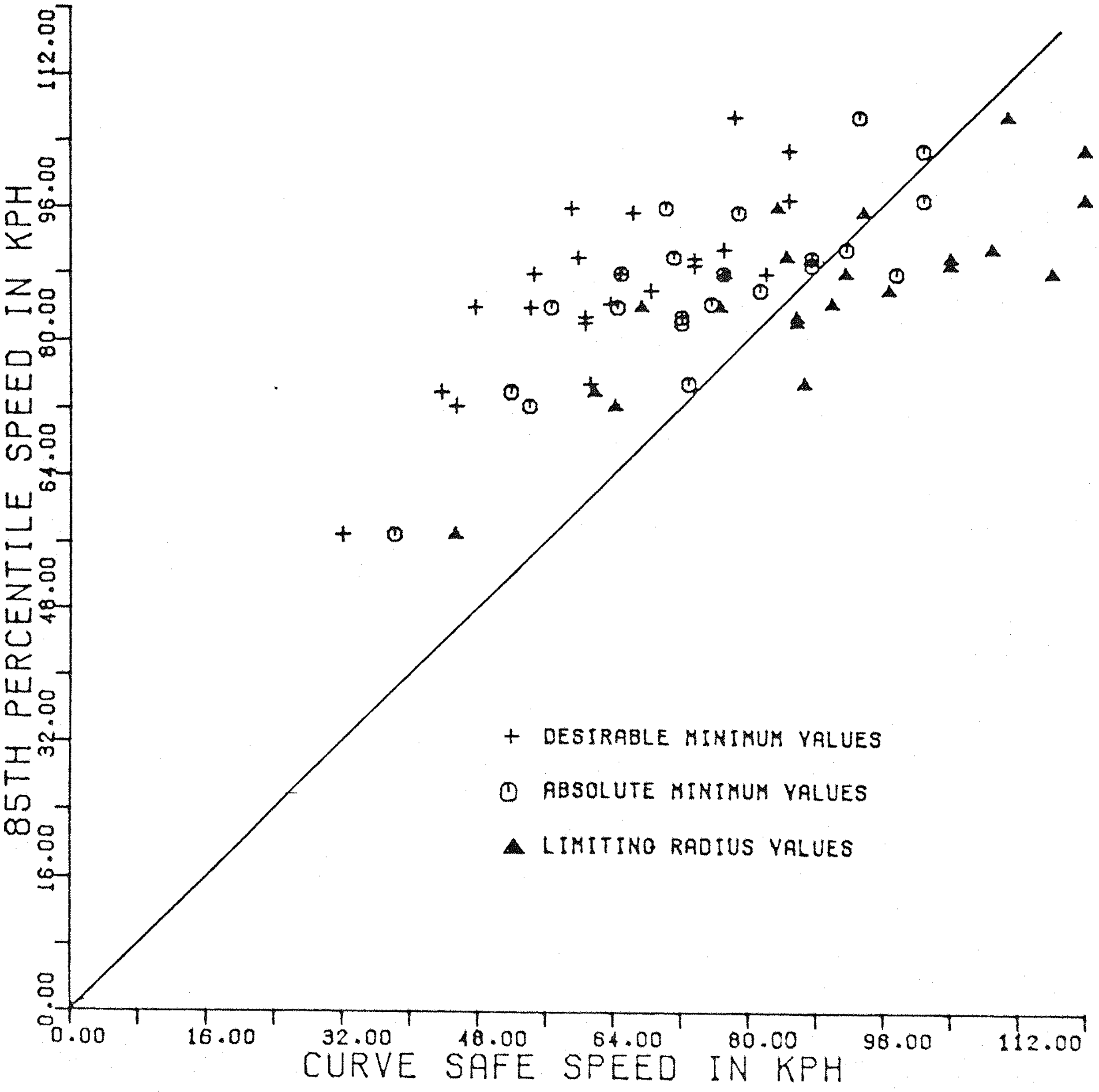


Figure 7.5: Relationship between Observed Curve Middle Speed and the Curve Safe Speed
(Single Carriageways - Goods Vehicles)

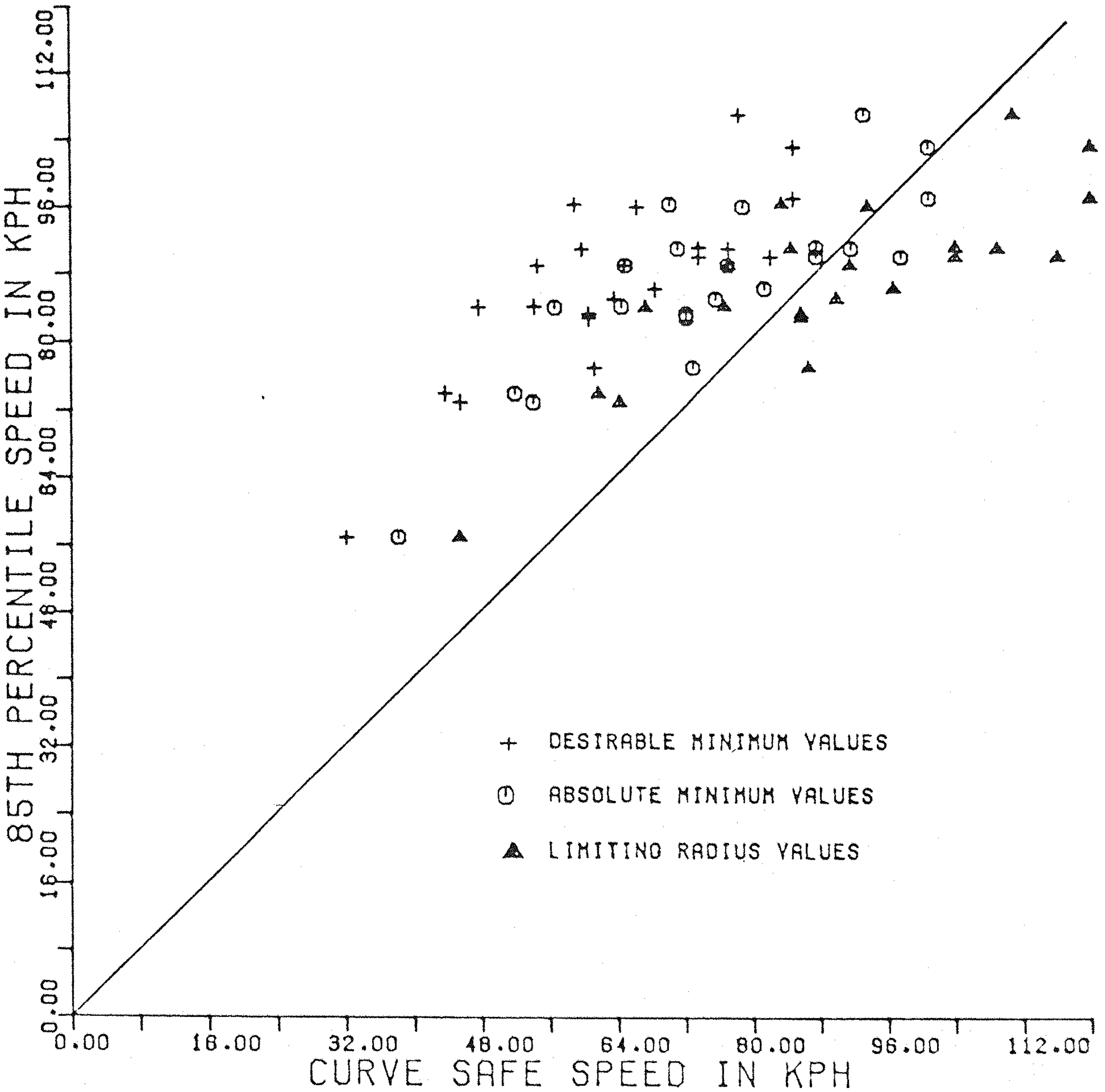


Figure 7.6: Relationship between Observed Curve Middle Speed and the Curve Safe Speed
(Dual Carriageways - All Cars)

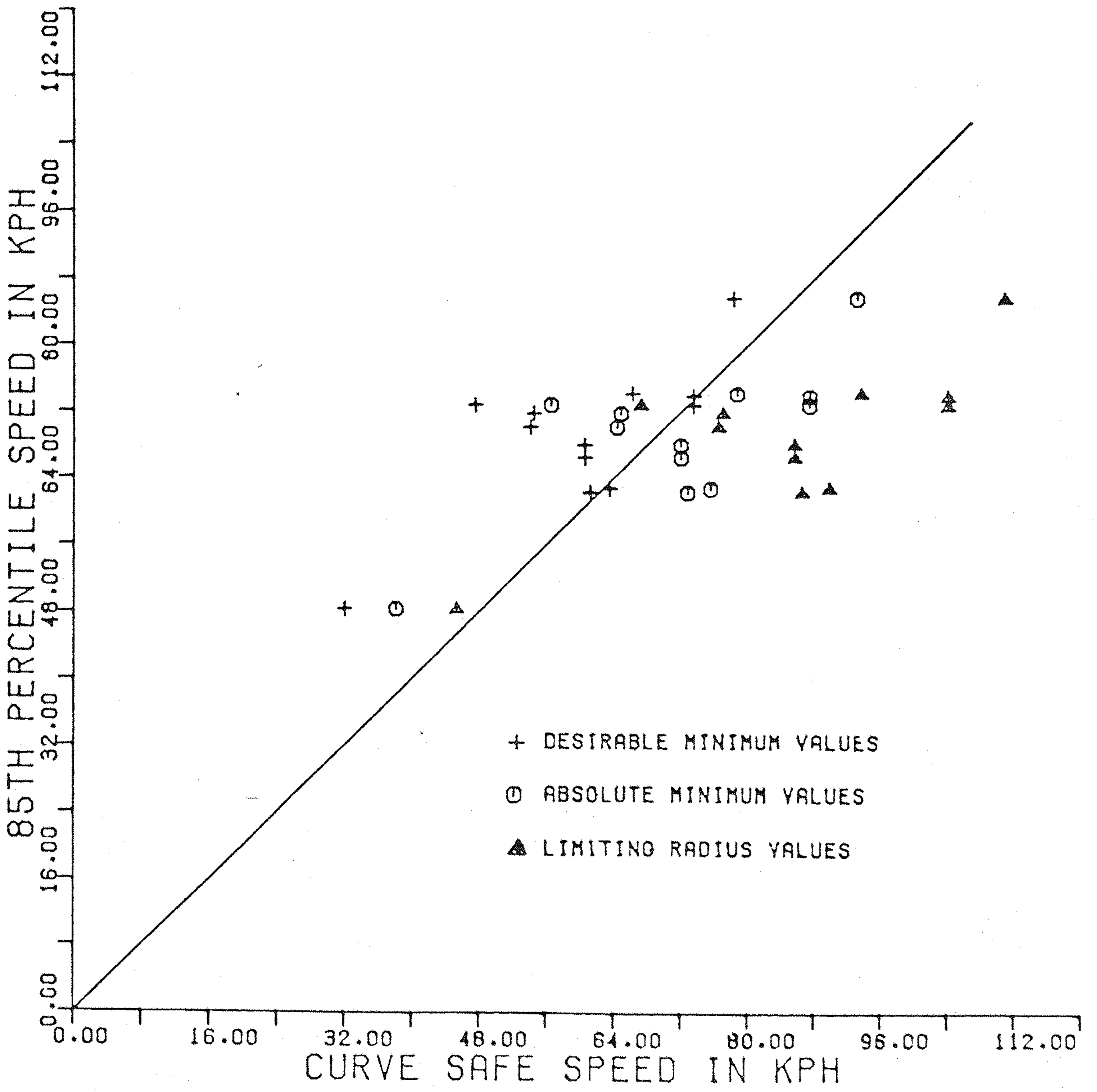


Figure 7.7: Relationship between Observed Curve Middle Speed and the Curve Safe Speed
(Dual Carriageways - Goods Vehicles)

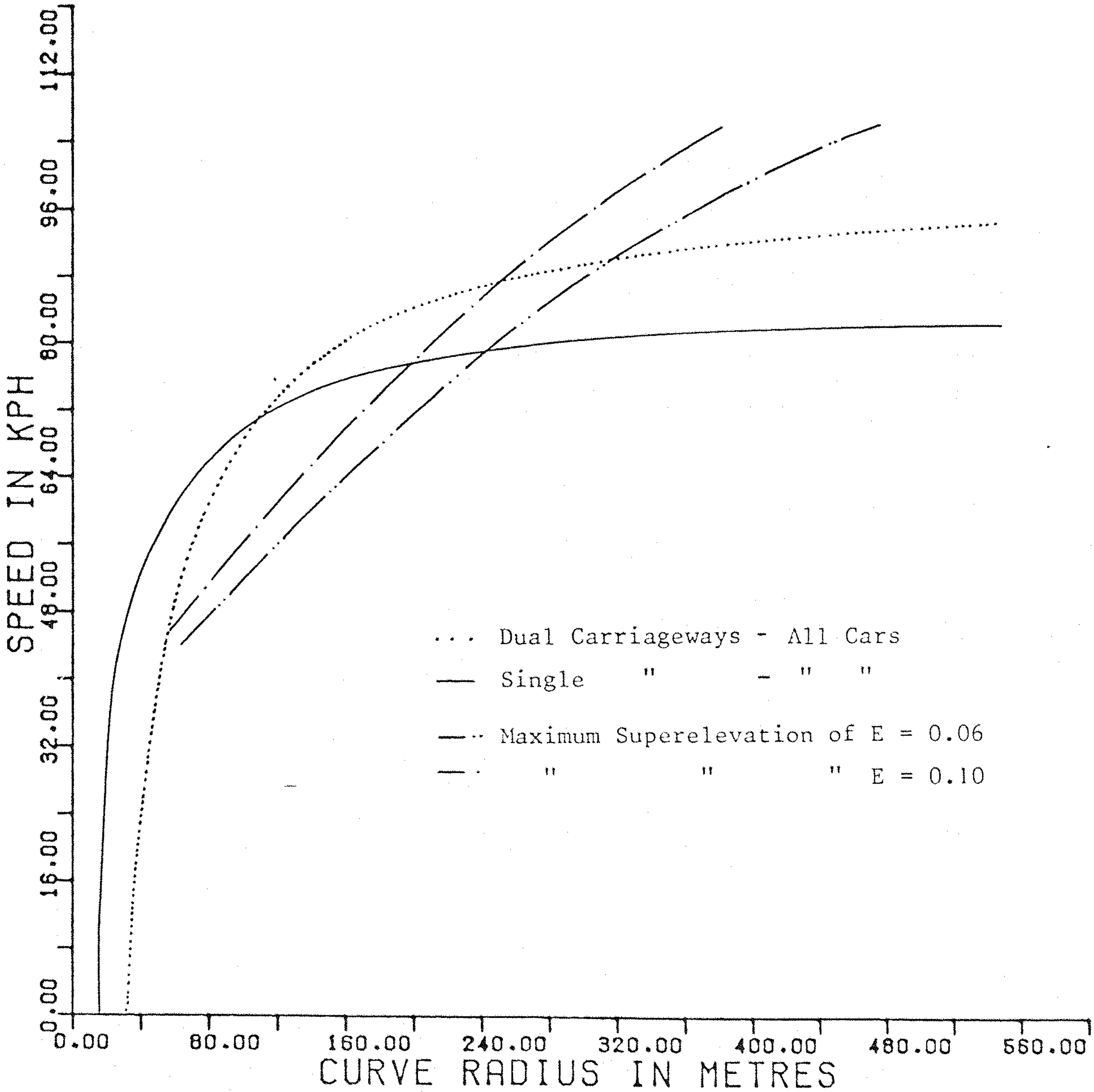


Figure 7.8: Observed 85th Percentile Middle Speed/Curve Radius Relationships compared with Current U.S.A. Design Standards

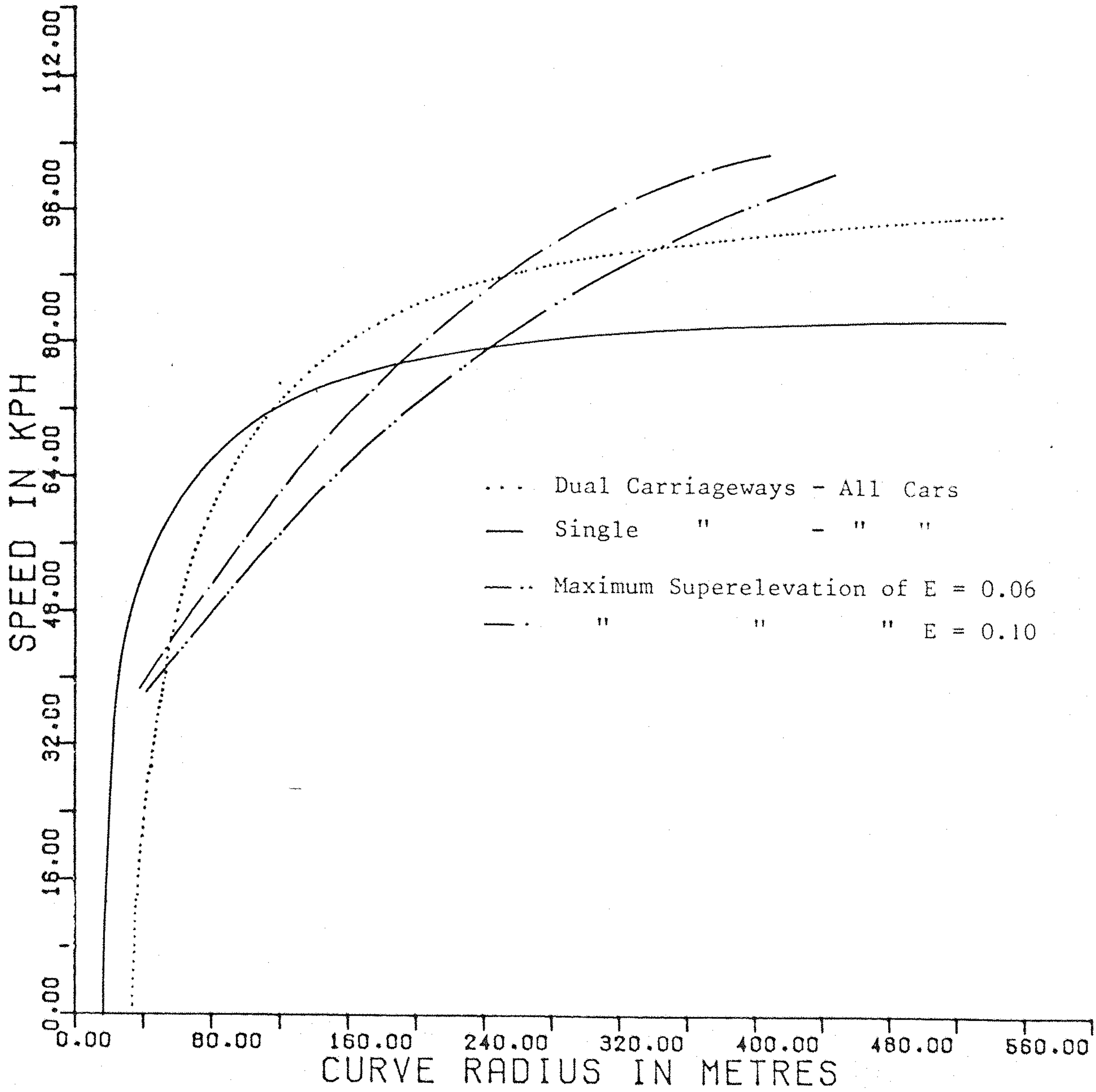


Figure 7.9: Observed 85th Percentile Middle Speed/Curve Radius Relationships compared with Current NAASRA (Australia) Design Standards

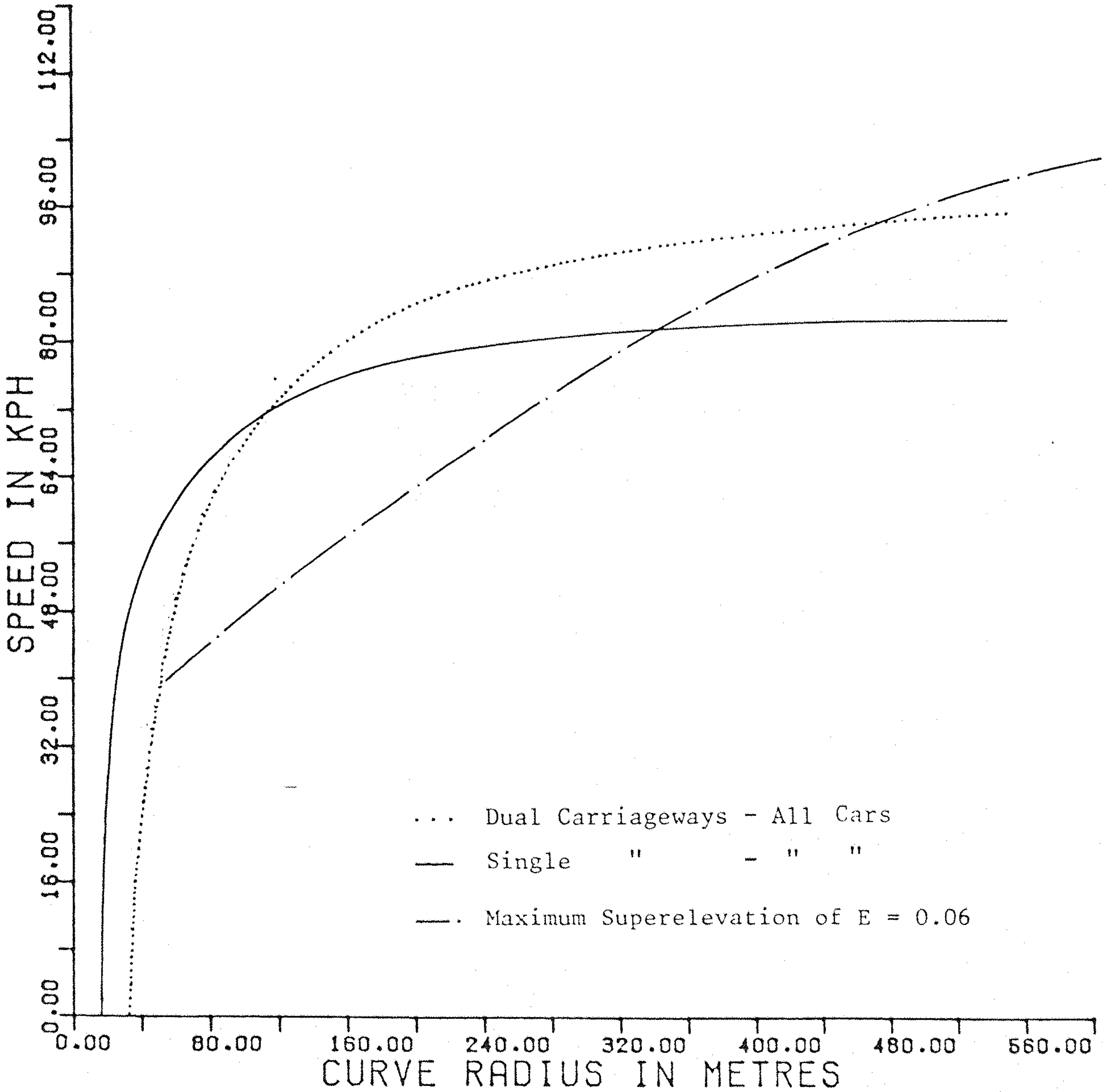


Figure 7.10: Observed 85th Percentile Middle Speed/Curve Radius Relationships compared with Current German (RAL-L) Design Standards

CHAPTER EIGHT

CONCLUSIONS

8.1 THE STUDY

The work described in this report is concerned with the interaction between the vehicle/driver combination and curves on open rural roads. The following two road types have been considered:

a. Two and three-lane single carriageways with varying carriageway width.

b. All purpose dual carriageways, two lanes wide with varying carriageway width.

Only road curves with radii smaller than 500 metres were used and each direction was treated separately. In all, 78 directional road curves were investigated.

Public road data consisting of vehicle speeds and lateral placements at four fixed locations on the approach to and within each directional curve was recorded during two separate stages. Data was collected separately for cars and goods vehicles. Allowances were also made for the traffic flow conditions. Public road speed information was supplemented by detailed results from a test vehicle driven around a larger sample of curves.

Public road data, merged over the two study phases, was used in the main analysis, with most emphasis being given to the investigation of associations between behavioural parameters, mainly vehicle speed, and road curve geometry, traffic flow and environmental factors. Whenever possible, public road behaviour was compared with that of the test vehicle/driver.

8.2 MAIN FINDINGS

The following conclusions were drawn from this study:

a. *The normal distribution was found to provide a statistically significant description of the speed samples observed. This was found on the approach to curves, as previously indicated*[22] *as well at the entry, middle and exit points, and for both cars and goods vehicles.* Out of the total of 448 car speed distributions observed for single carriageway curves only 29 displayed significant departures ($p<0.05$) from the normal distribution. Similarly, only 7 out of 176 car speed distribution observed for dual carriageways were statistically different from the normal distribution. Only one of the 172 goods vehicle speed distributions displayed significant departure ($p<0.05$) from the normal distribution. However in general only low samples were available for goods vehicles. Most of the speed distributions exhibited positive skewness and an almost equal number of platikurtic and leptokurtic distributions were noted. An examination of the upper end of the distributions thus revealed rather significant differences between the observed and the theoretical 99th percentile values. Even though no particular trends were identifiable, distributions of greater precision may be required for the data to be used in simulation studies.

b. An examination of the overall mean, 85th and 99th percentile speeds, averaged over the entire curvature range considered in the study, showed that *deceleration rates* for cars *were higher than acceleration rates for single carriageway curves.* This difference was not evident for dual carriageway curves. Goods vehicles displayed a similar pattern to that of cars, except that the magnitude of the speed changes, was lower. An evaluation of the performance of individual vehicles confirmed these findings, which are in contrast to previous results, mainly obtained from test-track experiments where lateral restrictions and opposing flow were absent.

c. The overall coefficients of variation for the distributions of car speeds on the approach sections, expressed in standardised form, was 0.137 and 0.125 for single and dual carriageway curves respectively. The corresponding figures for goods vehicles approach speed distributions were 0.118 and 0.110. *Comparison* with the values of 0.19 reported by the Transport and Road Research Laboratory(93), 0.17 reported by Leong(94) and 0.14 observed by McLean(22) *suggests that there has been a time trend of decreasing coefficient of variation by vehicle free speeds on rural roads.* This could be caused by increased mean speeds, reduced speed variances or both. The difference found between the values for single and dual carriageway curves can be attributed to higher mean speeds of the latter since almost identical values of the standard deviation were found for the two road types.

d. Coefficients of speed variation were not found to vary with curve radius over the complete range considered. However, *an examination of the data indicated that when car speeds were constrained by alignment geometry, the coefficients of variation of the distributions tended to decrease for lower distribution means and variances.* This trend, in agreement with earlier findings[22], was observed for both single and dual carriageway curves. In general coefficients of variation for curve middle locations were found to be the lowest. Less consistent results were found for goods vehicles, possibly due to the low sample sizes available, although the same trends were evident.

e. *Lateral accelerations, measured at the mid point at each curve, were normally distributed.* For the 56 all car lateral acceleration distributions observed at single carriageway sites, only 7 displayed statistically significant ($p<0.05$) departures from the normal distributions. Similarly, at dual carriageway sites only 2 out of 22 varied from the normal. Almost all the lateral acceleration distributions observed displayed significant positive skewness. This was more pronounced on low radius curves which exhibited surprisingly high values.

f. *Speed measurements collected during the two phases of the study were consistent,* the level of consistency varying with curve geometry and decreasing with reducing horizontal alignment standards. In general, 85 per cent of approach mean speeds for single carriageway curves and 90 per cent of approach mean speeds for dual carriageway curves were found to be consistent at a 5 per cent level of significance.

g. *Entry and middle speeds were highly correlated with approach speeds especially on dual carriageway curves.*

h. *Vehicle speeds appeared not to be significantly affected by the weather.* A comparison between all car speeds obtained under wet and dry road surface conditions revealed no statistically significant differences ($p<0.05$) at most single and dual carriageway sites.

i. *The pattern of variation in vehicle speeds around road curves was found to be highly dependent on the level of curvature.* On high curvatures with radii less than 200 metres, car speeds appeared to vary consistently throughout both single and dual carriageway curves reaching a minimum value near the curve centre. In all the cases examined, speed adjustment was found to continue throughout the road curves. A more constant car speed variation was observed for larger radius curves when speed adjustments mainly occurred before the curve entry. A similar pattern was observed for goods vehicles in which speeds were adjusted on the approach section and remained almost constant throughout the curve for both single and dual carriageway sites.

j. *Speeds at the entry and mid points were highly correlated with curve radius for small radius curves, the* *variation became less marked for larger radii.* On single carriageways a strong curvilinear relationship was found between entry and middle speeds and curve radius, with vehicle speeds increasing rapidly up to a radius of about 250m. A similar relationship was found between vehicle entry and middle speeds and curve radius for dual carriageways and for both vehicle types, and speeds increased rapidly up to radii of about 330m, before becoming more constant.

k. *The lateral acceleration (side-friction factor) at the mid point decreased linearly with increasing mid point speeds.* This was less marked for goods vehicles. However, in all the cases considered and for both single and dual carriageways a poor correlation was found to exist between these two behavioural parameters[4,22,73]. Furthermore, as Good[4,41] has stated, the relationships were developed from averaged data and were not, therefore necessarily representative of individual behaviour. None-the-less a strong correlation was obtained between the lateral acceleration (side-friction factor) at the mid point and curve radius for both vehicle classifications and road types. Such a relationship could replace the current f-V relationship[73].

l. Regression analyses of vehicle entry and middle speeds and lateral acceleration for both vehicle classifications and road types, found that *vehicle/driver behaviour on rural road curves is influenced primarily by the approach (desired) speed pertaining to the road section and the degree of curvature.* This is in general agreement with most earlier studies[22,59,63]. Available sight distance, verge and road width as well as traffic flow appeared to have only a marginal effect on observed vehicle speeds and lateral accelerations. *Design speed, superelevation and gradient did not have a statistically significant effect on vehicle/driver behaviour.* A series of linear and curvilinear regression models were developed to explain the variation in vehicle/driver behaviour around road curves. In general, higher coefficients of determination were obtained for single carriageway speed or lateral acceleration data than for dual carriageway data. This substantiates the early suggestion that vehicle/driver behaviour is less affected by curve geometry or traffic parameters on higher standard alignments. However, for both road types the level of dependence of curve speed on curvature and approach speed was again high. The form of the regression relationshps was less clear for goods vehicles. This is not surprising given the greater variation in goods vehicle performance characteristics compared with those for cars. Separate regression analyses were carried out for left and right-hand curves as well as for uphill and downhill situations. Overall, no significant departures from the overall regressions were observed considering that *no large differences exist in driving behaviour around left or right-hand curves.* Regression relationships developed for merged single and dual carriageway data base appeared to be as successful as those prodouced for the separate categories.

m. Separate regression analyses of data grouped according to approach speed produced a family of speed/curvature prediction models for both vehicle classifications and road types. *Entry and mid point vehicle speeds can* thus *be predicted* with a reasonable accuracy for a specified 'environment speed' as quantified by approach (desired) speed.

n. *The approach speed of cars were not found to be strongly correlated with lateral placements at both single and dual carriageway sites.* However, car drivers showed a strong tendency to 'cut the corner' on curves with radii less than about 250m. This was more pronounced on single carriageway curves[39,41,56]. A more marked difference appeared to exist between left and right-hand curves on both road types with a significantly higher number of drivers 'cutting the corner' on right-hand than on left-hand curves, probably because of the larger sight distances available. Surprisingly, this 'cut the corner' behaviour was not found to be related to faster vehicles. This suggests that unless factors, other than car speeds or lateral acceleration, affect path decisions, drivers adopt a path according to their preference (human factor) and the prevailing traffic flow conditions. On higher radius curves drivers appeared to follow road geometry rather accurately at both single and dual carriageway sites.

o. Comparisons between the current British Highway Link Design Policy and the speed and lateral acceleration data from this study (85th percentile values) showed that, *for curves with speed standards less than about 85.0 k.p.h., 85th percentile speeds and the associated f values are in excess of those assumed for design.* Translating that into minimum radius terms, drivers tend to 'overdrive' rural single and dual carriageway curves with radius below about 230m and 300m respectively for the minimum design level adopted in the Standards (Limiting Radius Minimum). The corresponding values for the Desirable Minimum and the Asbolute Minimum were found to be about 330m and 500m respectively for single carriageways and 450m and above 500m for dual carriageways. For curves of higher standards, driver behaviour tends to be more conservative relative to the design assumption.

Therefore a reduction of the lower end of the current Design Policy (Design Speed less than 85.0 k.p.h.) is not at all unjustified. The level of the reduction however should be determined with some consideration given to the accident potential of low radius curves and to extreme cases such as simultaneous cornering and braking which are likely to occur during driving. Also, consideration has to be given to goods vehicle cornering behaviour.

However, it should be emphasised that the design values assumed by the new British Design Policy are not inviolable and "*...departures should be assessed in terms of their effects on economic performance, the environment, and the road user*".

p. The current constant speed/lateral acceleration relationship assumed by the new British Design Policy does not reflect driving preference around rural road curves. A relationship with a decreasing form seems to be more realistic and justified by the study data.

q. An examination of other Design Policies revealed that in general they over-design for road curves with radius below about 200 to 250m or with speed standards less than 85.0 k.p.h. However, such comparisons should be carefully viewed because of different driving and environmental conditions existing in different countries.

8.3. FURTHER WORK

The following items are suggested for further work.

a. Detailed investigation of the effect of plan transition curves on vehicle/driver combination behaviour to establish their advantages or disadvantages against unspiralled curves. This would involve detailed examination of the speed/distance and speed/lateral placement profiles of vehicles along the entire length of transitional curves and comparison with respective vehicle profiles at unspiralled curves.

b. Re-consideration of the Halcrow-Fox(2) accident models with new independent variables such as approach or entry speed, total curvature and curve length being introduced. Such new models will probably allow a better understanding of the associations between accidents and curve geometry.

c. Detailed examination of the actual path around low radius curves to establish the level of the 'cutting the corner' behaviour and its significance to safe vehicle operations around high curvature road curves.

d. More extensive and detailed examination of the performance and the stability requirements of various types of goods vehicles especially around low radius road curves.

e. Extension of the highly significant vehicle speed/curve radius relationship to complete the lower end of the curvature range (i.e. curve radius between 0 and 40 metres). This would allow the development of a single and uniform relationship between vehicle speed and curve radius for both intersection and open road curves to be used in design practices.

REFERENCES

1. REPORT OF THE ADVISORY COMMITTEE ON TRUNK ROAD ASSESSMENT. Sir George Leitch (Chairman). HMSO, London, 1977.

2. HALCROW FOX AND ASSOCIATES. Effects on Safety of Marginal Design Elements. London, 1981.

3. MINTSIS, G. Effects of Road Curvature on Vehicle/Driver Behaviour. Transportation Research Group, Working Paper 24, June 1980. University of Southampton.

4. GOOD, M. C. Road Curve Geometry and Driver Behaviour. Australian Road Research Board, Special Report No. 15, Vermont South, May 1978.

5. BIRD, A. ROADS AND VEHICLES. LONGMANS 1969, London.

6. PUBLIC ROADS ADMINISTRATION. Highway Practice in the United States of America. Washington, 1949.

7. DOWNS, W. S. Purely Theoretic Superelevations Modified for Roads. Eng. News Rec., 80(17), 1918, p.805.

8. ANON. Superelevated Curve Practice on Minnesota Highways. Eng. News Rec., 86(5), 1921, p.220.

9. YOUNG, W. R. Road Design for Uniform Speed. Eng. News Rec., 105, 1930, p.539.

10. MOYER, R. A. Skidding Characteristics of Automobile Tires on Roadway Surfaces and their Ralation to Highway Safety. Iowa Eng. Exp. Stn. Bull. 120, 1934.

11. BALDOCK, R. H. Highway Design for Speeds up to 100 miles per hour. Eng. News Rec., 114, pp. 732-34.

12. BARNETT, J. Safe Side Friction Factors and Superelevation Design. Highway Research Board, Proc. Ann. Meet. 16, pp. 69-76.

13. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS. A POLICY OF GEOMETRIC DESIGN OF RURAL ROADS. AASHO, Washington, 1941.

14. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS. A POLICY OF GEOMETRIC DESIGN OF RURAL ROADS. AASHO, Washington, 1954.

15. AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS. A POLICY OF GEOMETRIC DESIGN OF RURAL ROADS. AASHO, Washington, 1965.

16. MINISTRY OF TRANSPORT. ADVISORY MANUAL: THE LAYOUT OF ROADS IN RURAL AREAS. HMSO, London, 1968.

17. DEPARTMENT OF TRANSPORT. Road Layout and Geometry: Highway Link Design. Roads and Local Transport Directorate, Departmental Standard TD 9/81. London, 1981.

18. NATIONAL ASSOCIATION OF AUSTRALIAN STATE ROAD AUTHORITIES. POLICY FOR GEOMETRIC DESIGN OF RURAL ROADS (Metric Units). 5th Edition, Sydney. 1973.

19. MULLIN, E. F. Road Safety and its Influence on Road Design. Main Roads, 38(1), 1972, pp. 9-14.

20. ARMSTRONG, J. T. The Geometric Design of Low Cost Rural Roads, Australian Road Research Board, Proc. 6th Conf., 6(3), 1972, pp. 397-417.

21. GLENNON, J. C. State of the Art Related to Safety Criteria for Highway Curve Design. Texas Transp. Inst. Res. Rep. No. 134-4, 1969.

22. McLEAN, J. R. Speed on Curves. Australian Road Research Board, Internal Reports AIR 200-1 to 200-5. Vermont South, 1978.

23. LUEDKE, A. L. and HARRISON J. C. Superelevation and Easement as Applied to Highway Curves. Public Roads, 3(3), 1921, p.3.

24. LEEMING, E. L. The Superelevation of Highway Curves. Sel. Eng. Paper Inst. Civ. Eng. No. 50, 1927.

25. LEEMING, E. L. ROAD ENGINEERING. Constable, 1924, London.

26. PURCELL, C. H. Design of Highways for Traffic Safety. Eng. News Rec., 106, p.22.

27. ROYAL-DAWSON, F. G. ELEMENTS OF DESIGN FOR ROAD, RAILWAY, AND RACING TRACK ON NATURAL TRANSITION PRINCIPLES. Spon, 1932, London.

28. MOYER, R. A. Speed versus Safety on Curves. Civil Engineer (N.Y.) 7(2), 1937, pp. 113-16.

29. WILEY, T. T. Discussion of NOBLE (1936). Proc. Am. Soc. Civ. Eng., 62(7), 1936, pp. 1656-60.

30. HAILE, E. R. Discussion of BARNETT (1936). Highway Research Board, Proc. Annu. Meet. 16, 1936, pp. 76-79.

31. MOYER, R. A. and BERRY, D.S. Marking Highway Curves with Safe Speed Indications. Highway Research Board, Proc. Annu. Meet. 20, 1940, pp. 399-428.

32. MEYER, C. F. ROUTE SURVEYING. International Textbook Company, 1949 and 1969, Pennsylvania.

33. FOX, M. L. Relations between Curvature and Speed. Highway Research Board, Proc. Annu. Meet. 17(1), 1937, pp. 202-11.

34. STONEX, K. A. and NOBLE, C. M. Curve Design and Test on the Pennsylvania Turnpike. Highway Research Board, Proc. Annu. Meet. 20, 1940, pp. 429-51.

35. COUNTRY ROADS BOARD. ROAD DESIGN MANUAL FOR RURAL AND URBAN ROADS OTHER THAN FREEWAYS. CBR, 1967, Melbourne.

36. DEPARTMENT OF MAIN ROADS. The Behaviour of Drivers on Horizontal Curves. Main Roads, 34(4), 1969, pp. 127-28.

37. WORKING PARTY ON PLANNING AND TRAFFIC - "LAND" ROADS. Guidelines for the Lay-Out of "Land" Roads (RAL-L), Road Lines (RAL-L). Edition 1973, West Germany.

38. WEINBERG, M. I. and THARP, K. J. Application of Vehicle Operating Characteristics to Geometric Design and Traffic Conditions. Nat. Coop. Highw. Res. Prog. Rep. 68, 1969.

39. EMMERSON, J. Speeds of Cars on Sharp Horizontal Curves. Traff. Eng. Control, 11(3), 1969, pp. 135-37.

40. GOOD, M. C., ROLLS, K. J. and JOUBERT, P. N. Driver-Vehicle Behaviour in Free Path Turns. Transp. Res., 3, 1969, pp. 43-68.

41. GOOD, M. C. and JOUBERT, P. N. Driver-Vehicle Behaviour in Restricted Path Turns. Human Factors Research Group, Res. Rep. HF27, 1975, University of Melbourne.

42. ANON. Pennsylvania Practice in Widening Highway Curves. Eng. News Rec., 86(22), 1921, p.957.

43. MYERS, C. J. Designing Banked Highway Curves for Safety. Eng. News Rec., 95(8), 1925, pp. 303-4.

44. ROYAL-DAWSON, F. G. Speed in Relation to Curvature, with Special Reference to Road Curves. Minutes Proc. Inst. Civ. Eng. 240, 1935, pp. 121-51.

45. ROYAL-DAWSON, F. G. ROAD CURVES FOR SAFE MODERN TRAFFIC AND HOW TO SET THEM OUT. Spon, 1936, London.

46. SCHULZE, K. H. and BECKMAN, L. Friction Properties of Pavements at Different Speeds. ASTM Special Technical Publication No. 326, 1962.

47. KUMMER, H. W. and MEYER, W. E. Tentative Skid-Resistance Requirements for Main Rural Highways. Nat. Coop. Highw. Res. Proj. Rep. 37, 1967.

48. MINISTRY OF TRANSPORT. Report of the Committee on Highway Maintenance. HMSO, 1970, London.

49. BABKOV, V. F. and ZALUGA, V. P. Longitudinal and Transverse Friction Coefficient. Interurban Roads and Motorways (U.S.S.R.) 15th World Congress, Vienna, 1979, pp. 14-16.

50. TARAGIN , A. Driver Performance on Horizontal Curves. Highway Research Board, Proc. Annu. Meet. 33, 1954, pp. 446-466.

51. KNEEBONE, D. C. Advisory Speed Signs and their Effect on Traffic. Australian Road Research Board, Proc. 2nd Conf., 2(1), 1964, pp. 524-38.

52. THARP, K. J. and HARR, M. E. A Quantitative Evaluation of the Geometric Aspects of Highways. Highw. Res. Rec., 83, 1965, pp. 29-44.

53. LEEMING, J. J. and BLACK, A. N. Road Curvature and Superelevation: Experiments on Comfort and Driving Practice. J. Inst. Munic. Eng., 71(5), 1944, pp. 137-49.

54. HOLMQUIST, C. Changes in Speeds of Vehicles on Horizontal Curves. National Road Research Institute, Rep. No. 104, 1970, Sweden.

55. NEUHARDT, J. B., HERRIN, G. D. and ROCKWELL, T. H. Demonstration of a Test-Driver Technique to Assess the Effects of Roadway Geometrics and Development on Speed Selection. Dept. Industrial Eng., Project EES 326B, 1971, Ohio State Univ.

56. McLEAN, J. R. Driver Behaviour on Curves - A Review. Australian Road Research, 5(5), 1974, pp. 76-91.

57. GOOD, M. C. Field Tests of Driver-Vehicle Behaviour on Intersection Curves during Day and Night. Human Factors Research Group, Res. Rep. HF29, 1975. University of Melbourne.

58. CHARLESWORTH, G. and COBURN, T. M. The Influence of Road Layout on Speeds and Accidents in Rural Areas. J. Inst. Munic. Eng., 83, 1957, pp. 221-240.

59. OPPENLANDER, J. C. Multivariate Analysis of Vehicular Speeds. Highw. Res. Rec., No. 35, 1962, pp. 41-77.

60. WORTMAN, R. H. A Multivariate Analysis of Vehicular Speeds on Four-Lane Rural Highways. Highw. Res. Rec., No. 72, 1965, pp. 1-17.

61. WAHLGREN, O. The Dependence of Vehicle Speeds on Different Factors - Particularly Road Geometry on Two-Lane Highways in Finland, Finland's Institute of Technology, Scientific Researches, No. 22, 1967.

62. EMMERSON, J. A Note on Speed-Curvature Relationships. Traff. Eng. Control, 12(7), 1970, p. 369.

63. COOMBE, R. D. Spot Speed Determinations on Level Rural Roads: A Multivariate Approach. Ph.D. Thesis, 1970, University of Leeds.

64. O'FLAHERTY, C. A. and COOMBE, R. D. Speeds on Level Rural Roads: Background to the Study. Traff. Eng. Control, May 1971, pp. 20-21.

65. O'FLAHERTY, C. A. and COOMBE, R. D. Speeds on Level Rural Roads: The Modelling Process. Traff. Eng. Control, June, 1971, pp. 68-70.

66. O'FLAHERTY, C. A. and COOMBE, R. D. Speeds on Level Rural Roads: The Speed Models Produced. Traff. Eng. Control, July 1971, pp. 108-111.

67. McLEAN, J. R. Driver Behaviour and Rural Road Alignment Design. Traff. Eng. Control, 22(4), April 1981, pp. 208-211.

68. DIETRICH, K. and LINDENMANN, H. P. Speed Behaviour in Curves Interurban Roads and Motorways (Switzerland), 15th World Congress, Vienna, 1979, pp. 15-18.

69. WALAWSKI, J. The Influence of Horizontal Curve Radius on Vehicle Speed. Interurban Roads and Motorways (Poland), 15th World Congress, Vienna, 1979, pp. 12-14.

70. MARTIN AND VOORHEES ASSOCIATES. A Study of Speed/Flow Relationships on Rural Single Carriageway Roads. London, 1979.

71. MARTIN AND VOORHEES ASSOCIATES. A Study of Speed/Flow Relationships on Rural Motorways and All Purpose Dual Carriageways. London, 1978.

72. RITCHIE, M. L., McCOY, W. K. and WELDE, W. L. A Study of the Relation between Forward Velocity and Lateral Acceleration in Curves during Normal Driving. Human Factors, 10(3), 1968, pp. 255-58.

73. GOOD, M. C. and SWEATMAN, P. F. Driver Strategies on Road Curves. FISITA XVIth Congress, Tokyo 1976, pp. 87-96.

74. RITCHIE, M. L. Some Relations between Visual and Kinesthetic Displays in Normal Driving. Proc. Fourth Annual NASA - Univ. Conf. on Manual Control, 1968, pp. 459-63.

75. RITCHIE, M. L. Choice of Speed in Driving Through Curves as a Function of Advisory Speed and Curve Signs. Human Factors, 14(6), 1972, pp. 533-38.

76. HERRIN, G. D. and NEUHARDT, J. B. An Empirical Model for Automobile Driver Horizontal Curve Negotiation. Human Factors, 16(2), 1974, pp. 129-33.

77. GLENNON, J. C. and WEAVER, G. D. The Relationship of Vehicle Paths to Highway Curve Design. Texas Transp. Inst., Res. Rep. 134-5, 1971.

78. LYFORD, R. W. Evaluation of Transition Curves on Two-Lane Rural Highways, Joint Highw. Res. Proj. Rep. No. 7, 1972. Purdue University.

79. OPPENLANDER, J. C., BUNTE, W. F. and KADAKIA, P. L. Sample Size Requirements for Vehicular Speed Studies. Highw. Res. Bull. 281, 1961, pp. 68-86.

80. BENNETT, N. The Connection between Road Geometry, Vehicle Characteristics and Vehicle Speed. Ph.D. Thesis, 1980. University College, London.

81. SHUMATE, R. P., GROWTHER, R. F. and SMITH, R. D. The Effect of Pneumatic Road Tubes on Vehicle Speeds. Traffic Safety Research Review 4-6, 1960-62, pp. 12-27.

82. SAAL, C. C. Hill Climbing Ability of Motor Trucks. Highway Research Board, Proc. Annu. Meet. 21, 1941, pp. 393-407.

83. ACKROYD, L. W. and BETTISON, M. Effects of Maximum Motorway Gradients on the Speeds of Goods Vehicles. Traff. Eng. Control, February 1971, pp. 530-31.

84. WILLEY, W. E. Survey of Uphill Speeds of Trucks on Mountain Grades. Highway Research Board, Proc. Annu. Meet. 25, 1945, pp. 342-53.

85. TRANSPORTATION RESEARCH GROUP. Geometric Delay at Intersections. Draft Report, 1981, University of Southampton.

86. BRITISH ROAD FEDERATION. Basic Road Statistic 1980.

87. BRANNAM, M. Relationships between the Weights and Dimensions of Goods Vehicles. Transport and Road Research Laboratory, SR 58UC, Crowthorne, 1974.

88. FINNEY, D. J. PROBIT ANALYSIS, A STATISTICAL TREATMENT OF THE SIGMOID RESPONSE CURVE. Cambridge University Press, 1947.

89. SALTER, R. J. HIGHWAY TRAFFIC ANALYSIS AND DESIGN. McMillan Press, 1976.

90. BROCK, G. Road Width Requirements of Commercial Vehicles when Cornering. Transport and Road Research Laboratory, LR608, Crowthorne, 1973.

91. HAYS, W. L. STATISTICS. Holt, Rinehart and Winston, 1970.

92. NETER, J. and WASSERMAN W. APPLIED LINEAR STATISTICAL MODELS. Irwin, 1974.

93. ROAD RESEARCH LABORATORY. RESEARCH ON ROAD TRAFFIC. HMSO, 1965, London.

94. LEONG, H. J. W. The Distribution and Trend of Free Speeds on Two-Lane Two-Way Rural Highways in New South Wales. Australian Road Research Board, Proc. 4th Conf., 4(1), p. 791-811.

95. OPPENLANDER, J. C. Variables Influencing Spot-Speed Characteristics: A Review of Literature. Highway Research Board, Special Report 89, 1966.

APPENDIX A

DESIGN OF THE STUDY AND DATA COLLECTION

LIST OF TABLES

LIST OF FIGURES

DEFINITIONS OF TERMS

In general, the following definitions of terms are used in this study. Additionally, a series of parameters are locally defined.

Speed:	The rate of movement of vehicle traffic or of specified components of traffic expressed in kilometers per hour.
Spot Speed:	The speed of a vehicle as it passes a specified point on a roadway.
Time-Mean Speed:	The arithmetic mean of spot-speeds of vehicles passing a specified point during a given interval of time.
Space-Mean Speed:	The mean of the speeds of the vehicles travelling over a given length of road and weighted according to the time spent travelling that length. It is the total distance travelled by all vehicles while in system divided by the total time that they were in the given length of road.
Environment Speed:	A measure that quantifies the speed expectancy that a driver develops on a specifically designed section of road in an area with generally uniform topographical character.
Superelevation Speed: (or Hands-off Speed)	The speed at which a vehicle can travel around a road curve with superelevation compensating fully for centrifugal effects at the specified speed.
Acceleration: (or Deceleration)	The rate of change of vehicle speed, expressed either in metres per square second or in g's ($g=9.81\ m/sec^2$).
Jerk:	The rate of change of acceleration and deceleration (forward or sideways), expressed in terms of metres per cubic second.
Lateral Acceleration: (or Cornering Ratio)	The total amount of sideways acceleration that applies to a vehicle when travelling around a road curve. It is the square of vehicle speed divided by the curve radius, expressed in metres per square second.
Side Friction Factor: (Unbalanced Centrifugal Ratio)	The proportion of lateral acceleration that is not balanced out by superelevation, expressed usually in g's.
Coefficient of Friction:	The amount of friction that develops between road surface and tyre surfacing during braking or corner-

ing. It is the friction force divided by the component of the weight perpendicular to the road surface.

Sideway Force Coefficient: (Skid Number)
: The force at right angles to the plane of an inclined wheel expressed as a fraction of the vertical force acting on the wheel.

Yaw Rate:
: The rate of change of vehicle movement, expressed in radians per second.

Roll Angle:
: The angle between the normal to the road surface and the normal to the vehicle, expressed in radians.

Bendiness:
: The sum of deflection angles divided by section length, expressed in degrees per kilometer.

Hilliness:
: The sum of all rises and falls along a road section divided by the section length, expressed in metres per kilometer.

TABLE A1: STUDY SITE LIST - SINGLE CARRIAGEWAYS

(All Halcrow-Fox sites below 500m radius)

MAIN STUDY

Group	Curve No.	Radius	Road	County
120	2	282.9	A688	Durham
120	4	363.1	"	"
120	6	265.8	"	"
121	4	368.7	A177	"
122	1	180.7	A690	North Yorkshire
130	2	349.4	A64	"
130	4	286.5	"	"
130	5	341.0	"	"
130	7	323.4	"	"
130	9	449.8	"	"
130	11	469.6	"	"
130	13	501.0	"	"
130	15	425.8	"	"
131	2	288.9	A61	"
131	4	232,3	"	"
131	6	355.6	"	"
131	8	386.7	"	"
131	12	203.2	"	"
131	13	203.8	"	"
131	14	157.6	"	"
131	16	493.9	"	"
131	18	361.1	"	"
132	2	316.8	"	"
132	4	404.2	"	"
133	2	406.8	"	"
133	6	231.0	"	"
140	2	237.4	A659	West Yorkshire
140	4	289.4	"	"
141	2	325.5	A660	"
141	4	294.5	"	"
142	1	344.6	A6038	"
142	3	214.0	"	"

... continued

TABLE A1: ... continued

MAIN STUDY

Group	Curve No.	Radius	Road	County
142	5	143.2	A6038	West Yorkshire
143	2	355.6	A62	"
143	4	172.9	"	"
143	5	369.7	"	"
143	7	243.1	"	"
143	9	250.9	"	"
144	2	139.1	A629	"
144	4	161.7	"	"
145	4	143.5	"	"
145	6	337.0	"	"
150	2	223.2	A40	Gloucester
150	4	272.0	"	"
150	6	272.8	"	"
152	1	215.4	A417	"
152	3	364.4	"	"
152	9	477.5	"	"
171	4	499.0	A465	Gwent
171	8	437.0	"	"
171	10	499.0	"	"
171	12	476.0	"	"
171	18	437.0	"	"
172	1	499.0	"	"
172	3	374.0	"	"
181	1	466.0	"	Mid-Glamorgan
183	2	458.4	A4059	"
183	3	194.4	"	"
183	5	167.7	"	"
183	7	102.7	"	"

MAIN STUDY 60 curves in total

... continued

TABLE A1: ... continued

PILOT STUDY

Group	Section No.	Radius	Road	County
2	2	375.0	A20	Kent
2	5	325.0	"	"
4	2	516.0	"	"
7	2	122.0	"	"
7	4	250.0	"	"
7	6	163.0	"	"
7	7	473.0	"	"
7	8	506.0	"	"
7	11	250.0	"	"
7	13	515.0	"	"
7	15	464.0	"	"
15	1	293.0	A229	"
15	2	299.0	"	"
15	3	309.0	"	"

PILOT STUDY 11 to 14 curves

TABLE A2: STUDY SITE LIST - DUAL CARRIAGEWAYS

(All Halcrow Fox Sites Below 500m radius)

MAIN STUDY

Group	Curve No.	Direction	Radius	Road	County
1103	1	B	476.0	A74	
1106	1	B	437.0	"	
1106	6	B	437.0	"	
1120	2	P	235.0	A167	
1120	2	N	222.7	"	
1161	2	B	436.0	A40	
1162	2	N	380.0	"	
1162	2	P	397.0	"	
1190	4	B	510.0	A38	Devon
1192	2	N	436.0	"	"
1192	4	N	436.0	"	"
1192	6	N	436.0	"	"
1192	3	P	160.3	"	"
1192	5	P	224.7	"	"
1192	7	P	286	"	"
1192	9	P	477.5	"	"
1192	11	P	231.5	"	"
1192	13	P	477.5	"	"
1192	14	P	420.9	"	"
1192	16	P	253.2	"	"
1192	20	P	297.2	"	"
1194	2	P	265.9	A380	"
1194	4	P	72.5	"	"
1194	5	P	412.9	"	"
1195	2	P	134.7	"	"
1195	4	P	145.8	"	"
1195	2	N	311.4	"	"
1197	1	N	246.6	"	"
1197	1	P	374.5	"	"
1200	1	B	320.2	A33	Hampshire
1200	3	B	260.2	"	"
1202	1	B	383.7	"	"

MAIN STUDY 40 directional curves in total

... continued

TABLE A2: ... continued

PILOT STUDY

Group	Section No.	Radius	Road	County
1001	4	480	A24	Surrey
1001	5	520	"	"
1001	6	490	"	"
1001	7	510	"	"
1001	8	510	"	"
1003	1	220	"	"
1003	2	403	"	"
1003	3	210	"	"
1003	4	200	"	"
1003	5	210	"	"
1003	6	184	"	"
1004	3	440	"	"
1004	4	440	"	"
1006	7	391	A22	"
1006	8	391	"	"
1006	9	410	"	"
1006	10	410	"	"
1006	11	397	"	"
1006	12	397	"	"
1006	21	268	"	"
1006	22	268	"	"
1006	23	250	"	"
1006	24	250	"	"
1006	25	220	"	"
1006	26	220	"	"
1007	3	380	A23	West Sussex
1007	4	470	"	"
1007	7	260	"	"
1007	8	360	"	"
1010	4	453	"	"

PILOT STUDY 30 sections - 12 to 15 curves

TABLE A3: GEOMETRIC DETAILS OF THE STUDY SITES - SINGLE CARRIAGEWAYS

Site Code	Group	Curve No.	Direction	Code	Section	No. of Lanes	H. Radius (m)	Length (m)	Total Angle (rad)	Road Width (m)	Verge Width (m)	Super-elevation (m/m)	Gradient (%)	Sight Distance (m)	Flow (veh/h)	Accident
1	100	1	1	1	0	1	34.00	77.85	2.290	3.51	2.00	0.087	3.44	354.00	107	99
2	100	1	2	2	0	1	34.00	77.85	2.290	3.46	5.00	0.087	-3.44	129.50	80	99
3	101	1	1	2	0	1	39.00	68.00	1.744	2.72	5.00	0.069	0.63	166.90	107	99
4	101	1	2	1	0	1	39.00	68.00	1.744	4.50	3.00	0.069	-0.63	100.00	94	99
5	102	1	1	2	0	1	290.00	121.00	0.417	3.02	1.00	0.013	1.80	573.00	231	99
6	102	1	2	1	0	1	290.00	121.00	0.417	3.40	2.00	0.013	-1.80	1920.00	177	99
7	103	1	1	1	0	1	45.00	47.90	1.064	3.30	0.10	0.067	-2.66	104.00	280	99
8	103	1	2	2	0	1	45.00	47.90	1.064	3.22	0.90	0.067	2.66	189.20	285	99
9	104	1	1	1	0	1	170.00	240.00	1.412	4.04	19.00	0.071	-1.06	150.90	274	99
10	104	1	2	2	0	1	170.00	240.00	1.412	3.16	4.00	0.071	1.06	142.50	235	99
11	104	2	1	1	0	1	161.00	112.80	0.701	3.64	4.00	0.070	-3.00	147.30	343	99
12	104	2	2	2	0	1	161.00	112.80	0.701	3.03	2.70	0.070	3.00	288.00	232	99
13	130	2	1	2	1-2	1	349.40	151.00	0.429	4.60	0.80	0.058	-2.25	389.00	0	4
14	130	2	2	1	1-2	1	349.40	151.00	0.429	4.60	2.00	0.058	2.25	228.00	0	1
15	130	4	1	2	7-8	1	286.50	173.00	0.593	3.45	4.00	0.058	-2.57	168.00	0	1
16	130	4	2	1	7-8	2	286.50	173.00	0.593	6.50	3.00	0.058	2.57	109.00	727	1
17	130	11	1	1	18-20	1	469.60	201.00	0.426	4.30	0.40	0.027	5.70	431.00	0	0
18	130	11	2	2	18-20	1	469.60	201.00	0.426	3.90	0.40	0.027	-5.70	135.00	0	1
19	130	15	1	2	25-27	1	425.80	222.00	0.517	4.80	0.50	0.035	5.25	175.00	633	1
20	130	15	2	1	25-27	1	425.80	222.00	0.517	4.30	2.00	0.035	-5.25	120.00	680	3
21	130	4	1	1	3-4	1	232.30	120.65	0.517	4.60	1.80	0.062	1.19	448.00	677	0

... continued

TABLE A3: ... continued

Site Code	Group	Curve No.	Direction	Code	Section	No. of Lanes	H. Radius (m)	Length (m)	Total Angle (rad)	Road Width (m)	Verge Width (m)	Super-elevation (m/m)	Gradient (%)	Sight Distance (m)	Flow (veh/h)	Accident
22	131	4	2	2	3-4	1	232.30	120.65	0.517	4.15	3.20	0.062	-1.19	158.00	625	0
23	131	6	1	2	7-8	1	355.60	91.00	0.253	4.45	1.50	0.044	-0.88	226.00	521	0
24	131	6	2	1	7-8	1	355.60	91.00	0.253	4.60	3.80	0.044	0.88	392.00	442	1
25	131	18	1	1	21-22	1	361.10	151.25	0.415	2.80	2.20	0.049	-1.13	122.00	545	1
26	131	18	2	2	21-22	2	361.10	151.25	0.415	5.55	3.50	0.049	1.13	107.00	551	2
27	133	2	1	1	1-2	1	406.80	121.00	0.295	4.65	5.60	0.045	0.25	175.00	704	1
28	133	2	2	2	1-2	1	406.80	121.00	0.295	4.20	1.40	0.045	-0.25	144.00	699	1
29	140	2	1	1	1-4	1	237.40	223.40	0.927	4.35	5.00	0.075	0.00	516.00	420	1
30	140	2	2	2	1-4	1	237.40	223.50	0.927	4.33	4.00	0.075	0.00	113.00	409	0
31	140	4	1	2	6-9	1	289.40	252.50	0.864	4.40	3.00	0.066	0.07	126.00	438	1
32	140	4	2	1	6-9	1	289.40	252.50	0.864	4.37	1.60	0.066	-0.07	125.00	463	0
33	141	4	1	2	2-4	1	294.50	168.00	0.560	4.30	6.10	0.068	-2.63	382.00	428	1
34	141	4	2	1	2-4	1	294.50	168.00	0.560	4.30	1.70	0.068	2.63	167.00	587	0
35	142	5	1	1	4-5	1	143.20	111.00	0.768	4.95	0.30	0.011	7.82	70.00	724	0
36	142	5	2	2	4-5	1	143.20	111.00	0.768	4.88	1.80	0.011	-7.82	85.00	532	7
37	143	4	1	1	4-7	2	172.90	288.00	1.620	6.35	2.70	0.056	4.13	76.00	160	2
38	143	4	2	2	4-7	1	172.90	288.00	1.620	3.05	1.90	0.056	-4.13	102.00	164	1
39	143	9	1	1	10	2	250.90	60.50	0.239	6.45	1.70	0.045	4.13	472.00	223	0
40	143	9	2	2	10	1	250.90	60.50	0.239	2.90	3.65	0.045	-4.13	1750.00	166	0
41	144	2	1	1	1-3	1	139.10	102.00	0.719	4.35	1.35	0.064	-4.75	114.00	411	1

... continued

TABLE A3: ... continued

Site Code	Group	Curve No.	Direction	Code	Section	No. of Lanes	H. Radius (m)	Length (m)	Total Angle (rad)	Road Width (m)	Verge Width (m)	Super-elevation (m/m)	Gradient (%)	Sight Distance (m)	Flow (veh/h)	Accident
42	144	2	2	2	1-3	1	139.10	102.00	0.719	4.45	1.85	0.064	4.75	82.00	522	1
43	145	4	1	2	4-6	1	143.50	154.80	1.045	5.10	2.15	0.070	-3.38	97.00	323	2
44	145	4	2	1	4-6	1	143.50	154.80	1.045	5.20	3.00	0.070	3.38	97.00	428	0
45	152	1	1	1	1	1	215.40	303.00	1.393	3.54	9.00	0.054	-2.38	286.00	411	0
46	152	1	2	2	1	2	215.40	303.00	1.393	6.64	4.00	0.054	2.38	197.00	479	0
47	171	4	1	1	6-7	2	499.00	95.50	0.190	6.46	0.50	0.045	5.00	317.00	579	2
48	171	4	2	2	6-7	1	499.00	95.50	0.190	3.40	0.50	0.045	-5.00	279.00	572	2
49	172	3	1	1	3-5	1	374.00	180.40	0.476	3.66	2.00	0.056	0.25	217.00	554	1
50	172	3	2	2	3-5	2	374.00	180.40	0.476	7.38	2.10	0.056	-0.25	176.00	827	1
51	183	3	1	1	2-4	1	194.40	174.50	0.874	5.00	1.75	0.067	-0.60	98.00	466	1
52	183	3	2	2	2-4	1	194.40	174.50	0.874	5.10	4.00	0.067	0.60	101.00	413	0
53	183	7	1	1	7-8	1	102.70	165.75	1.559	4.30	1.75	0.073	0.25	75.00	429	0
54	183	7	2	2	7-8	1	102.70	165.75	1.559	4.15	2.00	0.073	-0.25	71.00	436	3
55	190	1	1	1	-	1	89.90	138.75	1.543	3.46	4.00	0.081	4.41	79.00	220	99
56	190	1	2	2	-	1	89.90	138.75	1.543	3.30	3.10	0.081	-4.41	101.50	220	99

... continued

TABLE A3: ... continued - DUAL CARRIAGEWAYS

Site Code	Group	Curve No.	Direction	Code	Section	No. of Lanes	H. Radius (m)	Length (m)	Total Angle (rad)	Road Width Lane 1 (m)	Road Width Lane 2 (m)	Verge Width Lane 1 (m)	Verge Width Lane 2 (m)	Super-elevation (m/m)	Gradient (%)	Sight Distance (m)	Flow (veh/h)	Accident
1	1190	1	1	2	19-21	2	510.00	165.60	0.325	3.72	3.75	5.00	3.50	0.041	5.60	132.00	647*	1
2	1190	4	2	1	20-20	2	510.00	163.00	0.320	4.22	3.75	5.00	3.50	0.043	-5.60	121.00	656*	0
3	1192	2	2	1	2-8	2	436.00	306.80	0.704	3.67	3.72	7.00	4.00	0.072	-5.40	170.00	423	1
4	1192	3	1	2	3-5	2	160.30	84.00	0.524	4.00	4.42	2.50	2.00	0.056	3.80	85.00	370	6
5	1192	7	1	2	13	2	286.50	91.00	0.318	3.66	3.93	1.75	1.25	0.043	6.80	345.00	305	0
6	1192	9	1	2	15-17	2	477.50	90.60	0.190	3.66	3.75	2.10	1.50	0.031	5.55	117.00	632	1
7	1192	11	1	2	17-19	2	331.50	71.00	0.214	3.68	3.83	2.20	1.50	0.054	5.05	109.00	541	0
8	1192	14	1	1	27-31	2	420.90	204.00	0.485	3.70	3.67	1.10	1.05	0.069	3.80	143.00	526	0
9	1192	16	1	1	31-35	2	253.20	81.10	0.320	3.71	3.68	1.20	1.80	0.078	4.05	129.00	551	0
10	1192	20	1	2	37-39	2	297.20	153.50	0.517	3.11	3.42	3.00	2.50	0.051	3.05	114.00	523	0
11	1194	2	1	1	1-3	2	265.90	111.15	0.418	3.28	3.32	0.30	0.80	0.042	2.05	64.00	509	0
12	1194	4	1	1	1-5	2	72.50	157.50	2.172	3.98	3.64	0.50	2.00	0.104	0.40	36.00	569	3
13	1195	2	1	2	3-5	2	134.70	203.00	1.507	3.98	3.70	8.00	3.00	0.083	2.30	80.00	366	5
14	1195	2	2	1	8-10	2	311.40	151.50	0.487	3.58	3.50	4.80	18.30	0.071	-3.85	152.00	379	0
15	1195	4	1	2	7-9	2	145.80	71.10	0.488	2.80	2.82	0.20	1.00	0.056	2.65	69.00	470	3
16	1197	1	1	1	1-7	2	246.60	271.50	1.507	3.80	3.56	12.00	2.20	0.070	-8.55	153.00	672	1
17	1200	3	1	1	5-15	2	260.20	440.00	1.691	2.90	3.00	99.99	99.99	0.058	-0.15	80.00	886	13
18	1200	3	2	2	6-16	2	260.20	440.00	1.691	2.85	2.90	99.99	99.99	0.045	0.05	80.00	1063	8
19	1202	1	1	1	1-19	2	393.70	550.00	1.433	3.60	3.50	99.99	99.99	0.054	1.80	130.00	1153	7
20	1202	1	2	2	2-10	2	383.70	550.00	1.433	3.35	3.25	99.99	99.99	0.067	-1.80	80.00	1260	13
21	1210	1	1	2	-	2	210.85	366.70	1.739	3.42	3.80	0.40	12.00	0.072	-0.60	69.60	628	99
22	1211	1	1	2	-	2	208.00	159.35	0.766	3.66	3.60	3.00	12.00	0.083	-0.60	61.80	704	99

99 - No accident record available

Code - 1 - Left-hand curves

2 - Right-hand curves

TABLE A4: GEOMETRIC DETAILS OF THE SINGLE CARRIAGEWAY STUDY SITES

Site Code	Group	Curve No.	Direction	App. W (m)	En. W (m)	Mid. W (m)	Ex. W (m)	App. Gra (%)	En. Gra (%)	Mid. Gra (%)	Ex. Gra (%)	En. Sup (m/m)	Mid. Sup (m/m)	Ex. Sup (m/m)	Lane Code
1	100	1	1	2.80	2.90	3.51	2.57	0.08	6.81	3.44	0.03	0.071	0.087	0.044	1
2	100	1	2	2.80	2.64	3.46	2.50	-1.17	-0.03	-3.44	-6.81	0.044	0.087	0.071	1
3	101	1	1	3.20	3.07	2.72	2.91	0.85	0.93	0.63	0.11	0.028	0.069	0.034	1
4	101	1	2	3.20	2.75	4.50	2.75	-0.11	0.11	-0.63	-0.93	0.034	0.069	0.028	1
5	102	1	1	3.25	3.22	3.02	3.05	2.34	1.47	1.80	0.69	0.002	0.013	0.006	1
6	102	1	2	3.17	3.15	3.40	3.20	-0.14	-0.69	-1.80	-1.47	0.006	0.013	0.002	1
7	103	1	1	3.25	3.20	3.30	3.00	0.00	-0.98	-2.66	-3.18	0.041	0.067	0.052	1
8	103	1	2	3.25	3.10	3.22	2.86	0.00	3.18	2.66	0.98	0.052	0.067	0.041	1
9	104	1	1	3.34	3.35	4.04	3.25	0.00	-1.24	-1.06	0.63	0.011	0.071	0.042	1
10	104	1	2	2.96	3.09	3.16	3.04	-0.63	-0.63	1.06	1.24	0.042	0.071	0.011	1
11	104	2	1	3.29	3.22	3.64	2.65	-2.03	-2.03	-3.00	-1.85	0.049	0.070	0.019	1
12	104	2	2	3.30	3.33	3.03	2.86	1.08	1.85	3.00	2.03	0.019	0.070	0.049	1
13	130	2	1	4.80	4.16	4.60	4.25	-5.13	-3.00	-2.25	-1.50	0.022	0.058	0.030	1
14	130	2	2	4.70	4.45	4.60	5.70	1.50	1.50	2.25	3.00	0.030	0.058	0.022	1
15	130	4	1	3.50	3.45	3.45	3.40	-3.13	-2.25	-2.25	-2.88	0.029	0.058	0.026	1
16	130	4	2	6.45*	6.50*	6.50	6.40	5.13	2.88	2.57	2.25	0.026	0.058	0.029	2
17	130	11	1	4.25	4.20	4.30	4.00	-0.63	4.25	5.70	7.13	0.020	0.027	0.016	1
18	130	11	2	4.20	4.45	3.90	4.30	0.38	-7.13	-5.70	-4.25	0.016	0.027	0.018	1
19	130	15	1	4.40	4.50	4.80	3.95	0.88	5.13	5.25	4.63	0.018	0.035	0.013	1
20	130	15	2	4.25	4.40	4.30	4.25	0.63	-4.63	-5.25	-5.13	0.013	0.035	9.999	1
21	131	4	1	4.90	4.50	4.60	4.45	0.00	0.63	1.19	1.75	0.060	0.062	0.027	1
22	131	4	2	4.80	4.20	4.15	4.25	0.00	-1.75	-1.19	-0.63	0.027	0.062	0.060	1
23	131	6	1	4.55	4.30	4.45	4.55	-0.38	0.00	-0.88	-1.75	0.034	0.044	0.034	1
24	131	6	2	4.50	4.40	4.60	4.60	-0.75	1.75	0.88	0.00	0.034	0.044	0.031	1
25	131	18	1	4.95	3.70	2.80	2.70	0.95	-1.50	-1.13	-0.75	0.035	0.049	0.040	1
26	131	18	2	4.85	5.85	5.55	4.25	-1.00	0.75	1.13	1.50	0.040	0.049	0.035	2
27	133	2	1	4.65	4.40	4.65	4.40	0.25	-2.00	0.25	2.25	0.039	0.045	0.029	1

... continued

TABLE A4: ... continued

Site Code	Group	Curve No.	Direction	App. W (m)	En. W (m)	Mid. W (m)	Ex. W (m)	App. Gra (%)	En. Gra (%)	Mid. Gra (%)	Ex. Gra (%)	En. Sup (m/m)	Mid. Sup (m/m)	Ex. Sup (m/m)	Lane Code
28	133	2	2	4.70	4.20	4.20	4.25	-1.00	-2.25	-0.25	2.00	0.029	0.045	0.039	1
29	140	2	1	4.33	4.32	4.35	4.42	0.00	-0.38	0.00	0.00	0.014	0.075	0.033	1
30	14C	2	2	4.35	4.25	4.33	4.25	0.00	0.00	0.00	0.38	0.033	0.075	0.014	1
31	140	4	1	4.35	4.43	4.40	4.37	0.00	0.00	0.07	0.13	0.011	0.066	0.009	1
32	140	4	2	4.35	4.30	4.37	4.22	0.00	-0.13	-0.07	0.00	0.009	0.066	0.011	1
33	141	4	1	4.43	4.40	4.30	4.40	-2.88	-3.00	-2.63	-2.50	0.001	0.068	0.034	1
34	141	4	2	4.40	4.40	4.30	4.40	2.88	2.50	2.63	3.00	0.034	0.068	0.001	1
35	142	5	1	5.03	5.24	4.95	4.30	1.00	7.50	7.82	8.13	0.004	0.011	0.013	1
36	142	5	2	4.63	4.65	4.88	4.75	1.50	-8.13	-7.82	-7.50	0.013	0.011	0.004	1
37	143	4	1	6.35*	6.30*	6.35*	6.45*	3.00	4.13	4.13	4.00	0.017	0.056	0.048	2
38	143	4	2	2.95	2.91	3.05	2.95	-4.75	-4.00	-4.13	-4.13	0.048	0.056	0.017	1
39	143	9	1	6.40*	6.45*	6.45*	5.90	4.00	4.13	4.13	4.13	0.044	0.045	0.012	2
40	143	9	2	4.65	3.85	2.90	2.90	-4.31	-4.13	-4.13	-4.13	0.012	0.045	0.044	1
41	144	2	1	4.55	4.40	4.35	4.25	-4.25	-4.75	-4.75	-5.25	0.025	0.064	0.043	1
42	144	2	2	4.45	4.00	4.45	4.50	4.25	5.25	4.75	4.25	0.043	0.064	0.025	1
43	145	4	1	4.25	4.75	5.10	4.55	0.88	-0.13	-3.38	-5.13	0.020	0.070	0.011	1
44	145	4	2	4.75	4.45	5.20	4.65	2.38	5.13	3.38	0.13	0.011	0.070	0.020	1
45	152	1	1	3.32	3.34	3.54	3.44	-2.75	-2.38	-2.38	-2.38	0.051	0.054	0.050	1
46	142	1	2	6.62*	6.68*	6.64*	6.64*	2.38	2.38	2.38	2.38	0.050	0.054	0.051	2
47	171	4	1	6.25	6.57	6.46	6.66	5.00	5.00	5.00	5.00	0.017	0.045	0.028	2
48	171	4	2	3.25	3.30	3.40	3.38	-5.00	-5.00	-5.00	-5.00	0.028	0.045	0.017	1
49	172	3	1	3.42	3.48	3.66	3.50	-0.20	-0.20	0.25	0.70	0.029	0.056	0.030	1
50	172	3	2	6.78*	7.10*	7.38*	7.04*	-1.50	-0.70	-0.25	0.20	0.030	0.056	0.029	2
51	183	3	1	4.70	4.80	5.00	4.40	-2.00	-0.60	-0.60	0.20	0.065	0.067	0.010	1
52	183	3	2	4.48	4.67	5.10	4.35	-1.40	-0.20	0.60	0.60	0.010	0.067	0.065	1
53	183	7	1	3.66	3.88	4.30	4.12	0.40	0.40	0.25	0.10	0.069	0.073	0.063	1
54	183	7	2	4.10	4.12	4.15	4.04	0.60	-0.10	0.25	-0.40	0.063	0.073	0.069	1
55	190	1	1	3.60	3.66	3.46	3.13	0.42	1.90	4.50	6.80	0.062	0.081	0.050	1
56	190	1	2	3.45	3.43	3.30	3.63	-3.52	-6.00	-4.10	-2.40	0.050	0.081	0.062	1

*Three lane single carriageway

TABLE A4: ... continued - DUAL CARRIAGEWAYS

Site Code	Group	Curve No.	Dir.	App. W Lane 1 (m)	App. W Lane 2 (m)	En. W Lane 1 (m)	En. W Lane 2 (m)	Mid. W Lane 1 (m)	Mid. W Lane 2 (m)	Ex. W Lane 1 (m)	Ex. W Lane 2 (m)	App. Gra (%)	En. Gra (%)	Mid. Gra (%)	Ex. Gra (%)	En. Sup (m/m)	Mid. Sup (m/m)	Ex. Sup (m/m)
1	1190	4	1	3.72	3.75	3.70	3.78	3.72	3.75	3.75	3.60	3.80	5.60	5.60	4.40	0.053	0.041	0.021
2	1190	4	2	3.76	3.73	3.78	3.52	4.22	3.75	3.88	3.78	0.40	-4.40	-5.60	-5.60	0.022	0.043	0.050
3	1192	2	2	3.66	3.64	3.68	3.62	3.67	3.72	3.65	3.63	-6.20	-2.20	-5.40	-6.25	0.028	0.072	0.064
4	1192	3	1	3.72	3.67	3.72	3.70	4.00	4.42	3.84	3.56	4.80	4.80	3.80	2.80	0.040	0.056	0.033
5	1192	7	1	3.72	3.70	3.60	3.88	3.66	3.93	3.92	3.74	3.80	6.80	6.80	6.80	0.044	0.043	0.032
6	1192	9	1	3.72	3.70	3.84	3.80	3.66	3.75	3.80	3.80	3.80	5.80	5.55	5.30	0.031	0.031	0.031
7	1192	11	1	3.72	3.70	3.70	3.90	3.68	3.83	3.78	3.63	3.80	5.30	5.05	4.80	0.036	0.054	0.018
8	1192	14	1	3.70	3.78	3.75	3.85	3.70	3.67	3.70	3.87	2.40	5.30	3.80	4.30	0.052	0.069	0.037
9	1192	16	1	3.70	3.78	3.75	3.70	3.71	3.68	3.67	3.62	2.40	4.30	4.05	3.08	0.040	0.078	0.006
10	1192	20	1	3.44	3.40	3.40	3.38	3.22	3.42	3.70	3.64	2.40	2.80	3.05	3.30	0.026	0.051	0.038
11	1194	2	1	3.28	3.06	3.38	3.10	3.28	3.32	3.06	2.92	0.93	2.30	2.05	1.80	0.029	0.042	0.023
12	1194	4	1	3.10	2.98	3.60	3.42	3.98	3.64	3.66	3.24	0.93	1.80	0.40	0.85	0.052	0.104	0.036
13	1195	2	1	3.00	3.00	3.20	3.00	3.98	3.70	3.24	3.22	-0.30	1.80	2.30	2.80	0.021	0.083	0.022
14	1195	2	2	3.65	3.70	3.55	3.58	3.58	3.50	3.30	3.60	-0.90	-1.90	-3.85	-3.85	0.037	0.071	0.058
15	1195	4	1	3.11	3.14	3.13	2.95	2.80	2.82	2.79	3.02	2.80	3.30	2.65	2.00	0.024	0.056	0.048
16	1197	1	1	3.75	3.68	3.90	3.56	3.80	3.56	3.64	3.72	-1.00	-4.50	-8.55	-9.33	0.008	0.070	0.072
17	1200	3	1	3.20	3.20	3.05	3.10	2.90	3.00	3.05	2.90	-4.40	-2.80	-0.15	-0.30	0.024	0.058	0.020
18	1200	3	2	3.15	3.15	3.00	3.05	2.85	2.90	2.90	3.05	0.20	0.30	0.05	3.25	0.020	0.045	0.008
19	1202	1	1	3.64	3.65	3.65	3.65	3.60	3.50	3.55	3.55	0.40	0.40	1.80	2.60	0.035	0.054	0.029
20	1202	1	2	3.30	3.30	3.35	3.20	3.35	3.25	3.70	3.45	-2.60	-2.60	-1.80	-0.70	0.029	0.067	0.041
21	1210	1	1	3.35	3.85	3.27	3.78	3.42	3.80	3.52	3.63	-0.90	-2.30	-0.60	0.70	0.038	0.072	0.040
22	1211	1	2	3.45	3.80	3.42	3.76	3.66	3.60	3.16	3.30	1.70	1.60	-0.60	-1.60	0.042	0.083	0.004

Lane Code – 1 - Two lane carriageway
2 - Three lane carriageway

TABLE A5 : GECMETRIC DETAILS OF THE SINGLE CARRIAGEWAY SITES

Site Code	Group	Curve No.	Direction	ENW 1	ENW 2	MW 1	MW 2	EXW 1	EXW 2	ETD	MTD	EXTD	Lane Code
1	100	1	1	3.00	3.00	2.94	3.10	2.57	2.57	20.10	20.00	20.10	1
2	100	1	2	2.64	2.64	3.34	3.44	2.50	2.50	19.95	19.70	20.70	1
3	101	1	1	3.24	2.76	2.48	3.00	3.40	2.91	19.80	16.50	22.45	1
4	101	1	2	2.75	2.98	4.35	4.02	3.12	2.70	22.15	17.15	19.40	1
5	102	1	2	3.21	3.23	3.02	3.02	3.10	3.10	20.05	20.05	19.90	1
6	102	1	2	3.20	3.20	3.35	3.40	3.22	3.18	20.05	20.05	20.05	1
7	103	1	1	3.24	3.10	3.10	3.03	3.03	2.90	20.05	23.70	19.95	1
8	103	1	2	3.00	3.62	3.62	2.92	2.92	2.64	19.70	29.35	20.00	1
9	104	1	1	3.37	3.30	3.94	4.03	3.26	3.23	20.00	20.05	19.95	1
10	104	1	2	3.03	3.12	3.16	3.08	2.96	3.07	19.95	20.00	20.05	1
11	104	2	1	3.20	3.27	3.68	3.42	2.65	2.70	20.00	19.95	20.05	1
12	104	2	2	3.34	3.27	2.90	3.10	2.82	2.90	20.00	20.05	20.00	1
13	130	2	1	4.16	4.16	4.60	4.60	4.25	4.25	19.60	20.85	20.35	1
14	130	2	2	4.45	4.45	4.60	4.60	5.70*	5.70*	20.15	20.10	20.02	3
15	130	4	1	3.50	3.50	3.45	3.45	3.40	3.40	19.50	19.90	19.90	1
16	130	4	2	6.43*	6.43*	6.50*	6.50*	6.43*	6.43*	20.00	20.90	19.70	2
17	130	11	1	4.20	4.20	4.30	4.30	4.00	4.00	20.20	19.95	20.10	1
18	130	11	2	4.45	4.45	3.90	3.90	4.30	4.30	20.25	19.95	19.90	1
19	130	15	1	4.50	4.50	4.80	4.80	3.95	3.95	19.90	20.70	20.10	1
20	130	15	2	4.40	4.40	4.30	4.30	4.25	4.25	20.10	20.30	20.00	1
21	131	4	1	4.50	4.50	4.60	4.60	4.45	4.45	20.00	20.00	19.90	1
22	131	4	2	4.20	4.20	4.15	4.15	4.25	4.25	20.00	20.15	19.95	1
23	131	6	1	4.30	4.30	4.45	4.45	4.55	4.55	20.15	20.05	20.10	1
24	131	6	2	4.40	4.40	4.60	4.60	4.60	4.60	19.95	20.10	19.90	1

... continued

TABLE A5: ... continued

Site Code	Group	Curve No.	Direction	ENW 1	ENW 2	MW 1	MW 2	EXW 1	EXW 2	ETD	MTD	EXTD	Lane Code
25	131	18	1	3.70	3.70	2.80	2.80	2.70	2.70	19.80	20.20	20.10	1
26	131	18	2	5.85*	5.85*	5.55*	5.55*	4.25	4.25	20.20	21.00	20.15	2
27	133	2	1	4.40	4.40	4.65	4.65	4.40	4.40	20.10	19.90	19.90	1
28	133	2	2	4.20	4.20	4.20	4.20	4.25	4.25	20.20	20.15	20.10	1
29	140	2	1	4.32	4.32	4.35	4.35	4.42	4.42	20.00	19.95	20.00	1
30	140	2	2	4.25	4.25	4.33	4.33	4.25	4.25	19.90	20.55	20.25	2
31	140	4	1	4.43	4.43	4.40	4.40	4.37	4.37	20.00	20.00	20.25	1
32	140	4	2	4.30	4.30	4.37	4.37	4.22	4.22	20.00	20.40	20.30	1
33	141	4	1	4.40	4.40	4.30	4.30	4.40	4.40	16.85	20.00	20.00	1
34	141	4	2	4.40	4.40	4.40	4.40	4.40	4.40	20.15	20.10	16.95	1
35	142	5	1	5.25	5.24	4.95	4.95	4.30	4.30	20.05	18.50	20.20	1
36	142	5	2	4.65	4.65	4.88	4.88	4.75	4.75	20.05	20.10	20.00	1
37	143	4	1	6.30*	6.30*	6.35*	6.35*	6.45*	6.45*	19.90	20.00	20.00	2
38	143	4	2	2.90	2.90	3.05	3.05	2.95	2.95	20.00	20.05	19.95	1
39	143	9	1	6.45*	6.45*	6.45*	6.45*	5.80*	5.60*	20.10	20.05	20.00	2
40	143	9	2	4.05	3.55	2.90	2.90	2.90	2.90	20.10	20.10	19.65	1
41	144	2	1	4.40	4.40	4.35	4.35	4.25	4.25	19.90	19.90	19.90	1
42	144	2	2	4.00	4.00	4.45	4.45	4.50	4.50	19.90	19.90	20.00	1
43	145	4	1	4.75	4.75	5.10	5.10	4.55	4.55	20.05	20.00	20.00	1
44	145	4	2	4.45	4.45	5.20	5.20	4.65	4.65	20.00	20.05	20.05	1
45	152	1	1	3.34	3.34	3.54	3.54	3.44	3.44	20.05	20.05	20.00	1
46	152	1	2	6.68*	6.68*	6.64*	6.64*	6.64*	6.64*	20.00	20.00	20.05	2

... continued

TABLE A5: ... continued

Site Code	Group	Curve No.	Direction	ENW 1	ENW 2	MW 1	MW 2	EXW 1	EXW 2	ETD	MTD	EXTD	Lane Code
47	171	4	1	6.57*	6.57*	6.46*	6.46*	6.66*	6.66*	20.00	20.10	20.00	2
48	171	4	2	3.30	3.30	3.40	3.40	3.38	3.38	20.00	20.00	20.40	1
49	172	3	1	3.48	3.48	3.66	3.66	3.50	3.50	19.95	20.00	20.00	1
50	172	3	2	7.10*	7.10*	7.38*	7.38*	7.04*	7.04*	20.00	20.00	20.00	2
51	183	3	1	4.86	4.80	5.00	4.80	4.56	4.50	20.00	20.00	20.00	1
52	183	3	2	4.50	4.82	5.25	5.00	4.50	4.14	19.95	20.00	20.00	1
53	183	7	1	3.88	3.88	4.40	4.32	4.20	4.14	20.00	20.20	19.95	1
54	183	7	2	4.08	4.20	4.38	4.28	4.04	3.91	20.00	20.00	20.00	1
55	190	1	1	3.69	3.63	3.46	3.46	3.10	3.12	20.00	20.00	20.00	1
56	190	1	2	3.63	3.30	3.36	3.24	3.24	3.60	20.00	20.00	20.00	1

*Carriageway with more than two lanes

1 - Two lane road

2 - Three lane road

3 - More than three lane road

... continued

TABLE A5: ... continued - DUAL CARRIAGEWAYS

Site Code	Curve No.	ENWL1A	ENWL1B	ENWL2A	ENWL2B	MWL1A	MWL1B	MWL2A	MWL2B	EXWL1A	EXWL1B	EXWL2A	EXWL2B	ENDL1	ENDL2	MDL1	MDL2	EXDL1	EXDL2
1	41	3.65	3.71	3.88	3.75	3.75	3.80	3.72	3.75	3.75	3.75	3.60	3.60	20.00	20.00	20.00	20.00	20.05	20.05
2	42	3.78	3.78	3.52	3.52	4.44	4.02	3.75	3.75	3.88	3.88	3.78	3.78	20.00	20.05	20.00	20.00	20.00	20.00
3	22	3.67	3.67	3.66	3.62	3.66	3.63	3.65	3.72	3.60	3.66	3.68	3.66	19.95	20.00	19.95	20.00	20.05	20.00
4	31	3.62	3.76	3.70	3.82	3.83	4.04	4.42	4.18	3.74	3.80	3.68	3.70	20.05	20.00	20.00	20.00	20.00	20.00
5	71	3.69	3.56	3.86	3.90	3.69	3.70	3.99	3.83	3.72	3.80	3.90	3.84	20.00	20.00	20.00	20.05	20.00	20.00
6	91	3.84	3.84	3.80	3.80	3.66	3.72	3.85	3.68	3.75	3.82	3.77	3.85	20.00	19.95	20.00	19.95	20.05	20.00
7	11	3.71	3.50	3.90	3.93	3.80	3.63	3.76	3.80	3.72	3.77	3.68	3.65	20.00	20.00	20.00	20.00	20.05	20.00
8	14	3.76	3.83	3.87	3.75	3.77	3.73	3.67	3.80	3.69	3.70	3.80	3.81	20.00	2o.00	20.00	20.00	20.00	20.00
9	16	3.67	3.75	3.77	3.78	3.75	3.72	3.75	3.68	3.69	3.68	3.70	3.67	20.00	20.00	20.00	20.00	19.95	20.00
10	20	3.49	3.31	3.33	3.37	2.88	3.18	3.40	3.38	3.66	3.62	3.67	3.64	20.05	20.00	20.00	20.00	20.05	20.05
11	21	3.38	3.38	3.10	3.10	3.30	3.15	3.40	3.40	3.04	3.08	2.86	2.92	20.05	20.00	20.00	20.05	20.00	20.00
12	41	3.60	3.60	3.42	3.42	3.98	3.98	3.64	3.64	3.66	3.66	3.24	3.24	19.95	19.95	20.00	20.05	20.00	20.00
13	21	3.22	3.28	3.06	3.02	3.85	4.22	3.66	3.82	3.30	3.24	3.33	3.22	20.00	20.00	20.00	20.05	20.00	20.00
14	22	3.50	3.56	3.61	3.60	3.47	3.57	3.60	3.52	3.50	3.40	3.30	3.40	20.00	20.00	19.95	20.05	20.00	20.05
15	41	3.06	2.75	3.18	3.12	2.82	2.90	2.85	2.76	3.03	3.03	2.70	2.89	20.00	20.00	20.00	19.95	20.00	20.00
16	21	3.89	2.86	3.57	3.56	3.72	3.75	3.63	3.64	3.62	3.59	3.70	3.76	20.05	20.00	20.00	20.00	20.00	20.00
17	31	3.05	3.05	3.10	3.10	2.90	2.90	3.00	3.00	3.05	3.05	2.90	2.90	20.05	20.05	19.95	19.95	20.20	20.20
18	32	3.00	3.00	3.05	3.05	2.85	2.85	2.90	2.90	2.90	2.90	3.05	3.05	19.90	19.90	20.00	20.00	20.10	20.10
19	11	3.65	3.65	3.65	3.60	3.60	3.60	3.50	3.50	3.55	3.55	3.55	3.55	20.02	20.02	19.90	19.90	20.00	20.00
20	12	3.35	3.35	3.20	3.20	3.35	3.35	3.25	3.25	3.70	3.70	3.45	3.45	20.05	20.05	19.80	19.80	20.05	20.05
21	11	3.24	3.25	3.72	3.86	3.45	3.42	3.82	3.72	3.55	3.50	3.60	3.63	20.00	20.00	20.00	20.00	20.00	20.00
22	11	3.26	3.40	3.82	3.72	3.76	3.72	3.48	3.52	3.60	3.12	3.15	3.21	20.00	20.00	20.00	20.00	20.00	20.00

TABLE A6: NUMBER OF PROPSHAFT REVOLUTIONS AT VARIOUS SPEEDS OVER A 756 METRES LENGTH OF ROAD (FORD CORTINA TEST CAR)

SPEED (k.p.h.)	NUMBER OF PROPSHAFT REVOLUTIONS				AVERAGE
	Run 1	Run 2	Run 3	Run 4	
32	1700	1703	1701	1703	1702
48	1702	1704	1709	1706	1705
64	1706	1707	1680	1705	1700
80	1651	1706	1706	1649	1679
96	1702	1699	1699	1709	1703

Figure 6.1a Measured Edge-to-Edge Sight Distances

(LL and RR not measured on Single Carriageways)

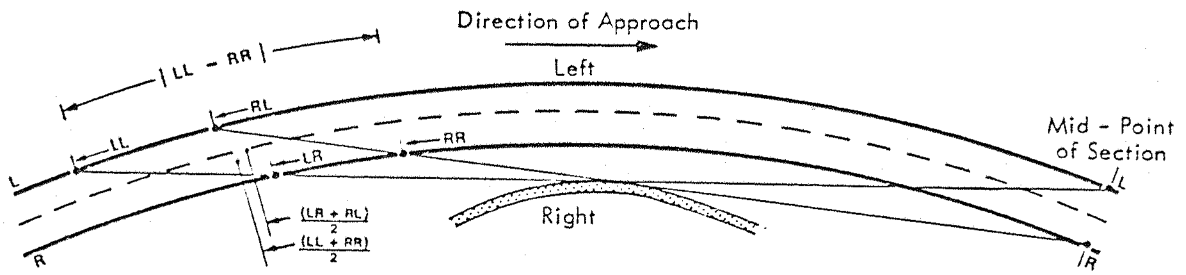
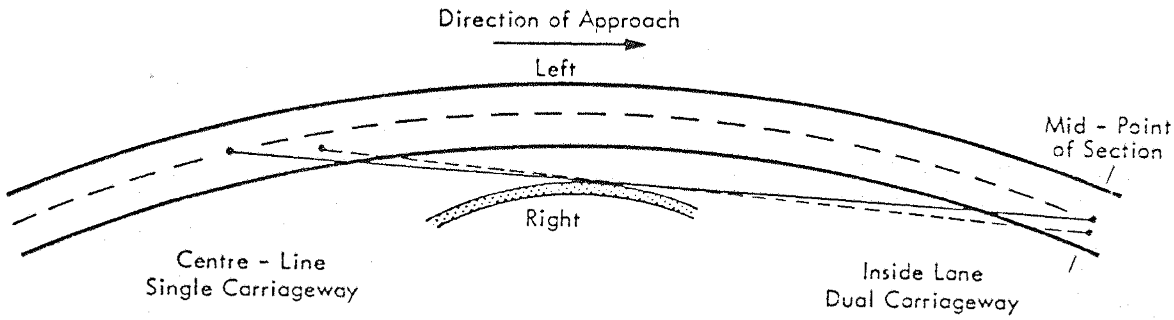


Figure 6.1b Required In-Carriageway Sight Distances



Using the notation of Fig. 6.1a, the formulae used to estimate in-carriageway sight distances were:

$$\text{Centre-line Sight Distance} = \frac{LR + RL}{2}$$

$$\left(\frac{LL + RR}{2} \text{ was less accurate}\right)$$

$$\text{Inside Lane Sight Distance} = \frac{LR + RL}{2} - \frac{1}{4} \text{ Modulus} \left| LL - RR \right|$$

The values of $\left[LR - RL\right]$ and $\left[\frac{LR + RL}{2} - \frac{LL + RR}{2}\right]$ were useful checks on the data. The former was usually ±30m, and the latter even smaller. Much larger values were found where sightlines were ill-conditioned or very sensitive (e.g. reverse bends, start of bend after long straight).

Transportation Research Group
Southampton University
Southampton SO9 5NH

Date ....
Time ....

GENERAL SURVEY FORM

County .... Road .... Group ....
Map .... Curve .... Group Name ....
General Location ....
Start .... GR ....
Finish .... GR ....
Number of Section in Curve .... Survey Direction ....
Direction 1 .... Direction 2 ....
Comments ....
....
....

SITE GEOMETRY DATA			
Approach	Entry	Middle	Exit
Width 1A = Width 1B = Width 2A = Width 2B = Superelevation	Width 1A = Width 1B = Width 2A = Width 2B = Superelevation	Width 1A = Width 1B = Width 2A = Width 2B = Superelevation	Width 1A = Width 1B = Width 2A = Width 2B = Superelevation

Figure A1: General Survey Form Curve Geometric Data

TRANSPORTATION RESEARCH GROUP, Southampton University, SOUTHAMPTON. SO9 5NH

VEHICLE SPEED/LOCATION SURVEY

Road .... Direction ....

Site .... Date ....

Time Start .... Time End ....

Weather .... Observer ....

Regis-tration No.	Driver Sex	No. of Pass.	Car	HGV	Bunch size	Speed (kph)	Lane (Dual)	Vehicle Make	Abort	Headway Comments	

Figure A2: Vehicle Survey Form for Curve Approach Data Collection

TRANSPORTATION RESEARCH GROUP, Southampton University, Southampton, SO9 4NH

VEHICLE SPEED/LOCATION SURVEY

Road .... Direction ....

Site .... Section .... Location ....

Date .... Time Start .... Time End ....

Weather .... Observer ....

Regis-tration No.	Location	Location	Time (sec)	Lane (Dual)	Abort	Headway Comments	Comments

Figure A3: Vehicle Survey Form for Within Curve Data Collection

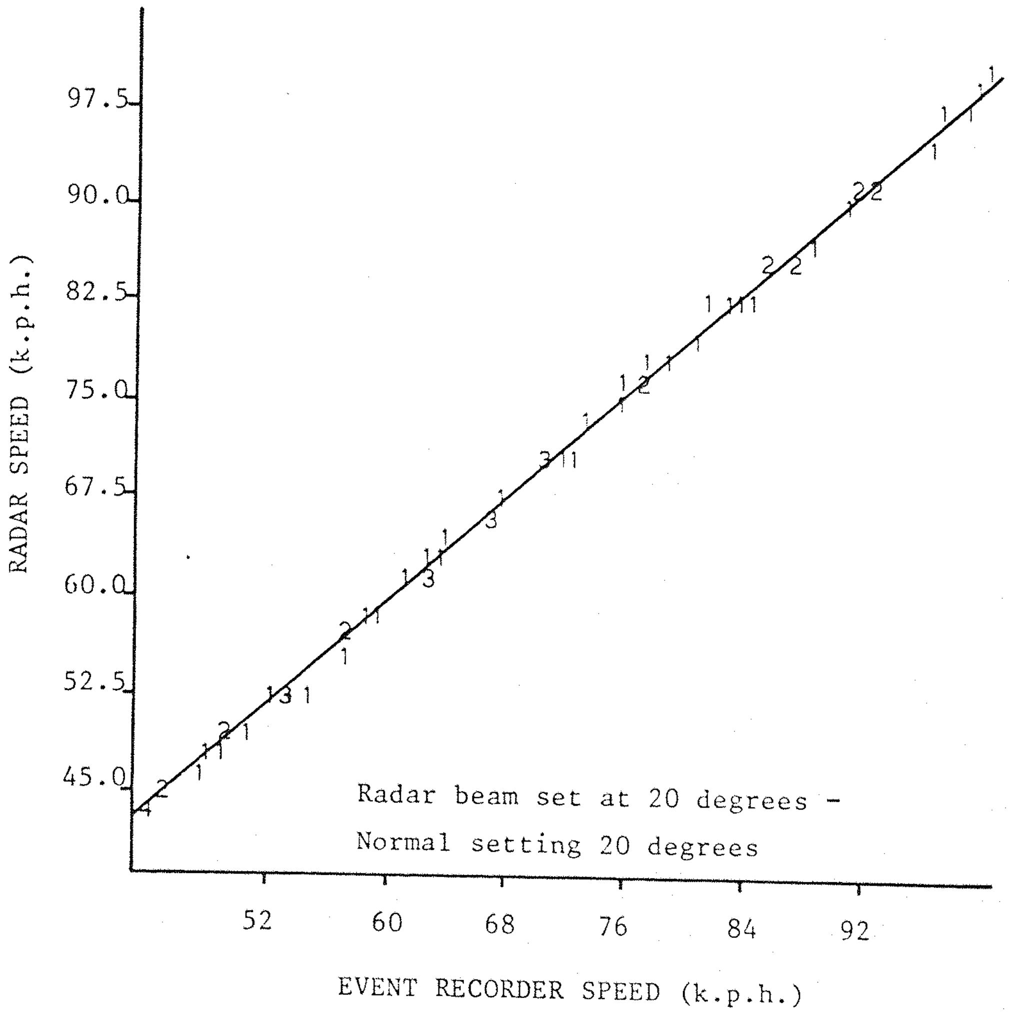


Figure A4 : Relationships between Radar Speedmeter and Event Recorder Speed Measurements

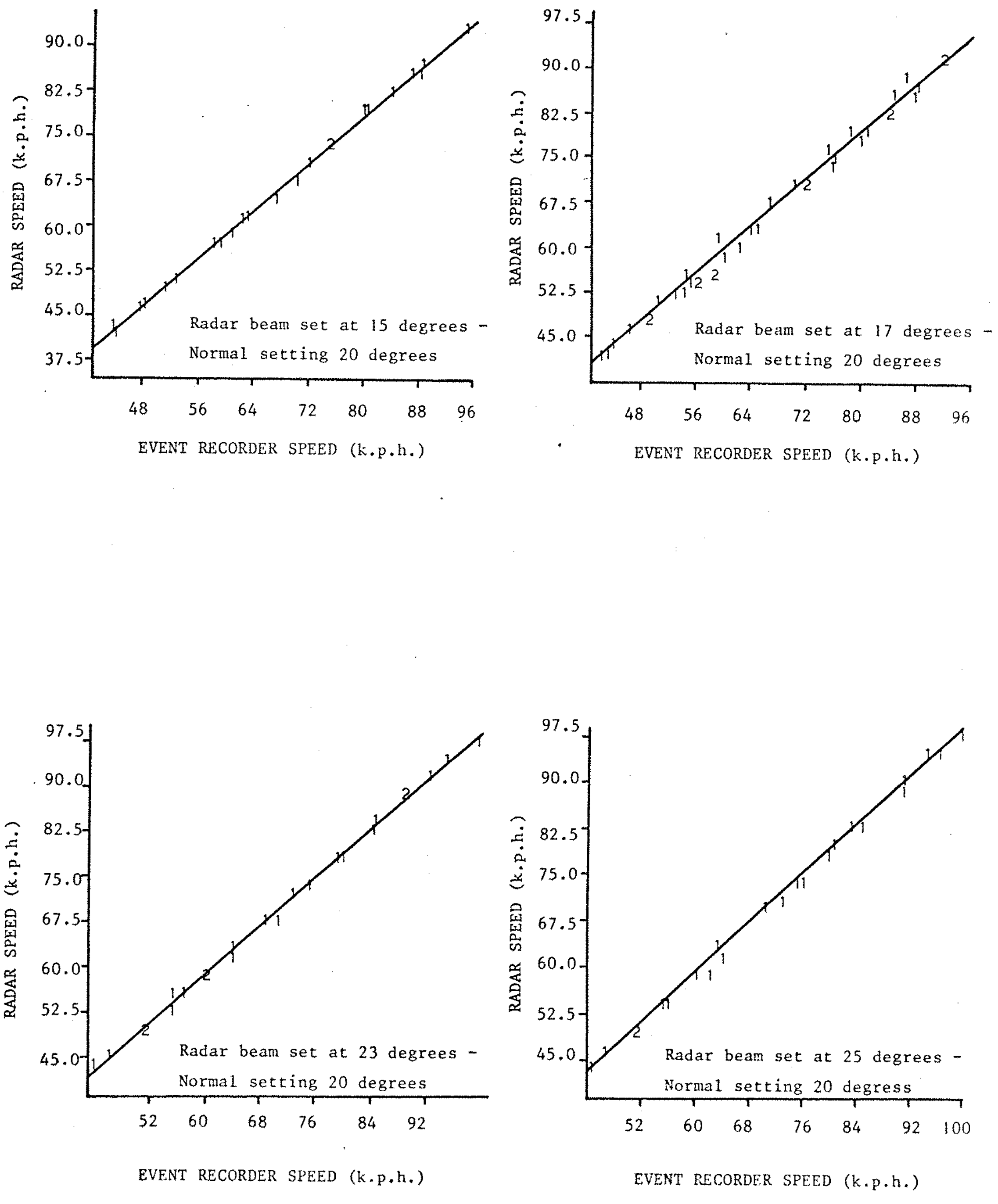


Figure A5 : Relationships between Radar Speedmeter and Event Recorder Speed Measurements

APPENDIX B

DATA MANIPULATION

LIST OF TABLES

LIST OF FIGURES

TABLE B1: DESIGN SPEEDS - SINGLE CARRIAGEWAYS

Group	Road Width (m)	Verge Width (m)	Bendi-ness (deg/km)	VISI (m)	L_C	A_C	Design Speed (k.p.h)
100	5.60	3.50	89.00	238.51	26	11.98	85.78
101	6.40	4.00	142.38	183.68	26	15.27	81.53
102	6.42	1.50	22.00	291.74	28	8.12	87.97
103	6.50	0.50	85.00	185.14	30	12.69	79.75
104	6.59	7.43	102.21	317.45	26	11.25	86.64
130	8.65	1.64	65.00	200.82	19	11.54	93.98
131	9.70	1.67	102.69	186.87	17	13.45	94.53
133	9.35	3.50	59.00	191.24	17	11.43	96.31
140	8.70	3.40	77.50	227.01	17	11.66	96.09
141	8.83	3.90	56.00	233.97	17	1059	97.34
142	9.66	1.05	68.50	157.14	19	12.43	92.97
143	9.30	2.49	90.00	185.31	17	12.91	94.77
144 & 145	9.00	2.09	147.27	156.83	17	15.93	91.56
152	9.94	6.50	108.50	231.51	17	12.96	94.38
171 & 172	10.2o	1.28	46.40	246.19	19	9.96	95.78
183	9.18	2.38	104.00	143.46	17	14.23	92.93
190	7.05	3.55	85.50	244.48	21	11.73	91.80

TABLE B2: DESIGN SPEEDS - DUAL CARRIAGEWAYS

Group	Road Width (m)	Verge Width (m)	Bendi-ness (deg/km)	VIS1 (m)	L_C	A_C	Design Speed (k.p.h.)
1190		4.25	48.64		10	11.46	105.51
1192		2.34	110.00		10	17.60	97.50
1194		0.90			9	17.01	99.22
1195		5.88	104.12		10	17.01	98.05
1197		7.10			10	17.01	98.05
1200		1.83	107.14		9	17.31	98.91
1202		2.78	52.38		10	11.84	103.93
1210		6.20	77.83		10	14.38	101.03
1211		7.50			10	14.38	101.03

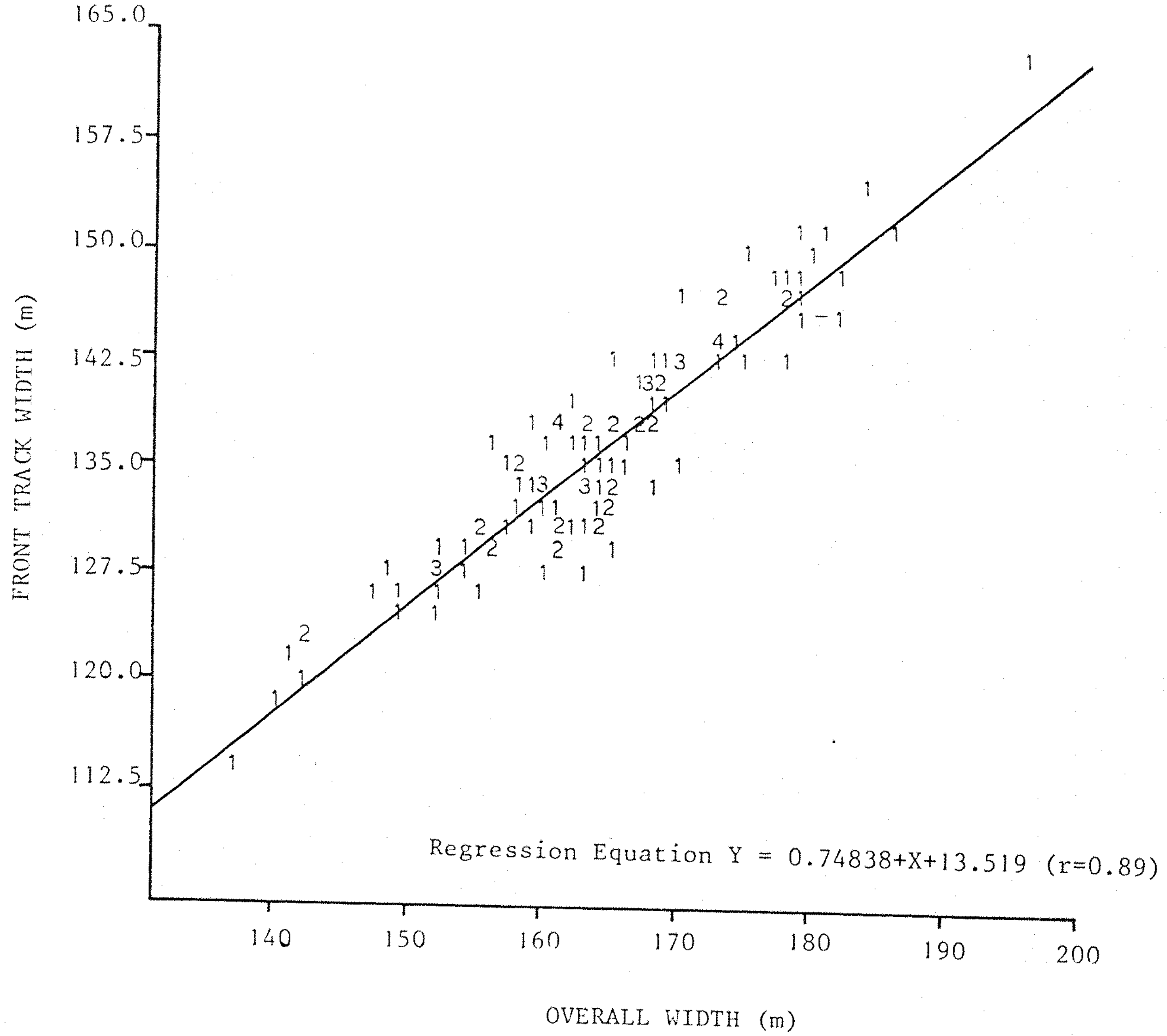


Figure B1 : Relationship between Front Track Width and Overall Width for All Cars)

APPENDIX C

METHOD OF ANALYSIS

LIST OF TABLES

LIST OF FIGURES

TABLE C1: LIST OF DEPENDENT AND INDEPENDENT VARIABLES USED IN THE CORRELATION AND REGRESSION ANALYSIS

CODE	VARIABLE
V(i)	i-th Percentile Vehicle Speed, k.p.h.
V_{CE}	All Car Entry Speed, k.p.h.
V_{FCE}	Free Car Entry Speed, k.p.h.
V_{GE}	Goods Vehicle Entry Speed, k.p.h.
V_{CM}	All Car Middle Speed, k.p.h.
V_{FCM}	Free Car Middle Speed, k.p.h.
V_{GM}	Goods Vehicle Middle Speed, k.p.h.
A_{CM}	All Car Middle Lateral Acceleration, m/sec^2.
A_{FCM}	Free Car Middle Lateral Acceleration, m/sec^2.
A_{GM}	Goods Vehicle Middle Lateral Acceleration, m/sec^2.
AS	Approach Vehicle Speed, k.p.h.
AS_C	All Car Approach Speed, k.p.h.
AS_{FC}	Free Car Approach Speed, k.p.h.
AS_G	Goods Vehicle Approach Speed, k.p.h.
DS	Design Speed, k.p.h.
R	Curve Radius, m.
C	Curvature, degrees per 100 feet.
TA	Total Angle, radians.
RCTA	Rate of Change of Total Angle, rad/km.
L	Curve Length, m.
RW	Lane on Carriageway Width for Single or Dual Carriageway Sites respectively, m.
VW	Average Middle Verge Width, m.
E	Superelevation, m/m.
GRA	Gradient, per cent.
SD	Sight Distance, m.
FL	Total or Directional Traffic Flow for Single or Dual Carriageway Sites respectively, Vehicles/hour.

Figure C1: Typical Example of Results from Normality Testing Computer Programs

SET 1

DATA CLASSIFICATION

****

NUMBER OF CASES 155

DATA AS INPUT -

81.00	69.00	89.00	75.00	68.00
79.00	77.00	77.00	64.00	76.00
83.00	86.00	69.00	94.00	66.00
79.00	71.00	90.00	90.00	104.00
81.00	73.00	91.00	75.00	84.00
77.00	91.00	70.00	73.00	57.00
81.00	79.00	99.00	82.00	77.00
75.00	74.00	77.00	99.00	71.00
76.00	73.00	90.00	92.00	80.00
84.00	69.00	82.00	73.00	80.00
75.00	87.00	85.00	67.00	76.00
77.00	79.00	78.00	69.00	85.00
68.00	81.00	87.00	80.00	76.00
86.00	76.00	73.00	55.00	87.00
90.00	73.00	67.00	69.00	82.00
78.00	77.00	81.00	76.00	69.00
65.00	73.00	73.00	77.00	77.00
86.00	67.00	76.00	64.00	79.00
80.00	86.00	73.00	77.00	91.00
69.00	83.00	73.00	81.00	82.00
78.00	81.00	78.00	67.00	92.00
77.00	74.00	77.00	87.00	84.00
78.00	104.00	81.00	68.00	66.00
87.00	82.00	86.00	80.00	64.00
62.00	73.00	88.00	63.00	88.00
62.00	82.00	88.00	62.00	77.00
63.00	71.00	59.00	82.00	73.00
84.00	82.00	69.00	65.00	60.00
87.00	64.00	85.00	76.00	95.00
86.00	65.00	68.00	92.00	77.00
85.00	86.00	69.00	80.00	82.00

CLASSIFIED SPEED DATA -

55.00	57.00	59.00	60.00	62.00
62.00	62.00	63.00	63.00	64.00
64.00	64.00	64.00	65.00	65.00
65.00	66.00	66.00	67.00	67.00
67.00	67.00	68.00	68.00	68.00
68.00	69.00	69.00	69.00	69.00
69.00	69.00	69.00	69.00	69.00
70.00	71.00	71.00	71.00	73.00
73.00	73.00	73.00	73.00	73.00
73.00	73.00	73.00	73.00	73.00
73.00	74.00	74.00	75.00	75.00
75.00	75.00	76.00	76.00	76.00
76.00	76.00	76.00	76.00	76.00
77.00	77.00	77.00	77.00	77.00
77.00	77.00	77.00	77.00	77.00
77.00	77.00	77.00	77.00	78.00

78.00	78.00	78.00	78.00	79.00
79.00	79.00	79.00	79.00	80.00
80.00	80.00	80.00	80.00	80.00
81.00	81.00	81.00	81.00	81.00
81.00	81.00	81.00	82.00	82.00
82.00	82.00	82.00	82.00	82.00
82.00	82.00	83.00	83.00	84.00
84.00	84.00	84.00	85.00	85.00
85.00	85.00	86.00	86.00	86.00
86.00	86.00	86.00	86.00	87.00
87.00	87.00	87.00	87.00	87.00
88.00	88.00	88.00	89.00	90.00
90.00	90.00	90.00	91.00	91.00
91.00	92.00	92.00	92.00	94.00
95.00	99.00	99.00	104.00	104.00

F R E Q U E N C Y   C L A S S   D I S T R I B U T I O N

****

C L A S S		MID. OF CLASS	FREQUENCY	SMOOTH. FREQ.
54.00	57.00	55.50	1	1.00
57.00	60.00	58.50	2	2.33
60.00	63.00	61.50	4	5.00
63.00	66.00	64.50	9	7.67
66.00	69.00	67.50	10	10.67
69.00	72.00	70.50	13	12.33
72.00	75.00	73.50	14	17.67
75.00	78.00	76.50	26	18.67
78.00	81.00	79.50	16	20.33
81.00	84.00	82.50	19	16.67
84.00	87.00	85.50	15	14.67
87.00	90.00	88.50	10	11.67
90.00	93.00	91.50	10	7.33
93.00	96.00	94.50	2	4.00
96.00	99.00	97.50	0	1.33
99.00	102.00	100.50	2	1.33
102.00	105.00	103.50	2	1.33
105.00	108.00	106.50	0	0.67
TOTAL			155	154.67

RESULTS FROM A SUCCESSFUL CALL OF G01AAF
NO. OF VALID CASES 155
MEAN 77.768
MEDIAN 77.000
STD DEVN 9.231
SKEWNESS 0.130

KURTOSIS -0.009
MINIMUM 55.000
MAXIMUM 104.000
COEFFICIENT OF VARIATION 0.119
SUM OF WEIGHTS 155.000

VEHICLE SPEED PERCENTILE VALUES - OBSERVED SPEED DISTRIBUTION

****

SPEED (85 PER CENT) = 87.000

SPEED (90 PER CENT) = 89.500

SPEED (95 PER CENT) = 92.000

SPEED (99 PER CENT) =101.250

VEHICLE SPEED PERCENTILE VALUES - THEORETICAL SPEED DISTRIBUTION
****

SPEED (85 PER CENT) = 87.334

SPEED (90 PER CENT) = 89.724

SPEED (95 PER CENT) = 92.805

SPEED (99 PER CENT) = 99.072

POSITIVE SKEW DISTRIBUTION

PLATIKURTIC DISTRIBUTION

C L A S S		CUMUL. FREQ.	PERCEN. CUMUL. FREQ.
54.00	57.00	1	0.65
57.00	60.00	3	1.94
60.00	63.00	7	4.52
63.00	66.00	16	10.32
66.00	69.00	26	16.77
69.00	72.00	39	25.16
72.00	75.00	53	34.19
75.00	78.00	79	50.97
78.00	81.00	95	61.29
81.00	84.00	114	73.55
84.00	87.00	129	83.23
87.00	90.00	139	89.68
90.00	93.00	149	96.13
93.00	96.00	151	97.42
96.00	99.00	151	97.42
99.00	102.00	153	98.71
102.00	105.00	155	100.00
105.00	108.00	155	100.00

UPPER LIMIT	UPPER LIMIT-S2	COLUMN 2/STD DEVN	NORMAL AREA
54.00	-23.77	-2.57	-0.495
57.00	-20.77	-2.25	-0.487
60.00	-17.77	-1.92	-0.473
63.00	-14.77	-1.60	-0.444
66.00	-11.77	-1.27	-0.398
69.00	-8.77	-0.95	-0.326
72.00	-5.77	-0.62	-0.232
75.00	-2.77	-0.30	-0.114
78.00	0.23	0.03	0.008
81.00	3.23	0.35	0.137
84.00	6.23	0.68	0.249
87.00	9.23	1.00	0.341
90.00	12.23	1.33	0.407
93.00	15.23	1.65	0.451
96.00	18.23	1.98	0.476
99.00	21.23	2.30	0.489
102.00	24.23	2.63	0.496
105.00	27.23	2.95	0.498
108.00	30.23	3.28	0.499

C H I - S Q U A R E D   D I S T R I B U T I O N   N O R M A L I T Y   T E S T

****

---THEOR. FREQ. AND OBSER. FREQ. BOTH GREATER THAN 5 - INCREASING ORDER---

NUMBER OF AGGREG. CASES 12

AGGREG. OBSER. FREQ.	AGGREG. THEOR. FREQ.	(((THFREQ-OBFREQ)**2)/THFREQ)
7	7.880	0.098
9	7.149	0.479
10	11.093	0.108
13	14.573	0.170
14	18.333	1.024
26	18.921	2.649
16	19.972	0.790
19	17.320	0.163
15	14.379	0.027
10	10.112	0.001
10	6.812	1.492
6	7.584	0.331

CHI-SQUARED = 7.332

NORMAL DISTRIBUTION FITS PUBLIC ROAD SPEED
DATA DISTRIBUTION AT A SIGNIFICANCE LEVEL OF 0.10

CHI-SQUARED = 14.684 DEGREES OF FREEDOM = 9

PROBABILITY MORE THAN 50 PERCENT WHICH MEANSTHAT THE VARIATION FOUND IN THE SAMPLE MIGHT OCCUR IN 50 PERCENT OF THE CASES IN THE POPULATION TESTED

CHI-SQUARED = 14.684 DEGREES OF FREEDOM = 9

C H I - S Q U A R E D D I S T R I B U T I O N N O R M A L I T Y T E S T

****

---THEOR. FREQ. AND OBSER. FREQ. BOTH GREATER THAN 5 - REVERSED ORDER---

NUMBER OF AGGREG. CASES 12

AGGREG. OBSER. FREQ.	AGGREG. THEOR. FREQ.	(((THFREQ-OBFREQ)**2)/THFREQ)
6	7.584	0.331
10	6.812	1.492
10	10.112	0.001
15	14.379	0.027
19	17.320	0.163
16	19.972	0.790
26	18.921	2.649
14	18.333	1.024
13	14.573	0.170
10	11.093	0.108
9	7.149	0.479
7	7.880	0.098

CHI-SQUARED = 7.332

NORMAL DISTRIBUTION FITS PUBLIC ROAD SPEED
DATA DISTRIBUTION AT A SIGNIFICANCE LEVEL OF 0.10

CHI-SQUARED = 14.684 DEGREES OF FREEDOM = 9

PROBABILITY MORE THAN 50 PERCENT WHICH MEANSTHAT THE VARIATION

FOUND IN THE SAMPLE MIGHT OCCUR IN 50 PERCENT OF THE CASES IN THE POPULATION TESTED

CHI-SQUARED = 14.684 DEGREES OF FREEDOM = 9

C H I - S Q U A R E D D I S T R I B U T I O N N O R M A L I T Y T E S T

****

---THEOR. FREQ. GREATER THAN 5 INCREASING ORDER---

NUMBER OF AGGREG. CASES 12

AGGREG. OBSER. FREQ.	AGGREG. THEOR. FREQ.	(((THFREQ-OBFREQ)**2)/THFREQ)
7	7.880	0.098
9	7.149	0.479
10	11.093	0.108
13	14.573	0.170
14	18.333	1.024
26	18.921	2.649
16	19.972	0.790

19	17.320	0.163
15	14.379	0.027
10	10.112	0.001
10	6.812	1.492
6	7.584	0.331

CHI-SQUARED = 7.332

NORMAL DISTRIBUTION FITS PUBLIC ROAD SPEED
DATA DISTRIBUTION AT A SIGNIFICANCE LEVEL OF 0.10

CHI-SQUARED = 14.684 DEGREES OF FREEDOM = 9

PROBABILITY MORE THAN 50 PERCENT WHICH MEANSTHAT THE VARIATION FOUND IN THE SAMPLE MIGHT OCCUR IN 50 PERCENT OF THE CASES IN THE POPULATION TESTED

CHI-SQUARED = 14.684 DEGREES OF FREEDOM = 9

C H I - S Q U A R E D D I S T R I B U T I O N N O R M A L I T Y T E S T

****

---THEOR. FREQ. GREATER THAN 5 REVERSED ORDER---

NUMBER OF AGGREG. CASES 12

AGGREG. OBSER. FREQ.	AGGREG. THEOR. FREQ.	(((THFREQ-OBFREQ)**2)/THFREQ)
6	7.584	0.331
10	6.812	1.492
10	10.112	0.001
15	14.379	0.027
19	17.320	0.163
16	19.972	0.790
26	18.921	2.649
14	18.333	1.024
13	14.573	0.170
10	11.093	0.108
9	7.149	0.479
7	7.880	0.098

CHI-SQUARED = 7.332

NORMAL DISTRIBUTION FITS PUBLIC ROAD SPEED
DATA DISTRIBUTION AT A SIGNIFICANCE LEVEL OF 0.10

CHI-SQUARED = 14.684 DEGREES OF FREEDOM = 9

PROBABILITY MORE THAN 50 PERCENT WHICH MEANSTHAT THE VARIATION FOUND IN THE SAMPLE MIGHT OCCUR IN 50 PERCENT OF THE CASES IN THE POPULATION TESTED

CHI-SQUARED = 14.684 DEGREES OF FREEDOM = 9

KOLMOGOROV - SMIRNOV NORMALITY TEST

****

---K-S TEST FOR RANKED CATEGORIES---

Z (STANDARD) SCORES

0.350	-0.950	1.217	-0.300	-1.058
0.133	-0.083	-0.083	-1.492	-0.192
0.567	0.892	-0.950	1.759	-1.275
0.133	-0.733	1.325	1.325	2.842
0.350	-0.517	1.434	-0.300	0.675
-0.083	1.434	-0.842	-0.517	-2.250
0.350	0.133	2.300	0.458	-0.083
-0.300	-0.408	-0.083	2.300	-0.733
-0.192	-0.517	1.325	1.542	0.242
0.675	-0.950	0.458	-0.517	0.242
0.168	0.329	0.510	0.723	0.832
1.000	0.133	0.025	-0.950	0.784
-1.058	0.350	1.000	0.242	-0.192
0.892	-0.192	-0.517	-2.467	1.000
1.325	-0.517	-1.167	-0.950	0.458
0.025	-0.083	0.350	-0.192	-0.950
-1.383	-0.517	-0.517	-0.083	-0.083
0.892	-1.167	-0.192	-1.492	0.133
0.242	0.892	-0.517	-0.083	1.434
-0.950	0.567	-0.517	0.350	0.458
0.025	0.350	0.025	-1.167	1.542
-0.083	-0.408	-0.083	1.000	0.675
0.025	2.842	0.350	-1.058	-1.275
1.000	0.458	0.892	0.242	-1.492
-1.708	-0.517	1.109	-1.600	1.109
-1.708	0.458	1.109	-1.708	-0.083
-1.600	-0.733	-2.033	0.458	-0.517
0.675	0.458	-0.950	-1.383	-1.925
1.000	-1.492	0.784	-0.192	1.867
0.892	-1.383	-1.058	1.542	-0.083
0.784	0.892	-0.950	0.242	0.458

Z - SCORE	FREQUENCY
-1.000	26
-0.500	25
0.000	28
0.500	33
1.000	17
1.000	26

CUMUL. FREQ.	CUMUL. PROPORTION	EXPECTED PROPORTION	DIFFERENCE
26	0.168	0.159	0.009
51	0.329	0.309	0.021
79	0.510	0.500	0.010
112	0.723	0.692	0.031
129	0.832	0.841	0.009
155	1.000	1.000	0.000

ABSOLUTE MAXIMUM DIFFERENCE = 0.031
K-VALUE(MAX*SQRT(N)) = 0.387

NORMAL DISTRIBUTION FITS PUBLIC ROAD SPEED
DATA DISTRIBUTION AT A SIGNIFICANCE LEVEL = 0.0500

K - TABLE LIMIT VALUE = 1.220

KOLMOGOROV - SMIRNOV NORMALITY TEST

****

---K-S TEST FOR RANKABLE SCORES---

RANKED SCORES	Z-SCORE	CUMUL. PROPORTION	EXPECTED PROPORTION
1.00	-2.467	0.006	0.007
2.00	-2.250	0.013	0.013
3.00	-2.033	0.019	0.021
4.00	-1.925	0.026	0.027
5.00	-1.708	0.032	0.045
6.00	-1.708	0.039	0.045
7.00	-1.708	0.045	0.045
8.00	-1.600	0.052	0.056
9.00	-1.600	0.058	0.056
10.00	-1.492	0.065	0.068
11.00	-1.492	0.071	0.068
12.00	-1.492	0.077	0.068
13.00	-1.492	0.084	0.068
14.00	-1.383	0.090	0.084
15.00	-1.383	0.097	0.084
16.00	-1.383	0.103	0.084
17.00	-1.275	0.110	0.102
18.00	-1.275	0.116	0.102
19.00	-1.167	0.123	0.123
20.00	-1.167	0.129	0.123
21.00	-1.167	0.135	0.123
22.00	-1.167	0.142	0.123
23.00	-1.058	0.148	0.147
24.00	-1.058	0.155	0.147
25.00	-1.058	0.161	0.147
26.00	-1.058	0.168	0.147
27.00	-0.950	0.174	0.174
28.00	-0.950	0.181	0.174
29.00	-0.950	0.187	0.174
30.00	-0.950	0.194	0.174
31.00	-0.950	0.200	0.174
32.00	-0.950	0.206	0.174
33.00	-0.950	0.213	0.174
34.00	-0.950	0.219	0.174
35.00	-0.950	0.226	0.174
36.00	-0.842	0.232	0.201
37.00	-0.733	0.239	0.233
38.00	-0.733	0.245	0.233
39.00	-0.733	0.252	0.233
40.00	-0.517	0.258	0.305
41.00	-0.517	0.265	0.305
42.00	-0.517	0.271	0.305
43.00	-0.517	0.277	0.305
44.00	-0.517	0.284	0.305
45.00	-0.517	0.290	0.305
46.00	-0.517	0.297	0.305
47.00	-0.517	0.303	0.305
48.00	-0.517	0.310	0.305
49.00	-0.517	0.316	0.305
50.00	-0.517	0.323	0.305
51.00	-0.517	0.329	0.305
52.00	-0.408	0.335	0.345
53.00	-0.408	0.342	0.345
54.00	-0.300	0.348	0.386
55.00	-0.300	0.355	0.386
56.00	-0.300	0.361	0.386
57.00	-0.300	0.368	0.386
58.00	-0.192	0.374	0.425
59.00	-0.192	0.381	0.425
60.00	-0.192	0.387	0.425
61.00	-0.192	0.394	0.425
62.00	-0.192	0.400	0.425

519	63.00	-0.192	0.406	0.425
520	64.00	-0.192	0.413	0.425
521	65.00	-0.192	0.419	0.425
522	66.00	-0.083	0.426	0.468
523	67.00	-0.083	0.432	0.468
524	68.00	-0.083	0.439	0.468
525	69.00	-0.083	0.445	0.468
526	70.00	-0.083	0.452	0.468
527	71.00	-0.083	0.458	0.468
528	72.00	-0.083	0.465	0.468
529	73.00	-0.083	0.471	0.468
530	74.00	-0.083	0.477	0.468
531	75.00	-0.083	0.484	0.468
532	76.00	-0.083	0.490	0.468
533	77.00	-0.083	0.497	0.468
534	78.00	-0.083	0.503	0.468
535	79.00	-0.083	0.510	0.468
536	80.00	0.025	0.516	0.508
537	81.00	0.025	0.523	0.508
538	82.00	0.025	0.529	0.508
539	83.00	0.025	0.535	0.508
540	84.00	0.025	0.542	0.508
541	85.00	0.133	0.548	0.552
542	86.00	0.133	0.555	0.552
543	87.00	0.133	0.561	0.552
544	88.00	0.133	0.568	0.552
545	89.00	0.133	0.574	0.552
546	90.00	0.242	0.581	0.595
547	91.00	0.242	0.587	0.595
548	92.00	0.242	0.594	0.595
549	93.00	0.242	0.600	0.595
550	94.00	0.242	0.606	0.595
551	95.00	0.242	0.613	0.595
552	96.00	0.350	0.619	0.637
553	97.00	0.350	0.626	0.637
554	98.00	0.350	0.632	0.637
555	99.00	0.350	0.639	0.637
556	100.00	0.350	0.645	0.637
557	101.00	0.350	0.652	0.637
558	102.00	0.350	0.658	0.637
559	103.00	0.350	0.665	0.637
560	104.00	0.458	0.671	0.674
561	105.00	0.458	0.677	0.674
562	106.00	0.458	0.684	0.674
563	107.00	0.458	0.690	0.674
564	108.00	0.458	0.697	0.674
565	109.00	0.458	0.703	0.674
566	110.00	0.458	0.710	0.674
567	111.00	0.458	0.716	0.674
568	112.00	0.458	0.723	0.674
569	113.00	0.567	0.729	0.712
570	114.00	0.567	0.735	0.712
571	115.00	0.675	0.742	0.749
572	116.00	0.675	0.748	0.749
573	117.00	0.675	0.755	0.749
574	118.00	0.675	0.761	0.749
575	119.00	0.784	0.768	0.782
576	120.00	0.784	0.774	0.782
577	121.00	0.784	0.781	0.782
578	122.00	0.784	0.787	0.782
579	123.00	0.892	0.794	0.813
580	124.00	0.892	0.800	0.813
581	125.00	0.892	0.806	0.813
582	126.00	0.892	0.813	0.813
583	127.00	0.892	0.819	0.813
584	128.00	0.892	0.826	0.813

129.00	0.892	0.832	0.813
130.00	1.000	0.839	0.841
131.00	1.000	0.845	0.841
132.00	1.000	0.852	0.841
133.00	1.000	0.858	0.841
134.00	1.000	0.865	0.841
135.00	1.000	0.871	0.841
136.00	1.109	0.877	0.864
137.00	1.109	0.884	0.864
138.00	1.109	0.890	0.864
139.00	1.217	0.897	0.887
140.00	1.325	0.903	0.907
141.00	1.325	0.910	0.907
142.00	1.325	0.916	0.907
143.00	1.325	0.923	0.907
144.00	1.434	0.929	0.924
145.00	1.434	0.935	0.924
146.00	1.434	0.942	0.924
147.00	1.542	0.948	0.938
148.00	1.542	0.955	0.938
149.00	1.542	0.961	0.938
150.00	1.759	0.968	0.960
151.00	1.867	0.974	0.969
152.00	2.300	0.981	0.989
153.00	2.300	0.987	0.989
154.00	2.842	0.994	0.998
155.00	2.842	1.000	0.998

ABSOLUTE MAXIMUM DIFFERENCE = 0.052
K-VALUE(MAX*SQRT(N)) = 0.650

NORMAL DISTRIBUTION FITS PUBLIC ROAD SPEED
DATA DISTRIBUTION AT A SIGNIFICANCE LEVEL = 0.0500

K - TABLE LIMIT VALUE = 1.220

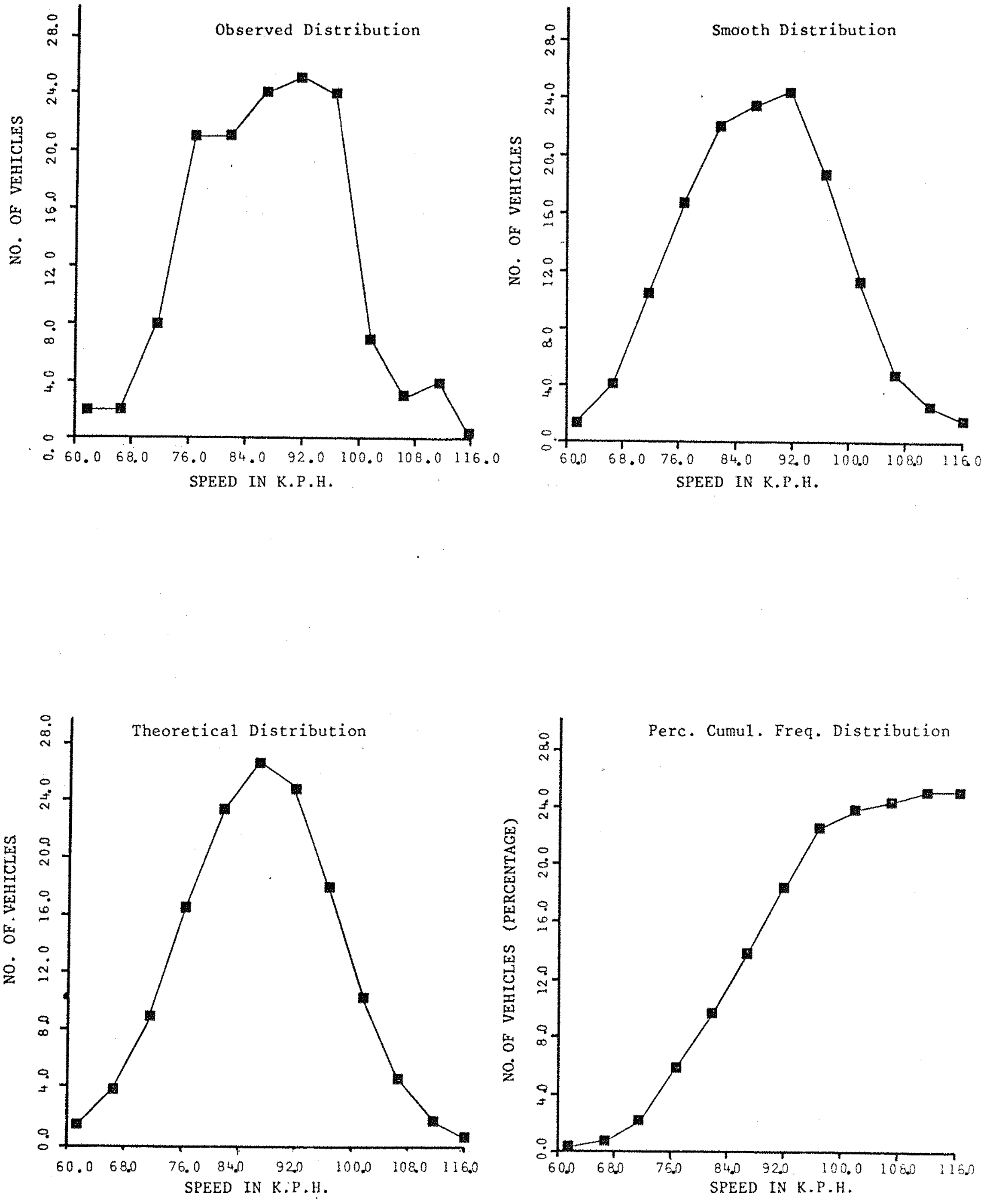


Figure C2 : Typical Example of Speed Distribution Plots produced for Normality Testing (Dual Carriageways - All Cars)

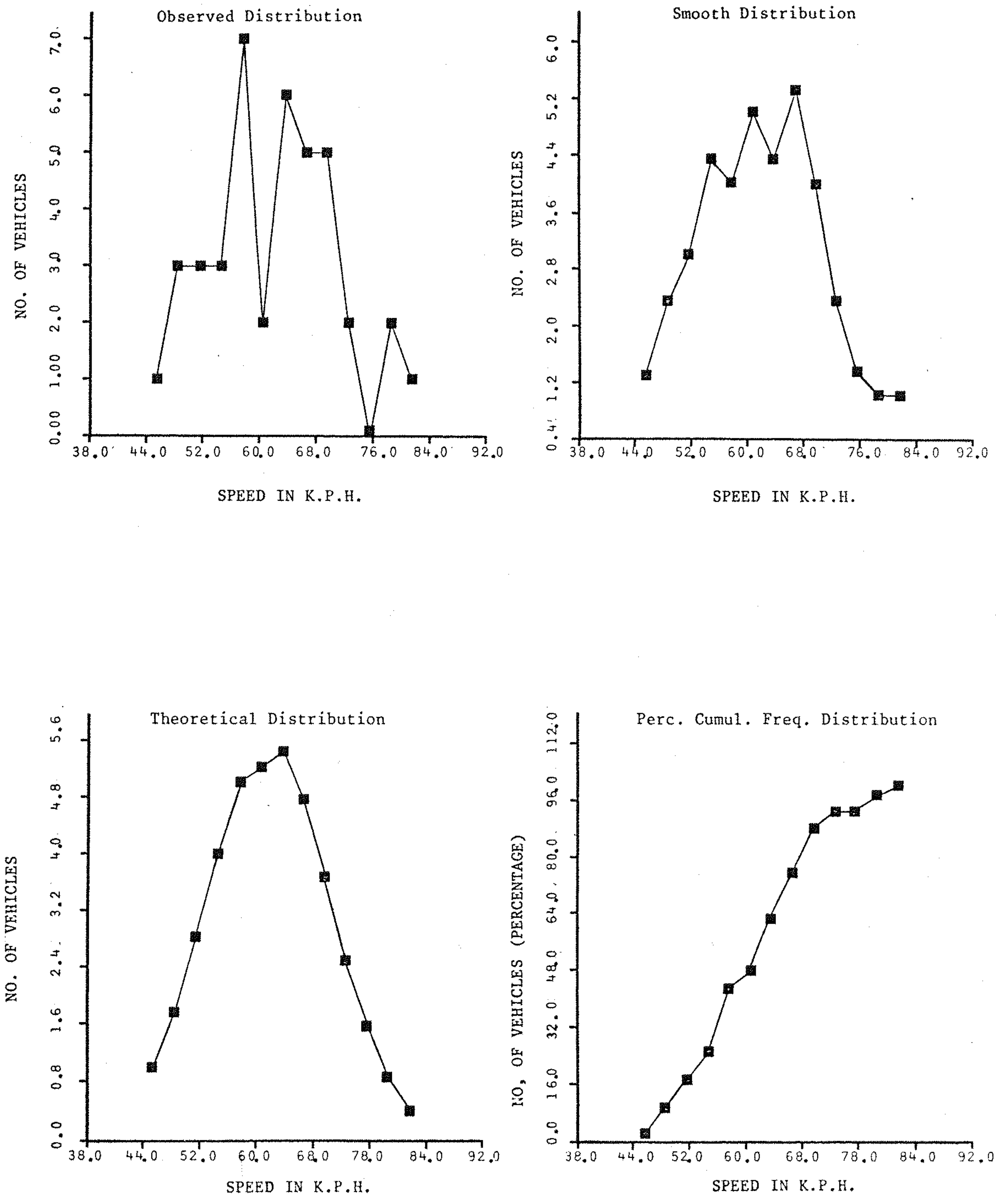


Figure C3 :Typical Example of Speed Distribution Plots produced for Normality Testing (Single Carriageways - Goods Vehicles)

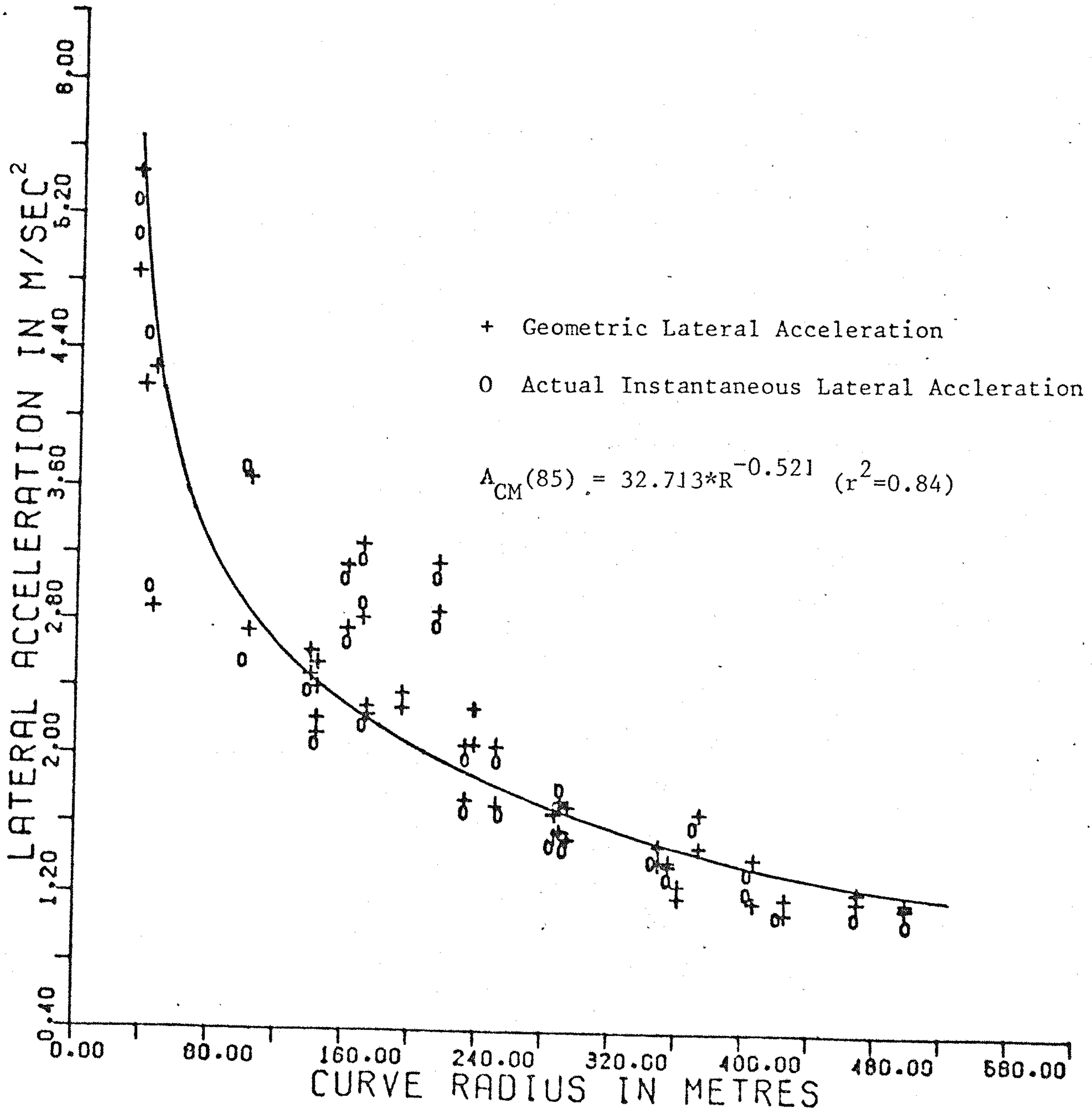


Figure C4 : Relationship between Middle Lateral Acceleration and Curve Radius
(Single Carriageways - All Cars - Phase I)

LISTING OF COMUPTER PROGRAMS FOR NORMALITY TESTING

DATA CLASSIFICATION

```
******************************************************************
      PROGRAM ABCD
      REAL XBAR,S2,S3,S4,XMIN,XMAX,WTSUM,X(300),WT(300),
     * AA(311),BB(311),CC(311),DK(10),Z(300),PCFR(60),ZZ(60),ZS(60),
     * EXFR(60),D(60),DBAR,DMIN,DMAX,D2,D3,D4,DT,TM(60),TTM,DDK,DR(60),
     * PTM,STM
      INTEGER I,NSET,N,K,IWT,IFAIL,ICFR(60),IZM1,IZM05,IZMO,IZP05,IZP1,
     * IZP15,L
      READ (5,101) NSET
      WRITE(8,101) NSET
      READ(9,104) (AA(I),BB(I),CC(I),I=1,311)
      WRITE(8,104) (AA(I),BB(I),CC(I),I=1,311)
      READ(9,105) (DK(I),I=1,4)
      WRITE(8,105) (DK(I),I=1,4)
      DO 80 J=1,NSET
      IZM1=0
      IZM05=0
      IZMO=0
      IZP05=0
      IZP1=0
      IZP15=0
      READ (5,102) N,IWT
      WRITE(8,102) N,IWT
      IF (N.LT.1) GO TO 20
      READ (3,103) (X(I),I=1,N)
      IF (IWT.EQ.1) READ (5,103) (WT(I),I=1,N)
      WRITE (8,203) (X(I),I=1,N)
      IF (IWT.NE.1) GO TO 20
      WRITE (8,203) (WT(I),I=1,N)
   20 IFAIL=1
      CALL G01AAF(N,X,IWT,WT,XBAR,S2,S3,S4,XMIN,XMAX,WTSUM,IFAIL)
      IF (IFAIL) 40,40,60
   40 WRITE (8,101) IFAIL
      DO 82 I=1,N
      Z(I)=((X(I)-XBAR)/S2)
   82 CONTINUE
      L=0
   49 L=L+1
      IF(L.GT.N) GO TO 51
      IF(Z(L).GE.(-1.0)) GO TO 30
      IZM1=IZM1+1
      GO TO 49
   30 IF((Z(L).LT.(-1.0)) .OR. (Z(L).GE.(-0.50))) GO TO 31
      IZM05=IZM05+1
      GO TO 49
   31 IF((Z(L).LT.(-0.50)) .OR. (Z(L).GE.0.0)) GO TO 32
      IZMO=IZMO+1
      GO TO 49
   32 IF((Z(L).LT.0.0) .OR. (Z(L).GE.0.50)) GO TO 33
      IZP05=IZP05+1
      GO TO 49
   33 IF((Z(L).LT.0.50) .OR. (Z(L).GE.1.0)) GO TO 34
      IZP1=IZP1+1
      GO TO 49
   34 IZP15=IZP15+1
      GO TO 49
   51 ICFR(1)=IZM1
      ICFR(2)=ICFR(1)+IZM05
      ICFR(3)=ICFR(2)+IZMO
      ICFR(4)=ICFR(3)+IZP05
      ICFR(5)=ICFR(4)+IZP1
      ICFR(6)=ICFR(5)+IZP15
      DO 84 I=1,6
      PCFR(I)=ICFR(I)/FLOAT(N)
   84 CONTINUE
      ZZ(1)=-1.0
      ZZ(2)=-0.5
      ZZ(3)=0.0
      ZZ(4)=0.5
      ZZ(5)=1.0
      ZZ(6)=1.0
      DO 85 M=1,5
      IF(ZZ(M).GE.0.0) GO TO 52
      ZS(M)=ZZ(M)*(-1.0)
```

```
      DO 86 I=1,311
      IF(ZS(M).NE.AA(I)) GO TO 86
      EXFR(M)=BB(I)/100.0
   86 CONTINUE
      GO TO 85
   52 ZS(M)=ZZ(M)
      DO 87 I=1,311
      IF(ZS(M).NE.AA(I)) GO TO 87
      EXFR(M)=CC(I)/100.0
   87 CONTINUE
   85 CONTINUE
      EXFR(6)=1.0
      DO 88 I=1,6
      DR(I)=PCFR(I)-EXFR(I)
      D(I)=ABS(DR(I))
   88 CONTINUE
      CALL G01AAF(6,D,IWT,WT,DBAR,D2,D3,D4,DMIN,DMAX,WTSUM,IFAIL)
      DT=DMAX*(SQRT(FLOAT(N)))
      TM(1)=0.050
      TM(2)=0.025
      TM(3)=0.010
      TM(4)=0.001
      DO 89 I=1,4
      IF(DT.GE.DK(I)) GO TO 89
      TTM=TM(I)
      DDK=DK(I)
      GO TO 99
   89 CONTINUE
      PTM=0.0
      GO TO 50
   99 PTM=1.0
   50 DO 81 K=1,N
      IF(X(K).NE.XMIN) GO TO 81
      WRITE(8,203) X(K)
   81 CONTINUE
      XMIN=XMIN+1.0
      IF(XMIN.LT.151.0) GO TO 50
      STM=PTM
      WRITE(8,210) (Z(I),I=1,N)
      WRITE(8,211) IZM1,IZM05,IZM0,IZP05,IZP1,IZP15
      WRITE(8,212) (ICFR(I),I=1,6)
      WRITE(8,213) (PCFR(I),I=1,6)
      WRITE(8,214) (ZZ(I),I=1,6)
      WRITE(8,213) (EXFR(I),I=1,6)
      WRITE(8,213) (D(I),I=1,6)
      WRITE(8,213) DMAX
      WRITE(8,214) DT
      WRITE(8,215) (TM(I),I=1,4)
      WRITE(8,215) STM
      IF(PTM.EQ.0.0) GO TO 98
      WRITE(8,216) TTM,DDK
   98 WRITE(8,215) PTM
      GO TO 80
   60 WRITE (8,101) IFAIL
      IF (IFAIL.EQ.2) WRITE (8,208) IWT,XMIN,XMAX
   80 CONTINUE
      STOP
  104 FORMAT (F4.2,F5.2,F5.2)
  105 FORMAT (4F4.2)
  210 FORMAT (F6.3)
  211 FORMAT (6I2)
  212 FORMAT (I3)
  213 FORMAT (F6.3)
  214 FORMAT (F7.4)
  215 FORMAT (F5.3)
  216 FORMAT (F5.3,F4.2)
  101 FORMAT (I2)
  102 FORMAT (I3,I2)
  103 FORMAT (F5.0)
  203 FORMAT (F5.0)
  208 FORMAT (I5,2F5.0)
      END
```

NORMALITY TESTING

```
*************************************************************************
      PROGRAM AAAA
      REAL XBAR,S2,S3,S4,XMIN,XMAX,WTSUM,X(300),WT(300),DIFER,DIV,R(99),
     * DAY,FTIME,RTIME,OBS,ROD,ROUT,ROUTE,DRWT,RAIN,TYPE,GRAD,
     * PERFREQ(50),RELFREQ(50),PCFREQ(50),SMFSUM,RDIF(50),DDIF(50),
     * SIGDIS,MIDDLE(50),FREQ(50),SMFREQ(50),PSUM,RSUM,WID,SWID,
     * FNAREA(50),B(401),PROBAB(50),THFREQ(50),MDDIF(50),FN,STFREQ,
     * THXFREQ(50),XX,XY(50),D(20,50),ISUPER,IRADIUS,LENGTH,THIREQ(300),
     * AA(320),BB(320),CC(320),DK(10),Z(50),PCFR(300),EXFR(300),
     * DP(300),ZZ(300),DMAX,DT,TM(300),TTM,DDK,PTM,U(300),UT(300),
     * G(300),GG(300),EXPFR(300),HH(300),H(300),HBAR,H2,H3,H4,HMIN,
     * HMAX,HG,HTM,HDM,HT,FMEDIAN,COV,PCOV,PIL,GR(300),AS(320),STM,
     * GX(400),UPR(400)
      INTEGER I,NSET,J,N,L,LL,K,M,IWT,IFAIL,IFREQ(50),IFRSUM,ICFREQ(50),
     * LIM,IDAY,KDAY,LDAY,ICUR,NUM,CUR(2),RCUR(2),
     * ISIZE,NSIZE,IDIV,ITFREQ(50),POSIT(2),IMDDIF(50),A(401),
     * XTITL(3),YTITL(4),YYTITL(7),ATITL(5),BTITL(5),CTITL(6),DTITL,
     * ETITL(2),FTITL(2),HTITL(3),RTITL(8),IXFREQ(50),MM,KM,K1,K2,K3,
     * K4,K5,K6,KN,IK,MK,IN,IHREQ(300),II,KK,NI,IZM1,IZM05,IZMO,
     * IZP05,IZP1,IZP15,ICFR(300),IPIL,JPIL,NL,NJ,MJ,IGG(300),IAA(320)
      DATA XTITL/12HSPEED IN KPH/
      DATA YTITL/15HNO. OF VEHICLES/
      DATA YYTITL/28HNO. OF VEHICLES (PERCENTAGE)/
      DATA ATITL/18HOBSERVED FREQUENCY/
      DATA BTITL/18HSMOOTHED FREQUENCY/
      DATA CTITL/21HTHEORETICAL FREQUENCY/
      DATA DTITL/3HSET/
      DATA ETITL/7HSITE : /
      DATA FTITL/8HROUTE : /
      DATA HTITL/11HPOSITION : /
      DATA RTITL/31HPERC. CUMUL. FREQ. DISTRIBUTION/
      CALL PLOTS(0,0,1)
      READ (2,500) (A(I),B(I),I=1,401)
      DO 40 J=1,14
      DO 44 I=1,30
      READ(2,501) D(J,I)
   44 CONTINUE
   40 CONTINUE
      READ (3,100) NSET
      READ(3,171) (AA(I),BB(I),CC(I),I=1,311)
      READ(3,172) (DK(I),I=1,4)
      DO 80 J=1,NSET
      READ (3,101) N,IWT
      WRITE(7,200) J
      WRITE (7,229)
      WRITE (7,239)
      WRITE (7,230) N
      IF (N.LT.1) GO TO 20
      READ (3,102) (X(I),I=1,N)
      IF (IWT.EQ.1) READ (3,102) (WT(I),I=1,N)
      WRITE (7,231)
      WRITE (7,232) (X(I),I=1,N)
      IF (IWT.NE.1) GO TO 22
      WRITE (7,233)
      WRITE (7,232) (WT(I),I=1,N)
   20 WRITE (7,234)
      GO TO 80
   22 READ(3,100) IFAIL
      IF (IFAIL) 23,23,24
   23 READ(3,102) (X(K),K=1,N)
      WRITE(7,235)
      WRITE(7,232) (X(K),K=1,N)
      GO TO 25
   24 WRITE(7,236) IFAIL
      READ(3,103) IWT,XMIN,XMAX
      IF (IFAIL.EQ.2) WRITE (6,237) IWT,XMIN,XMAX
      GO TO 80
   25 CALL G01AAF(N,X,IWT,WT,XBAR,S2,S3,S4,XMIN,XMAX,WTSUM,IFAIL)
      COV=S2/XBAR
      PCOV=100.0*COV
      IPIL=N/2*100
      PIL=N/2.0*100.0
      NJ=N/2
```

```
      MJ=((N/2)+1)
      JPIL=IFIX(PIL+0.50)
      IF(IPIL.NE.JPIL) GO TO 29
      FMEDIAN=(X(NJ)+X(MJ))/2.0
      GO TO 19
   29 FMEDIAN=X(MJ)
   19 DIFER=XMAX-XMIN
      IF (DIFER.GT.49.0) GO TO 21
      DIV=(DIFER/3.0)+1.0
      IDIV=IFIX(DIV)
      R(1)=XMIN-1.0
      K=IDIV+2
      L=K-1
      DO 81 I=2,K
      R(I)=R(I-1)+3.0
   81 CONTINUE

      GO TO 26
   21 DIV=(DIFER/5.0)+1.0
      IDIV=IFIX(DIV)
      R(1)=XMIN-1.0
      K=IDIV+2
      L=K-1
      DO 82 I=2,K
      R(I)=R(I-1)+5.0
   82 CONTINUE
   26 DO 85 M=1,L
      IFREQ(M)=0
   85 CONTINUE
      DO 83 I=1,N
      DO 84 M=1,L
      IF ((X(I).GE.R(M)) .AND. (X(I).LT.R(M+1))) GO TO 86
      GO TO 84
   86 IFREQ(M)=IFREQ(M)+1
      GO TO 83
   84 CONTINUE
   83 CONTINUE
      IFRSUM=0

      DO 98 I=1,L
      IFRSUM=IFRSUM+IFREQ(I)
   98 CONTINUE
      DO 87 I=1,L
      MIDDLE(I)=(R(I)+R(I+1))/2.0
      UPR(I)=R(I+1)
   87 CONTINUE
      DO 88 I=1,L
      FREQ(I)=FLOAT(IFREQ(I))
   88 CONTINUE
      SMFREQ(1)=(FREQ(1)+FREQ(2))/3.0
      LL=L-1
      SMFREQ(L)=(FREQ(L)+FREQ(LL))/3.0
      DO 89 I=2,LL
      SMFREQ(I)=(FREQ(I-1)+FREQ(I)+FREQ(I+1))/3.0
   89 CONTINUE
      SMFSUM=0.0
      DO 90 I=1,L
      SMFSUM=SMFSUM+SMFREQ(I)
   90 CONTINUE
      PSUM=0.0

      DO 91 I=1,L
      PERFREQ(I)=100.0*FREQ(I)/N
      PSUM=PSUM+PERFREQ(I)
   91 CONTINUE
      RSUM=0.0
      DO 92 I=1,L
      RELFREQ(I)=FREQ(I)/N
      RSUM=RSUM+RELFREQ(I)
   92 CONTINUE
      DO 93 I=1,L
      ICFREQ(I)=IFREQ(I)
   93 CONTINUE
      DO 94 I=2,L
      ICFREQ(I)=ICFREQ(I)+ICFREQ(I-1)
   94 CONTINUE
```

```
      DO 95 I=1,L
      PCFREQ(I)=100.0*ICFREQ(I)/ICFREQ(L)
   95 CONTINUE
      DO 96 I=1,K
      RDIF(I)=R(I)-XBAR
      DDIF(I)=RDIF(I)/S2
   96 CONTINUE
      DO 10 M=1,K
      MDDIF(M)=100.0*DDIF(M)
      IMDDIF(M)=IFIX(MDDIF(M))
      IF(IMDDIF(M).LT.0) GO TO 47
      GO TO 48
   47 IMDDIF(M)=IMDDIF(M)*(-1)
   48 DO 11 I=1,401
      IF(IMDDIF(M).NE.A(I)) GO TO 11
      FNAREA(M)=B(I)
      GO TO 10
   11 CONTINUE
   10 CONTINUE
      DO 18 I=1,K
      IF(DDIF(I).LT.0.0) GO TO 49
      FNAREA(I)=FNAREA(I)*(1.0)
      GO TO 18
   49 FNAREA(I)=FNAREA(I)*(-1.0)
   18 CONTINUE
      DO 12 I=2,K
      PROBAB(I)=FNAREA(I)-FNAREA(I-1)
   12 CONTINUE
      FN=FLOAT(N)
      STFREQ=0.0
      DO 13 I=2,K
      THFREQ(I)=PROBAB(I)*FN
      STFREQ=STFREQ+THFREQ(I)
      ITFREQ(I)=IFIX(THFREQ(I))
   13 CONTINUE
      DO 14 I=1,L
      THFREQ(I)=THFREQ(I+1)
   14 CONTINUE
      WRITE (7,238)
      WRITE (7,239)
      WRITE (7,240)
      WRITE (7,241) (R(I),R(I+1),MIDDLE(I),IFREQ(I),SMFREQ(I),
     * PERFREQ(I),RELFREQ(I),I=1,L)
      WRITE (7,242) IFRSUM,SMFSUM,PSUM,RSUM
      WRITE (7,243) IWT,XBAR,FMEDIAN,S2,S3,S4,XMIN,XMAX,COV,WTSUM
      WRITE (7,904)
      WRITE (7,239)
      FQ=0.85
  900 FP=FQ*N
      NA=INT(FP)
      FS=FLOAT(NA)
      FT=FP-FS
      NB=NA+1
      FA=X(NB)-X(NA)
      FC=FT*FA
      SQ=X(NA)+FC
      Q1=(FQ*100.0)+0.50
      JQ=INT(Q1)
      WRITE (7,903) JQ,SQ
      IF(JQ .GE. 95) GO TO 901
      FQ=FQ+0.05
      GO TO 900
  901 FQ=0.99
      FJ=FQ*N
      N1=INT(FJ)
      F1=FLOAT(N1)
      FE=FJ-F1
      N2=N1+1
      FB=X(N2)-X(N1)
      FD=FE*FB
      SQ=X(N1)+FD
      Q2=FQ*100.0
```

```
      MQ=INT(Q2)
      WRITE (7,903) MQ,SQ
      IQ1=85
      IQ2=90
      IQ3=95
      IQ4=99
      WRITE (7,905)
      WRITE (7,239)
      V1=(1.0364*S2)+XBAR
      WRITE (7,903) IQ1,V1
      V2=(1.2953*S2)+XBAR
      WRITE (7,903) IQ2,V2
      V3=(1.6290*S2)+XBAR
      WRITE (7,903) IQ3,V3
      V4=(2.308*S2)+XBAR
      WRITE (7,903) IQ4,V4

      IF(S3.NE.0.0) GO TO 607
      WRITE(7,304)
      GO TO 609
  607 IF(S3.LT.0.0) GO TO 608
      WRITE(7,305)
      GO TO 609
  608 WRITE(7,306)
  609 IF(S4.NE.0.0) GO TO 693
      WRITE(7,307)
      GO TO 695
  693 IF(S4.LT.0.0) GO TO 694
      WRITE(7,308)
      GO TO 695
  694 WRITE(7,309)
  695 WRITE (7,244)
      WRITE (7,245) (R(I),R(I+1),ICFREQ(I),PCFREQ(I),I=1,L)
      WRITE (7,246)
      WRITE(7,248) R(1),RDIF(1),DDIF(1),FNAREA(1)
      DO 17 NL=1,L
      I=NL+1
      WRITE(7,247) R(I),RDIF(I),DDIF(I),FNAREA(I),PROBAB(I),THFREQ(NL),

     * IFREQ(NL)
   17 CONTINUE
      WRITE(7,249) STFREQ,IFRSUM
      CALL PLOT(20.0,4.0,-3)
      CALL SCALE(MIDDLE,15.,L,1)
      CALL SCALE(FREQ,15.,L,1)
      CALL AXIS(0.0,0.0,XTITL,-12,15.0,0.0,MIDDLE(L+1),MIDDLE(L+2))
      CALL AXIS(0.0,0.0,YTITL,15,15.0,90.0,FREQ(L+1),FREQ(L+2))
      CALL LINE(MIDDLE,FREQ,L,1,1,11)
      CALL SYMBOL(3.0,20.0,0.21,DTITL,0.0,3)
      CALL SYMBOL(5.0,20.0,0.21,J,0.0,2)
      CALL SYMBOL(3.0,19.0,0.21,ETITL,0.0,7)
      CALL SYMBOL(6.0,19.0,0.21,CUR,0.0,8)
      CALL SYMBOL(7.5,19.0,0.21,ICUR,0.0,2)
      CALL SYMBOL(8.5,19.0,0.21,RCUR,0.0,8)
      CALL SYMBOL(3.0,18.0,0.21,HTITL,0.0,11)
      CALL SYMBOL(6.0,18.0,0.21,POSIT,0.0,8)
      CALL SYMBOL(6.0,16.0,0.21,ATITL,0.0,18)
      CALL PLOT(20.0,0.0,-3)


      CALL SCALE(MIDDLE,15.,L,1)
      CALL SCALE(SMFREQ,15.,L,1)
      CALL AXIS(0.0,0.0,XTITL,-12,15.0,0.0,MIDDLE(L+1),MIDDLE(L+2))
      CALL AXIS(0.0,0.0,YTITL,15,15.0,90.0,SMFREQ(L+1),SMFREQ(L+2))
      CALL LINE(MIDDLE,SMFREQ,L,1,1,3)
      CALL SYMBOL(3.0,20.0,0.21,DTITL,0.0,3)
      CALL SYMBOL(5.0,20.0,0.21,J,0.0,2)
      CALL SYMBOL(3.0,19.0,0.21,ETITL,0.0,7)
      CALL SYMBOL(6.0,19.0,0.21,CUR,0.0,8)
      CALL SYMBOL(7.5,19.0,0.21,ICUR,0.0,2)
      CALL SYMBOL(8.5,19.0,0.21,RCUR,0.0,8)
      CALL SYMBOL(3.0,18.0,0.21,HTITL,0.0,11)
      CALL SYMBOL(6.0,18.0,0.21,POSIT,0.0,8)
      CALL SYMBOL(6.0,16.00,0.21,BTITL,0.0,18)
      CALL PLOT(20.0,0.0,-3)
      CALL SCALE(MIDDLE,15.,L,1)
```

```
      CALL SCALE(THFREQ,15.,L,1)
      CALL AXIS(0.0,0.0,XTITL,-12,15.0,0.0,MIDDLE(L+1),MIDDLE(L+2))
      CALL AXIS(0.0,0.0,YTITL,15,15.0,90.0,THFREQ(L+1),THFREQ(L+2))
      CALL LINE(MIDDLE,THFREQ,L,1,1,4)
      CALL SYMBOL(3.0,20.0,0.21,DTITL,0.0,3)
      CALL SYMBOL(5.0,20.0,0.21,J,0.0,2)
      CALL SYMBOL(3.0,19.0,0.21,ETITL,0.0,7)
      CALL SYMBOL(6.0,19.0,0.21,CUR,0.0,8)
      CALL SYMBOL(7.5,19.0,0.21,ICUR,0.0,2)
      CALL SYMBOL(8.5,19.0,0.21,RCUR,0.0,8)
      CALL SYMBOL(3.0,18.0,0.21,HTITL,0.0,11)
      CALL SYMBOL(6.0,18.0,0.21,POSIT,0.0,8)
      CALL SYMBOL(6.0,15.0,0.21,CTITL,0.0,21)
      CALL PLOT(20.0,0.0,-3)
      CALL SCALE(UPR,15.,L,1)
      CALL SCALE(PCFREQ,15.,L,1)
      CALL AXIS(0.0,0.0,XTITL,-12,15.0,0.0,MIDDLE(L+1),MIDDLE(L+2))
      CALL AXIS(0.0,0.0,YYTITL,28,15.0,90.0,PCFREQ(L+1),PCFREQ(L+2))
      CALL LINE(MIDDLE,PCFREQ,L,1,1,11)
      CALL SYMBOL(3.0,20.0,0.21,DTITL,0.0,3)
      CALL SYMBOL(5.0,20.0,0.21,J,0.0,2)
      CALL SYMBOL(3.0,19.0,0.21,ETITL,0.0,7)
      CALL SYMBOL(6.0,19.0,0.21,CUR,0.0,8)
      CALL SYMBOL(7.5,19.0,0.21,ICUR,0.0,2)
      CALL SYMBOL(8.5,19.0,0.21,RCUR,0.0,8)
      CALL SYMBOL(3.0,18.0,0.21,HTITL,0.0,11)
      CALL SYMBOL(6.0,18.0,0.21,POSIT,0.0,8)
      CALL SYMBOL(1.0,6.0,0.21,RTITL,0.0,31)
      MK=0
   63 MK=MK+1
      IF(MK.GT.2) GO TO 65
      MM=0
      K=1
   15 IF(K.GT.L) GO TO 79
      MM=MM+1
      IF(IFREQ(K).LT.5) GO TO 70
      IF(THFREQ(K).LT.5.0) GO TO 70
      IXFREQ(MM)=IFREQ(K)
      THXFREQ(MM)=THFREQ(K)
      IF(K.GE.L) GO TO 79
      K=K+1
      GO TO 15
   70 IXFREQ(MM)=IFREQ(K)+IFREQ(K+1)
      THXFREQ(MM)=THFREQ(K)+THFREQ(K+1)
      K1=K+1
      IF(K1.GE.L) GO TO 79
      IF(IXFREQ(MM).LT.5) GO TO 71
      IF(THXFREQ(MM).LT.5.0) GO TO 71
      K=K+2
      IF(K.GT.L) GO TO 79
      GO TO 15
   71 IXFREQ(MM)=IXFREQ(MM)+IFREQ(K+2)
      THXFREQ(MM)=THXFREQ(MM)+THFREQ(K+2)
      K2=K+2
      IF(K2.GE.L) GO TO 79
      IF(IXFREQ(MM).LT.5) GO TO 72
      IF(THXFREQ(MM).LT.5.0) GO TO 72
      K=K+3
      IF(K.GT.L) GO TO 79
      GO TO 15
   72 IXFREQ(MM)=IXFREQ(MM)+IFREQ(K+3)
      THXFREQ(MM)=THXFREQ(MM)+THFREQ(K+3)
      K3=K+3
      IF(K3.GE.L) GO TO 79
      IF(IXFREQ(MM).LT.5) GO TO 73
      IF(THXFREQ(MM).LT.5.0) GO TO 73
      K=K+4
      IF(K.GT.L) GO TO 79
      GO TO 15
   73 IXFREQ(MM)=IXFREQ(MM)+IFREQ(K+4)
      THXFREQ(MM)=THXFREQ(MM)+THFREQ(K+4)
      K4=K+4
```

```
      IF(K4.GE.L) GO TO 79
      IF(IXFREQ(MM).LT.5) GO TO 74
      IF(THXFREQ(MM).LT.5.0) GO TO 74
      K=K+5
      IF(K.GT.L) GO TO 79
      GO TO 15
   74 IXFREQ(MM)=IXFREQ(MM)+IFREQ(K+5)
      THXFREQ(MM)=THXFREQ(MM)+THFREQ(K+5)
      K5=K+5
      IF(K5.GE.L) GO TO 79
      IF(IXFREQ(MM).LT.5) GO TO 75

      IF(THXFREQ(MM).LT.5.0) GO TO 75
      K=K+6
      IF(K.GT.L) GO TO 79
      GO TO 15
   75 IXFREQ(MM)=IXFREQ(MM)+IFREQ(K+6)
      THXFREQ(MM)=THXFREQ(MM)+THFREQ(K+6)
      K6=K+6
      IF(K6.GE.L) GO TO 79
      IF(IXFREQ(MM).LT.5) GO TO 76
      IF(THXFREQ(MM).LT.5.0) GO TO 76
      K=K+7
      IF(K.GT.L) GO TO 79
      GO TO 15
   76 IXFREQ(MM)=IXFREQ(MM)+IFREQ(K+7)
      THXFREQ(MM)=THXFREQ(MM)+THFREQ(K+7)
   79 IF(IXFREQ(MM).LT.5) GO TO 60
      IF(THXFREQ(MM).LT.5.0) GO TO 60
      KM=MM
   77 WRITE(7,252)
      WRITE(7,257)
      IF(MK.EQ.2) GO TO 64

      WRITE(7,300)
      GO TO 41
   64 WRITE(7,301)
      GO TO 41
   60 IXFREQ(MM-1)=IXFREQ(MM)+IXFREQ(MM-1)
      THXFREQ(MM-1)=THXFREQ(MM)+THXFREQ(MM-1)
      KM=MM-1
      GO TO 77
   41 XX=0.0
      DO 43 I=1,KM
      XY(I)=(((THXFREQ(I)-IXFREQ(I))**2)/THXFREQ(I))
      XX=XX+XY(I)
   43 CONTINUE
      WRITE(7,251) KM
      WRITE(7,255)
      WRITE(7,250) (IXFREQ(I),THXFREQ(I),XY(I),I=1,KM)
      WRITE(7,254) XX
      KN=KM-3
      IF(KN.EQ.0) GO TO 36
      IF(KN.LT.0) GO TO 36
      IN=9

   39 IN=IN+1
      IF(IN.GT.13) GO TO 37
      IF(D(IN,KN).GT.XX) GO TO 38
      GO TO 39
   38 IF(IN.NE.10) GO TO 42
      WRITE(7,276) D(IN,KN) ,KN
      GO TO 37
   42 IF(IN.NE.11) GO TO 45
      WRITE(7,277) D(IN,KN),KN
      GO TO 37
   45 IF(IN.NE.12) GO TO 46
      WRITE(7,278) D(IN,KN),KN
      GO TO 37
   46 IF(IN.NE.13) GO TO 37
      WRITE(7,279) D(IN,KN),KN
   37 IK=0
   52 IK=IK+1
      IF(IK.GT.14) GO TO 51
      IF(D(IK,KN).GT.XX) GO TO50
      GO TO 52
```

```
   50 IF(IK.NE.1) GO TO 53
      WRITE(7,260) D(IN,KN),KN
      GO TO 62
   53 IF(IK.NE.2) GO TO 54
      WRITE(7,261) D(IN,KN),KN
      GO TO 62
   54 IF(IK.NE.3) GO TO 55
      WRITE(7,262) D(IN,KN),KN
      GO TO 62
   55 IF(IK.NE.4) GO TO 56
      WRITE(7,263) D(IN,KN),KN
      GO TO 62
   56 IF(IK.NE.5) GO TO 57
      WRITE(7,264) D(IN,KN),KN
      GO TO 62
   57 IF(IK.NE.6) GO TO 58
      WRITE(7,265) D(IN,KN),KN
      GO TO 62
   58 IF(IK.NE.7) GO TO 59
      WRITE(7,266) D(IN,KN),KN
      GO TO 62
   59 IF(IK.NE.8) GO TO 30
      WRITE(7,267)D(IN,KN),KN
      GO TO 62
   30 IF(IK.NE.9) GO TO 31
      WRITE(7,268) D(IN,KN),KN
      GO TO 62
   31 IF(IK.NE.10) GO TO 32
      WRITE(7,269) D(IN,KN),KN
      GO TO 62
   32 IF(IK.NE.11) GO TO 33
      WRITE(7,270) D(IN,KN),KN
      GO TO 62
   33 IF(IK.NE.12) GO TO 34
      WRITE(7,271) D(IN,KN),KN
      GO TO 62
   34 IF(IK.NE.13) GO TO 35
      WRITE(7,272) D(IN,KN),KN
      GO TO 62
   35 IF(IK.NE.14) GO TO 51
      WRITE(7,273) D(IN,KN),KN
      GO TO 62
   51 WRITE(7,274) KN
      GO TO 62
   36 WRITE(7,275) KN
   62 IHREQ(1)=IFREQ(L)
      THIREQ(1)=THFREQ(L)
      DO 61 I=2,L
      II=I-1
      IHREQ(I)=IFREQ(L-II)
      THIREQ(I)=THFREQ(L-II)
   61 CONTINUE
      DO 66 I=1,L
      IFREQ(I)=IHREQ(I)
      THFREQ(I)=THIREQ(I)
   66 CONTINUE
      IF(MK.LT.2) GO TO 63
   65 KK=0
  400 KK=KK+1
      IF(KK.GT.2)GO TO 990
      MM=0
      K=1
  750 IF(K.GT.L) GO TO 790
      MM=MM+1
      IF(THFREQ(K).LT.5.0) GO TO 401
      THXFREQ(MM)=THFREQ(K)
      IXFREQ(MM)=IFREQ(K)
      IF(K.GE.L) GO TO 790
      K=K+1
      GO TO 750
  401 THXFREQ(MM)=THFREQ(K)+THFREQ(K+1)
      IXFREQ(MM)=IFREQ(K)+IFREQ(K+1)
```

```
      K1=K+1
      IF(K1.GE.L) GO TO 790
      IF(THXFREQ(MM).LT.5.0) GO TO 402
      K=K+2
      IF(K.GT.L) GO TO 790
      GO TO 750
  402 THXFREQ(MM)=THXFREQ(MM)+THFREQ(K+2)
      IXFREQ(MM)=IXFREQ(MM)+IFREQ(K+2)
      K2=K+2
      IF(K2.GE.L) GO TO 790
      IF(THXFREQ(MM).LT.5.0) GO TO 403
      K=K+3
      IF(K.GT.L) GO TO 790
      GO TO 750
  403 THXFREQ(MM)=THXFREQ(MM)+THFREQ(K+3)
      IXFREQ(MM)=IXFREQ(MM)+IFREQ(K+3)
      K3=K+3
      IF(K3.GE.L) GO TO 790
      IF(THXFREQ(MM).LT.5.0) GO TO 404
      K=K+4
      IF(K.GT.L) GO TO 790
      GO TO 750
  404 THXFREQ(MM)=THXFREQ(MM)+THFREQ(K+4)
      IXFREQ(MM)=IXFREQ(MM)+IFREQ(K+4)
      K4=K+4
      IF(K4.GE.L) GO TO 790
      IF(THXFREQ(MM).LT.5.0) GO TO 405

      K=K+5
      IF(K.GT.L) GO TO 790
      GO TO 750
  405 THXFREQ(MM)=THXFREQ(MM)+THFREQ(K+5)
      IXFREQ(MM)=IXFREQ(MM)+IFREQ(K+5)
      K5=K+5
      IF(K5.GE.L) GO TO 790
      IF(THXFREQ(MM).LT.5.0) GO TO 406
      K=K+6
      IF(K.GT.L) GO TO 790
      GO TO 750
  406 THXFREQ(MM)=THXFREQ(MM)+THFREQ(K+6)
      IXFREQ(MM)=IXFREQ(MM)+IFREQ(K+6)
      K6=K+6
      IF(K6.GE.L) GO TO 790
      IF(THXFREQ(MM).LT.5.0) GO TO 407
      K=K+7
      IF(K.GT.L) GO TO 790
      GO TO 750
  407 THXFREQ(MM)=THXFREQ(MM)+THFREQ(K+7)
      IXFREQ(MM)=IXFREQ(MM)+IFREQ(K+7)

  790 IF(THXFREQ(MM).LT.5.0) GO TO 600
      KM=MM
  770 WRITE(7,252)
      WRITE(7,257)
      IF(KK.EQ.2) GO TO 640
      WRITE(7,302)
      GO TO 410
  640 WRITE(7,303)
      GO TO 410
  600 THXFREQ(MM-1)=THXFREQ(MM)+THXFREQ(MM-1)
      IXFREQ(MM-1)=IXFREQ(MM)+IXFREQ(MM-1)
      KM=MM-1
      GO TO 770
  410 XX=0.0
      DO 430 I=1,KM
      XY(I)=(((THXFREQ(I)-IXFREQ(I))**2)/THXFREQ(I))
      XX=XX+XY(I)
  430 CONTINUE
      WRITE(7,251) KM
      WRITE(7,255)
      WRITE(7,250) (IXFREQ(I),THXFREQ(I),XY(I),I=1,KM)

      WRITE(7,254) XX
      KN=KM-3
      IF(KN.EQ.0) GO TO 360
      IF(KN.LT.0) GO TO 360
```

```
      IN=9
  390 IN=IN+1
      IF(IN.GT.13) GO TO 370
      IF(D(IN,KN).GT.XX) GO TO 380
      GO TO 390
  380 IF(IN.NE.10) GO TO 420
      WRITE(7,276) D(IN,KN) ,KN
      GO TO 370
  420 IF(IN.NE.11) GO TO 450
      WRITE(7,277) D(IN,KN),KN
      GO TO 370
  450 IF(IN.NE.12) GO TO 460
      WRITE(7,278) D(IN,KN),KN
      GO TO 370
  460 IF(IN.NE.13) GO TO 30
      WRITE(7,279) D(IN,KN),KN
  370 IK=0

  520 IK=IK+1
      IF(IK.GT.14) GO TO 510
      IF(D(IK,KN).GT.XX) GO TO550
      GO TO 520
  550 IF(IK.NE.1) GO TO 530
      WRITE(7,260) D(IN,KN),KN
      GO TO 620
  530 IF(IK.NE.2) GO TO 540
      WRITE(7,261) D(IN,KN),KN
      GO TO 620
  540 IF(IK.NE.3) GO TO 555
      WRITE(7,262) D(IN,KN),KN
      GO TO 620
  555 IF(IK.NE.4) GO TO 560
      WRITE(7,263) D(IN,KN),KN
      GO TO 620
  560 IF(IK.NE.5) GO TO 570
      WRITE(7,264) D(IN,KN),KN
      GO TO 620
  570 IF(IK.NE.6) GO TO 580
      WRITE(7,265) D(IN,KN),KN

      GO TO 620
  580 IF(IK.NE.7) GO TO 590
      WRITE(7,266) D(IN,KN),KN
      GO TO 620
  590 IF(IK.NE.8) GO TO 330
      WRITE(7,267)D(IN,KN),KN
      GO TO 620
  330 IF(IK.NE.9) GO TO 310
      WRITE(7,268) D(IN,KN),KN
      GO TO 620
  310 IF(IK.NE.10) GO TO 320
      WRITE(7,269) D(IN,KN),KN
      GO TO 620
  320 IF(IK.NE.11) GO TO 333
      WRITE(7,270) D(IN,KN),KN
      GO TO 620
  333 IF(IK.NE.12) GO TO 340
      WRITE(7,271) D(IN,KN),KN
      GO TO 620
  340 IF(IK.NE.13) GO TO 350
      WRITE(7,272) D(IN,KN),KN

      GO TO 620
  350 IF(IK.NE.14) GO TO 510
      WRITE(7,273) D(IN,KN),KN
      GO TO 620
  510 WRITE(7,274) KN
      GO TO 620
  360 WRITE(7,275) KN
  620 IHREQ(1)=IFREQ(L)
      THIREQ(1)=THFREQ(L)
      DO 610 I=2,L
      NI=I-1
      IHREQ(I)=IFREQ(L-NI)
      THIREQ(I)=THFREQ(L-NI)
  610 CONTINUE
```

```
      DO 660 I=1,L
      IFREQ(I)=IHREQ(I)
      THFREQ(I)=THIREQ(I)
  660 CONTINUE
      IF(KK.LT.2) GO TO 400
  990 READ(3,180) (Z(I),I=1,N)
      READ(3,181) IZM1,IZM05,IZMO,IZP05,IZP1,IZP15
      READ(3,182) (ICFR(I),I=1,6)
      READ(3,183) (PCFR(I),I=1,6)
      READ(3,184) (ZZ(I),I=1,6)
      READ(3,183) (EXFR(I),I=1,6)
      READ(3,183) (DP(I),I=1,6)
      READ(3,183) DMAX
      READ(3,184) DT
      READ(3,185) (TM(I),I=1,4)
      READ(3,185) STM
      IF(STM.EQ.0.0) GO TO 921
      READ(3,186) TTM,DDK
  921 READ(3,185) PTM
      WRITE(7,280)
      WRITE(7,239)
      WRITE(7,281)
      WRITE(7,282)
      WRITE(7,283) (Z(I),I=1,N)
      WRITE(7,284)
      WRITE(7,285) ZZ(1),IZM1,ZZ(2),IZM05,ZZ(3),IZMO,ZZ(4),IZP05,
     * ZZ(5),IZP1,ZZ(6),IZP15
      WRITE(7,286)
      WRITE(7,287) (ICFR(I),PCFR(I),EXFR(I),DP(I),I=1,6)
      WRITE(7,288) DMAX,DT
      IF(PTM.EQ.0.0) GO TO 747
      WRITE(7,289) TTM,DDK
      GO TO 748
  747 WRITE(7,290) PTM
  748 U(1)=1.0
      DO 746 I=2,N
      U(I)=U(I-1)+1.0
  746 CONTINUE
      DO 753 I=1,N
      UT(I)=U(I)/N
  753 CONTINUE
      DO 754 I=1,N
      G(I)=((X(I)-XBAR)/S2)
  754 CONTINUE
      DO 613 I=1,N
      IF(G(I).GE.0.0) GO TO 614
      GX(I)=ABS(G(I))
      IF(GX(I).LT.3.10) GO TO 613
      G(I)=-3.10
      GO TO 613
  614 IF(G(I).LT.3.10) GO TO 613
      G(I)=3.10
  613 CONTINUE
      DO 755 M=1,N
      IF(G(M).GE.0.0) GO TO 756
      GR(M)=G(M)*(-1.0)
      GG(M)=GR(M)*100.0
      IGG(M)=IFIX(GG(M))
      DO 757 I=1,311
      AS(I)=AA(I)*100.0
      IAA(I)=IFIX(AS(I)+0.50)
      IF(IGG(M).NE.IAA(I)) GO TO 757
      EXPFR(M)=BB(I)/100.0
      GO TO 755
  757 CONTINUE
      GO TO 755
  756 GG(M)=G(M)*100.0
      IGG(M)=IFIX(GG(M))
      DO 758 I=1,311
      AS(I)=AA(I)*100.0
      IAA(I)=IFIX(AS(I)+0.50)
      IF(IGG(M).NE.IAA(I)) GO TO 758
```

```
      EXPFR(M)=CC(I)/100.0
      GO TO 755
  758 CONTINUE
  755 CONTINUE
      DO 759 I=1,N
      HH(I)=UT(I)-EXPFR(I)
      H(I)=ABS(HH(I))
  759 CONTINUE
      CALL G01AAF(N,H,IWT,WT,HBAR,H2,H3,H4,HMIN,HMAX,WTSUM,IFAIL)
      HG=HMAX*(SQRT(FLOAT(N)))
      DO 761 I=1,4
      IF(HG.GE.DK(I)) GO TO 761
      HTM=TM(I)
      HDM=DK(I)
      GO TO 762
  761 CONTINUE
      HT=0.0
      GO TO 763
  762 HT=1.0
  763 WRITE(7,280)
      WRITE(7,239)
      WRITE(7,291)
      WRITE(7,292)
      WRITE(7,293) (U(I),G(I),UT(I),EXPFR(I),H(I),I=1,N)
      WRITE(7,288) HMAX,HG
      IF(HT.EQ.0.0) GO TO 764
      WRITE(7,289) HTM,HDM
      GO TO 80
  764 WRITE(7,290) HT
   80 CONTINUE
      CALL PLOT(20.0,0.0,999)
      STOP
  100 FORMAT (I2)
  101 FORMAT (I3,I2)
  102 FORMAT (F5.0)
  103 FORMAT (I5,2F5.0)
  104 FORMAT (F5.2)
  171 FORMAT (F4.2,F5.2,F5.2)
  172 FORMAT (4F4.2)
  180 FORMAT (F6.3)
  181 FORMAT (6I2)
  182 FORMAT (I3)
  183 FORMAT (F6.3)
  184 FORMAT (F7.4)
  185 FORMAT (F5.3)
  186 FORMAT (F5.3,F4.2)
  200 FORMAT (1H1,5H SET , I3//)
  229 FORMAT (10X,37H D A T A   C L A S S I F I C A T I O N/)
  230 FORMAT (6X,17HNUMBER OF CASES, I5/)
  231 FORMAT (6X, 15HDATA AS INPUT -/)
  232 FORMAT (1H , 5F12.2)
  233 FORMAT (6X, 18HWEIGHTS AS INPUT -/)
  234 FORMAT (/19H N IS LASS THAN ONE)
  235 FORMAT (/6X,23HCLASSIFIED SPEED DATA -/)
  236 FORMAT (1H0, 5X, 27HUNSUCCESSFUL CALL OF G01AAF/6X, 7HIFAIL =, I2)
  237 FORMAT (6X, 18HNO. OF VALID CASES, I5/6X,7HMINIMUM,7X,F10.3,
     * /6X,7HMAXIMUM,7X,F10.3)
  238 FORMAT (////10X,46H F R E Q U E N C Y   C L A S S   D I S T R I B U,
     * 8H T I O N/)
  239 FORMAT (5X,50H**************************************************,
     * 15H***************///)
  240 FORMAT (1H0,7X,9HC L A S S,8X,13HMID. OF CLASS,8X,9HFREQUENCY,
     * 8X,13HSMOOTH. FREQ.,8X,14HPER. OF VEHIC.,8X,10HREL. FREQ./)
  241 FORMAT (1H,2F10.2,4X,F13.2,8X,I9,8X,F12.2,8X,F14.2,8X,F10.2)
  242 FORMAT (1H0,7X,5HTOTAL,33X,I9,8X,F12.2,8X,F14.2,8X,F10.2)
  243 FORMAT (1H0, 5X, 40HRESULTS FROM A SUCCESSFUL CALL OF G01AAF/
     * 6X, 18HNO. OF VALID CASES, I5/6X, 4HMEAN, 10X, F10.3/6X,
     * 6HMEDIAN,8X,F10.3/6X,
     * 8HSTD DEVN, 6X, F10.3/6X, 8HSKEWNESS, 6X, F10.3/6X, 6HKURTOS,
     * 2HIS, 6X, F10.3/6X, 7HMINIMUM, 7X, F10.3/6X, 7HMAXIMUM, 7X,
     * F10.3/6X,24HCOEFFICIENT OF VARIATION,F10.3/6X, 14HSUM OF WEIGHTS,
     * F10.3//)
```

```
244 FORMAT (1H0,7X,9HC L A S S,8X,12HCUMUL. FREQ.,8X,
   * 20HPERCEN. CUMUL. FREQ./)
245 FORMAT (1H,2F10.2,6X,I9,16X,F12.2)
246 FORMAT (1H0,7X.11HUPPER LIMIT,8X,14HUPPER LIMIT-S2,8X,
   * 18HTHAT THE VARIATION/8X,37HFOUND IN THE SAMPLE MIGHT OCCUR IN 50,
   * 12HTHEOR. FREQ.,5X,12HOBSER. FREQ./)
247 FORMAT (1H,7X,F11.2,8X,F14.2,13X,F12.2,5X,F11.3,5X,F11.3,5X,
   * F11.3,15X,I2)
248 FORMAT (1H,7X,F11.2,8X,F14.2,13X,F12.2,5X,F11.3)
249 FORMAT (1H0,7X,5HTOTAL,90X,F11.3,14X,I3)
250 FORMAT (1H,23X,I3,17X,F11.3,26X,F11.3)
251 FORMAT (1H0,7X,23HNUMBER OF AGGREG. CASES, I5/)
252 FORMAT (////10X,46HC H I - S Q U A R E D  D I S T R I B U T I O N,

   * 28H  N O R M A L I T Y  T E S T/)
254 FORMAT (/1H0,7X,13HCHI-SQUARED =, F8.3)
255 FORMAT (1H0,7X,20HAGGREG. OBSER. FREQ.,8X,20HAGGREG. THEOR. FREQ.,
   * 8X,29H(((THFREQ-OBFREQ)**2)/THFREQ)/)
257 FORMAT (5X,50H**************************************************,
   * 40H****************************************//)
260 FORMAT (/1H0,7X,44HPROBABILITY MORE THAN 99 PERCENT WHICH MEANS,
   *18HTHAT THE VARIATION/8X,37HFOUND IN THE SAMPLE MIGHT OCCUR IN 99,
   * 1X,27HPERCENT OF THE CASES IN THE/8X,17HPOPULATION TESTED//8X,
   * 13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
261 FORMAT (/1H0,7X,44HPROBABILITY MORE THAN 98 PERCENT WHICH MEANS,
   *18HTHAT THE VARIATION/8X,37HFOUND IN THE SAMPLE MIGHT OCCUR IN 98,
   * 1X,27HPERCENT OF THE CASES IN THE/8X,17HPOPULATION TESTED//8X,

   * 13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
262 FORMAT (/1H0,7X,44HPROBABILITY MORE THAN 95 PERCENT WHICH MEANS,
   *18HTHAT THE VARIATION/8X,37HFOUND IN THE SAMPLE MIGHT OCCUR IN 95,
   * 1X,27HPERCENT OF THE CASES IN THE/8X,17HPOPULATION TESTED//8X,
   * 13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
263 FORMAT (/1H0,7X,44HPROBABILITY MORE THAN 90 PERCENT WHICH MEANS,
   *18HTHAT THE VARIATION/8X,37HFOUND IN THE SAMPLE MIGHT OCCUR IN 90,
   * 1X,27HPERCENT OF THE CASES IN THE/8X,17HPOPULATION TESTED//8X,
   * 13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
264 FORMAT (/1H0,7X,44HPROBABILITY MORE THAN 80 PERCENT WHICH MEANS,
   *18HTHAT THE VARIATION/8X,37HFOUND IN THE SAMPLE MIGHT OCCUR IN 80,
   * 1X,27HPERCENT OF THE CASES IN THE/8X,17HPOPULATION TESTED//8X,

   * 13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
265 FORMAT (/1H0,7X,44HPROBABILITY MORE THAN 70 PERCENT WHICH MEANS,
   *18HTHAT THE VARIATION/8X,37HFOUND IN THE SAMPLE MIGHT OCCUR IN 70,
   * 1X,27HPERCENT OF THE CASES IN THE/8X,17HPOPULATION TESTED//8X,
   * 13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
266 FORMAT (/1H0,7X,44HPROBABILITY MORE THAN 50 PERCENT WHICH MEANS,
   *18HTHAT THE VARIATION/8X,37HFOUND IN THE SAMPLE MIGHT OCCUR IN 50,
   * 1X,27HPERCENT OF THE CASES IN THE/8X,17HPOPULATION TESTED//8X,
   * 13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
267 FORMAT (/1H0,7X,44HPROBABILITY MORE THAN 30 PERCENT WHICH MEANS,
   *18HTHAT THE VARIATION/8X,37HFOUND IN THE SAMPLE MIGHT OCCUR IN 30,
   * 1X,27HPERCENT OF THE CASES IN THE/8X,17HPOPULATION TESTED//8X,

   * 13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
268 FORMAT (/1H0,7X,44HPROBABILITY MORE THAN 20 PERCENT WHICH MEANS,
   *18HTHAT THE VARIATION/8X,37HFOUND IN THE SAMPLE MIGHT OCCUR IN 20,
   * 1X,27HPERCENT OF THE CASES IN THE/8X,17HPOPULATION TESTED//8X,
   * 13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
269 FORMAT (/1H0,7X,44HPROBABILITY MORE THAN 10 PERCENT WHICH MEANS,
   *18HTHAT THE VARIATION/8X,37HFOUND IN THE SAMPLE MIGHT OCCUR IN 10,
   * 1X,27HPERCENT OF THE CASES IN THE/8X,17HPOPULATION TESTED//8X,
   * 13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
270 FORMAT (/1H0,7X,43HPROBABILITY MORE THAN 5 PERCENT WHICH MEANS,
   *18HTHAT THE VARIATION/8X,36HFOUND IN THE SAMPLE MIGHT OCCUR IN 5,
   * 1X,27HPERCENT OF THE CASES IN THE/8X,17HPOPULATION TESTED//8X,

   * 13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
271 FORMAT (/1H0,7X,43HPROBABILITY MORE THAN 2 PERCENT WHICH MEANS,
   *18HTHAT THE VARIATION/8X,36HFOUND IN THE SAMPLE MIGHT OCCUR IN 2,
   * 1X,27HPERCENT OF THE CASES IN THE/8X,17HPOPULATION TESTED//8X,
   * 13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
272 FORMAT (/1H0,7X,43HPROBABILITY MORE THAN 1 PERCENT WHICH MEANS,
   *18HTHAT THE VARIATION/8X,36HFOUND IN THE SAMPLE MIGHT OCCUR IN 1,
   * 1X,27HPERCENT OF THE CASES IN THE/8X,17HPOPULATION TESTED//8X,
   * 13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
```

```
  273 FORMAT (/1HO,7X,43HPROBABILITY MORE THAN O PERCENT WHICH MEANS,
     *18HTHAT THE VARIATION/8X,36HFOUND IN THE SAMPLE MIGHT OCCUR IN O,
     * 1X,27HPERCENT OF THE CASES IN THE/8X,17HPOPULATION TESTED//8X,
     * 13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
  274 FORMAT (/1HO,7X,44HPUBLIC ROAD SPEED DATA DISTRIBUTION DOES NOT,
     *35HAPPROXIMATE THE NORMAL DISTRIBUTION/8X,6HAT ANY,
     * 25HSIGNIFICANCE LEVEL TESTED//8X,20HDEGREES OF FREEDOM =,I5)
  275 FORMAT (/1HO,7X,43HTHE NUMBER OF DEGREES OF FREEDOM IS ZERO OR,
     * 8HNEGATIVE,8X,5HDOF =,I5//8X,26HLARGER SAMPLE OR DIFFERENT,
     * 34HSPEED CLASS ARRANGMENT IS REQUIRED)
  276 FORMAT (/1HO,7X,42HNORMAL DISTRIBUTION FITS PUBLIC ROAD SPEED/,
     * 8X,49HDATA DISTRIBUTION AT A SIGNIFICANCE LEVEL OF 0.10//,
     * 8X,13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
  277 FORMAT (/1HO,7X,42HNORMAL DISTRIBUTION FITS PUBLIC ROAD SPEED/,
     * 8X,49HDATA DISTRIBUTION AT A SIGNIFICANCE LEVEL OF 0.05//,
     * 8X,13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
  278 FORMAT (/1HO,7X,42HNORMAL DISTRIBUTION FITS PUBLIC ROAD SPEED/,
     * 8X,49HDATA DISTRIBUTION AT A SIGNIFICANCE LEVEL OF 0.02//,
     * 8X,13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
  279 FORMAT (/1HO,7X,42HNORMAL DISTRIBUTION FITS PUBLIC ROAD SPEED/,
     * 8X,49HDATA DISTRIBUTION AT A SIGNIFICANCE LEVEL OF 0.01//,
     * 8X,13HCHI-SQUARED =,F8.3,8X,20HDEGREES OF FREEDOM =,I5)
  280 FORMAT (////10X,35HKOLMOGOROV - SMIRNOV NORMALITY TEST/)
  281 FORMAT (10X,3H---,30HK-S TEST FOR RANKED CATEGORIES,3H---/)
  282 FORMAT (1HO,40X,19HZ (STANDARD) SCORES/)
  283 FORMAT ((8X,5(5X,F11.3)))
  284 FORMAT (/1HO,7X,9HZ - SCORE,8X,9HFREQUENCY/)
  285 FORMAT (1H,5X,F11.3,10X,I7/6X,F11.3,10X,I7/6X,F11.3,10X,I7/,
     * 6X,F11.3,10X,I7/6X,F11.3,10X,I7/6X,F11.3,10X,I7)
  286 FORMAT (/1HO,7X,12HCUMUL. FREQ.,8X,17HCUMUL. PROPORTION,8X,
     * 19HEXPECTED PROPORTION,8X,10HDIFFERENCE/)
  287 FORMAT (1H,15X,I3,15X,F11.3,16X,F11.3,7X,F11.3)
  288 FORMAT (/1HO,7X,29HABSOLUTE MAXIMUM DIFFERENCE =,F8.3/8X,
     * 22HK-VALUE(MAX*SQRT(N)) =,F8.3/)
  289 FORMAT (/1HO,7X,42HNORMAL DISTRIBUTION FITS PUBLIC ROAD SPEED/,
     * 8X,43HDATA DISTRIBUTION AT A SIGNIFICANCE LEVEL =,F8.4//,
     * 8X,23HK - TABLE LIMIT VALUE =,F6.3/)
  290 FORMAT (/1HO,7X,44HPUBLIC ROAD SPEED DATA DISTRIBUTION DOES NOT,
     *35HAPPROXIMATE THE NORMAL DISTRIBUTION/8X,6HAT ANY,
     * 25HSIGNIFICANCE LEVEL TESTED//8X,4HTM =,F8.3/)
  291 FORMAT (1HO,3H---,28HK-S TEST FOR RANKABLE SCORES,3H---/)
  292 FORMAT (1HO,7X,13HRANKED SCORES,8X,7HZ-SCORE,8X,
     * 17HCUMUL. PROPORTION,8X,19HEXPECTED PROPORTION,8X,10HDIFFERENCE/)
  293 FORMAT (1H,14X,F6.2,4X,F11.3,14X,F11.3,16X,F11.3,7X,F11.3)
  300 FORMAT (15X,3H---,42HTHEOR. FREQ. AND OBSER. FREQ. BOTH GREATER,
     * 1X,25HTHAN 5 - INCREASING ORDER,3H---/)
  301 FORMAT (15X,3H---,42HTHEOR. FREQ. AND OBSER. FREQ. BOTH GREATER,
     * 1X,23HTHAN 5 - REVERSED ORDER,3H---/)
  302 FORMAT (15X,3H---,27HTHEOR. FREQ. GREATER THAN 5,1X,
     * 16HINCREASING ORDER,3H---/)
  303 FORMAT (15X,3H---,27HTHEOR. FREQ. GREATER THAN 5,1X,
     * 14HREVERSED ORDER,3H---/)
  304 FORMAT (1HO,5X,40HNORMAL DISTRIBUTION IN TERMS OF SKEWNEES/)
  305 FORMAT (1HO,5X,26HPOSITIVE SKEW DISTRIBUTION/)
  306 FORMAT (1HO,5X,26HNEGATIVE SKEW DISTRIBUTION/)
  307 FORMAT (1HO,5X,40HNORMAL DISTRIBUTION IN TERMS OF KURTOSIS/)
  308 FORMAT (1HO,5X,24HLEPTOKURTIC DISTRIBUTION//)
  309 FORMAT (1HO,5X,24HPLATIKURTIC DISTRIBUTION//)
  500 FORMAT (I3,F7.5)
  501 FORMAT (F6.3)
  903 FORMAT (5X,5HSPEED,1X,1H(,I2,1X,11HPER CENT) =,F7.3//)
  904 FORMAT (//10X,31HVEHICLE SPEED PERCENTILE VALUES, 1X,
     * 1H-,1X,27HOBSERVED SPEED DISTRIBUTION//)
  905 FORMAT (//10X,31HVEHICLE SPEED PERCENTILE VALUES,1X,
     * 1H-,1X,30HTHEORETICAL SPEED DISTRIBUTION)
      END
```

APPENDIX D

RESULTS

LIST OF TABLES

LIST OF FIGURES

TABLE D1: NORMALITY STATISTICS OF ALL CAR SPEED DISTRIBUTIONS AT THE DIFFERENT LOCATIONS

LOCATION	SINGLE CARRIAGEWAYS			
	Skewness		Kurtosis	
	Positive	Negative	Leptokurtic	Platykurtic
Approach	52	4	28	28
(%)	(92.9)	(7.1)	(50.0)	(50.0)
Entry	47	9	31	25
(%)	(83.9)	(16.1)	(55.4)	(44.6)
Middle	45	11	31	25
(%)	(80.4)	(19.6)	(55.4)	(44.6)
Exit	48	8	30	26
(%)	(85.7)	(14.3)	(53.6)	(46.4)
Total No. of Sites	56		56	

LOCATION	DUAL CARRIAGEWAYS			
	Skewness		Kurtosis	
	Positive	Negative	Leptokurtic	Platykurtic
Approach	21	1	7	15
(%)	(95.5)	(4.5)	(31.8)	(68.2)
Entry	17	5	10	12
(%)	(77.3)	(22.7)	(45.5)	(54.5)
Middle	17	5	9	13
(%)	(77.3)	(22.7)	(40.9)	(59.1)
Exit	16	6	10	12
(%)	(72.7)	(27.3)	(45.5)	(54.5)
Total No. of Sites	22		22	

TABLE D2: NORMALITY STATISTICS OF FREE CAR SPEED DISTRIBUTIONS AT THE DIFFERENT LOCATIONS

LOCATION	SINGLE CARRIAGEWAYS			
	Skewness		Kurtosis	
	Positive	Negative	Leptokurtic	Platykurtic
Approach	50	6	26	30
(%)	(89.3)	(10.7)	(46.4)	(53.6)
Entry	47	9	28	28
(%)	(83.9)	(16.1)	(50.0)	(50.0)
Middle	44	12	29	27
(%)	(78.6	(21.4)	(51.8)	(48.2)
Exit	46	10	33	23
(%)	(82.1)	(17.9)	(58.9)	(41.1)
Total No. of Sites	56		56	

LOCATION	DUAL CARRIAGEWAYS			
	Skewness		Kurtosis	
	Positive	Negative	Leptokurtic	Platykurtic
Approach	19	3	8	14
(%)	(86.4)	(13.6)	(36.4)	(63.6)
Entry	18	4	12	10
(%)	(81.8)	(18.2)	(54.5)	(45.5)
Middle	17	5	6	16
(%)	(77.3)	(22.7)	(27.3)	(72.7)
Exit	18	4	12	10
(%)	(81.8)	(18.2)	(54.5)	(45.5)
Total No. of Sites	22		22	

TABLE D3: NORMALITY STASTICS OF ALL GOODS VEHICLE SPEED DISTRIBUTIONS AT THE DIFFERENT LOCATIONS

LOCATION	SINGLE CARRIAGEWAYS			
	Skewness		Kurtosis	
	Positive	Negative	Leptokurtic	Platykurtic
Approach	19	12	11	20
(%)	(61.3)	(38.7)	(35.5)	(64.5)
Entry	16	15	14	17
(%)	(52.6)	(48.4)	(45.2)	(54.8)
Middle	13	18	5	26
(%)	(41.9)	(58.1)	(16.1)	(83.9)
Exit	18	13	12	19
(%)	(58.1)	(41.9)	(38.7)	(61.3)
Total No. of Sites	31		31	

LOCATION	DUAL CARRIAGEWAYS			
	Skewness		Kurtosis	
	Positive	Negative	Leptokurtic	Platykurtic
Approach	6	6	1	11
(%)	(50.0)	(50.0)	(8.3)	(91.7)
Entry	5	7	5	7
(%)	(41.7)	(58.3)	(41.7)	(58.3)
Middle	5	7	5	7
(%0	(41.7)	(58.3)	(41.7)	(58.3)
Exit	5	7	6	6
(%)	(41.7)	(58.3)	(50.0)	(50.0)
Total No. of Sites	12		12	

TABLE D4 : CORRELATIONS BETWEEN ENTRY SPEEDS AND INDEPENDENT VARIABLES FOR ALL STUDY SITES SINGLE CARRIAGEWAYS (85TH PERCENTILE)

	V_{PCE}	V_{HGE}	AS_{PC}	AS_{HG}	DS	R	C	TA	RCTA	L	RW	VW	E	GRA	SD	FL
V_{PCE}	1.0	/	.62	/	.67	.74	-.87	-.58	-.87	.53	.25	.16	.35	.02	.22	.46
V_{HGE}	/	1.0	/	.26	.36	.41	-.72	-.36	-.72	.14	-.05	.11	-.37	-.17	.40	.03
AS_{PC}	.62	/	1.0	/	/	.46	-.35	-.29	-.35	.31	.01	.08	-.21	.12	.26	.21
AS_{HG}	/	.26	/	1.0	/	.22	-.06	-.35	-.06	-.14	-.14	-.30	-.41	-.02	.49	-.17
DS	.67	.36	/	/	1.0	.66	-.79	-.50	-.79	.44	.42	-.14	-.24	0.0	0.0	.63
R	.74	.41	.46	.22	.66	1.0	-.75	-.79	-.75	.21	.25	-.25	-.55	0.0	.16	.69
C	-.87	-.72	-.35	-.06	-.79	-.75	1.0	.74	1.0	-.44	-.32	.04	.47	0.0	-.15	-.60
TA	-.58	-.36	-.29	-.35	-.50	-.79	.74	1.0	.74	.18	-.20	.38	.60	0.0	-.30	-.62
RCTA	-.87	-.72	-.35	-.06	-.79	-.75	1.0	.74	1.0	-.44	-.32	.04	.47	0.0	-.15	-.60
L	.53	.14	.31	-.14	.44	.21	-.44	.18	-.44	1.0	.20	.37	.03	0.0	-.22	.19
RW	.25	-.05	.01	-.14	.42	.25	-.32	-.20	-.32	.20	1.0	-.09	-.12	.34	-.21	.38
VW	.16	.11	.08	-.30	-.14	-.25	.04	.38	.04	.37	-.09	1.0	.39	0.0	-.09	-.32
E	.35	-.37	-.21	-.41	-.24	-.55	.47	.60	.47	.03	-.12	.39	1.0	0.0	-.35	-.42
GRA	.02	-.17	.12	-.02	0.0	0.0	0.0	0.0	0.0	0.0	.34	0.0	0.0	1.0	-.09	.06
SD	.22	.40	.26	.49	0.0	.16	-.15	-.30	-15	-.22	-.21	-.09	-.35	-.09	1.0	-.22
FL	.46	.03	.21	-.17	.63	.69	-.60	-.62	-.60	.19	.38	-.32	-.42	.06	-.22	1.0

TABLE D5 : CORRELATIONS BETWEEN ENTRY SPEEDS AND INDEPENDENT VARIABLES FOR ALL STUDY SITES DUAL CARRIAGEWAYS (85TH PERCENTILE)

V_{PCE}	V_{HGE}	AS_{PC}	AS_{HG}	DS	R	C	TA	RCTA	L	RW	VW	E	GRA	SD	FL
1.0	/	.82	/	.26	.69	-.74	-.28	-.74	.24	.29	.57	-.19	-.36	.45	-.02
/	1.0	/	.84	.19	.78	-.82	-.38	-.82	.36	.02	.46	-.26	-.36	.28	.01
.82	/	1.0	/	/	.38	-.36	.09	-.36	.34	.35	.74	.15	-.54	.22	.02
/	.84	/	1.0	/	.44	-.43	-.20	-.43	.21	.31	.67	.16	-.42	.11	-.18
.26	.19	/	/	1.0	.44	-.23	.13	-.23	.40	.06	.12	-.16	-.20	-.17	.54
.69	.78	.38	.44	.44	1.0	-.82	-.47	-.82	.13	.14	.05	-.57	-.03	.36	.21
-.74	-.82	-.36	-.43	-.23	-.82	1.0	.56	1.0	-.19	.07	-.24	.64	.03	-.42	-.20
-.28	-.38	.09	-.20	.13	-.47	.56	1.0	.52	.71	-.25	.08	.52	-.39	-.40	.49
-.74	-.82	-.36	-.43	-.23	-.82	1.0	.52	1.0	-.19	.07	-.14	.64	.03	-.42	-.20
.24	.36	.34	.21	.40	.13	-.19	.71	-.19	1.0	-.37	.12	.09	-.46	-.14	.80
.29	.02	.35	.31	.06	.14	.07	-.25	.07	-.37	1.0	.23	.18	.05	.27	-.44
.57	.46	.74	.67	.12	.05	-.14	.08	-.14	.12	.23	1.0	.33	-.59	.07	-.22
-.19	-.26	.15	.16	-.16	-.57	.64	.52	.64	.09	.18	.33	1.0	-.33	-.30	-.1
-.36	-.36	-.54	-.42	-.20	-.03	.03	-.39	.03	-.46	.05	-.59	-.33	1.0	.13	-.16
.45	.28	.22	.11	-.17	.36	-.42	-.40	-.42	-.14	.27	.07	-.30	.13	1.0	-.22
-.02	.01	.02	-.18	.54	.21	-.20	.49	-.20	.80	-.44	-.22	-.13	-.16	-.22	1.0

TABLE D6 : CORRELATIONS BETWEEN ENTRY SPEEDS AND INDEPENDENT VARIABLES FOR SELECTED SITES SINGLE CARRIAGEWAYS (85TH PERCENTILE)

	V_{PCE}	V_{HGE}	AS_{PC}	AS_{HG}	DS	R	C	TA	RCTA	L	RW	VW	E	GRA	SD	FL
V_{PCE}	1.0	/	.63	/	/	.79	-.92	-.69	-.92	.62	.22	.05	-.49	-.01	.28	.52
V_{HGE}	/	1.0	/	.49	/	.62	-.80	-.50	-.80	.18	.04	.18	-.62	-.26	.54	.06
AS_{PC}	.63	/	1.0	/	/	.55	-.42	-.44	-.42	.33	-.05	.01	-.40	.07	.27	.30
AS_{HG}	/	.49	/	1.0	/	.36	.11	-.53	-.11	-.18	.10	-.30	-.61	.08	.58	-.2
DS	/	/	/	/	1.0	/	/	/	/	/	/	/	/	/	/	/
R	.79	.62	.55	.36	/	1.0	-.77	-.77	-.77	.51	.18	-.23	-.64	-.04	.20	.69
C	-.92	-.80	-.42	-.11	/	-.77	1.0	.76	1.0	-.60	-.31	.08	.51	0.0	-.35	-.64
TA	-.69	-.50	-.44	-.53	/	-.77	.76	1.0	.76	-.07	-.08	.32	.64	0.0	-.35	-.64
RCTA	-.92	-.80	-.42	-.11	/	-.77	1.0	.76	1.0	-.60	-.31	.09	.51	0.0	-.18	-.61
L	.62	.18	.33	-.18	/	.51	-.60	-.07	-.60	1.0	.41	.16	-.14	-.02	-.22	.31
RW	.22	.04	-.05	-.10	/	.18	-.31	-.08	-.31	.41	1.0	-.06	-.03	.33	-.31	.39
VW	.05	.18	.01	-.30	/	-.23	.08	.32	.09	.16	-.06	1.0	.44	-.11	-.06	-.32
E	-.49	-.62	-.40	-.61	/	-.64	.51	.64	.51	-.14	-.03	.44	1.0	-.12	-.40	-.40
GRA	-.01	-.26	.07	.08	/	-.04	0.0	0.0	0.0	-.02	.33	-.11	-.12	1.0	-.15	.20
SD	.28	.54	.27	.58	/	.20	-.35	-.35	-.18	-.22	-.31	-.06	-.40	-.15	1.0	-.21
FL	.52	.06	.30	-.23	/	.69	-.64	-.64	-.61	.31	.39	-.32	-.40	.20	-.21	1.0

TABLE D7 : CORRELATIONS BETWEEN ENTRY SPEEDS AND INDEPENDENT VARIABLES FOR SELECTED SITES DUAL CARRIAGEWAYS (85TH PERCENTILE)

V_{PCE}	V_{HGE}	AS_{PC}	AS_{HG}	DS	R	C	TA	RCTA	L	RW	VW	E	GRA	SD	FL
1.0	/	.85	/	/	.55	-.73	-.16	-.73	.37	.23	.72	-.18	-.50	.83	.08
/	1.0	/	.86	/	.74	-.89	-.47	-.89	.32	-.08	.44	-.53	-.05	.19	.12
.85	/	1.0	/	/	.30	-.39	.13	-.39	.38	.41	.77	.18	-.60	.68	-.36
/	.86	/	1.0	/	.49	-.56	-.37	-.56	.18	.20	.62	-.09	-.26	-.10	-.06
/	/	/	/	1.0	/	/	/	/	/	/	/	/	/	/	/
.55	.74	.30	.49	/	1.0	-.82	-.39	-.82	.25	-.10	.07	-.70	.10	.64	.39
-.73	-.89	-.39	-.56	/	-.82	1.0	.44	1.0	-.32	.25	-.24	.73	.08	-.63	-.32
-.16	-.47	.13	-.37	/	-.39	.44	1.0	.44	.67	-.05	-.03	.54	-.35	-.24	.44
-.73	-.89	-.39	-.56	/	-.82	1.0	.44	1.0	-.32	.25	-.24	.73	.08	-.63	-.32
.37	.32	.38	.18	/	.25	-.32	.67	-.32	1.0	-.29	.06	-.06	-.36	.27	.80
.23	-.08	.41	.20	/	-.10	.25	-.05	.25	-.29	1.0	.31	.37	.05	.13	-.47
.72	.44	.77	.62	/	.07	-.24	-.03	-.24	.06	.31	1.0	.42	-.65	.53	-.31
-.18	-.53	.18	-.09	/	-.70	.73	.54	.73	-.06	.37	.42	1.0	-.39	-.29	-.29
-.50	-.05	-.60	-.26	/	.10	.08	-.35	.08	-.36	.05	-.65	-.39	1.0	-.45	-.08
.83	.19	.68	-.10	/	.64	-.63	-.24	-.63	.27	.13	.53	-.29	-.45	1.0	.05
.08	.12	-.36	-.06	/	.39	-.32	.44	-.32	.80	-.47	-.31	-.29	-.08	.05	1.0

TABLE D8 : CORRELATIONS BETWEEN ENTRY SPEED AND INDEPENDENT VARIABLES FOR ALL STUDY SITES SINGLE AND DUAL CARRIAGEWAYS (85TH PERCENTILE)

	V_{PCE}	V_{HGE}	A_{PCE}	A_{HGE}	AS_{PC}	AS_{HG}	DS	R	C	TA	RCTA	L	RW	VW	E	GRA	SD	FL
$V_{PCE/M}$	1.0	/	/	/	.75	/	/	.72	-.80	-.43	-.80	.45	51	.30	-.22	-.03	.09	.45
$V_{HGE/M}$	/	1.0	/	/	/	.50	/	.48	-.71	-.26	-.71	.31	.14	.29	-.24	-.21	.26	.11
$A_{PCE/M}$	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
$A_{HGE/M}$	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
AS_{PC}	.75	/	/	/	1.0	/	/	.46	-.38	-.13	-.38	.41	.47	.33	-.03	-.03	.07	.32
AS_{HG}	/	.50	/	/	/	1.0	/	.25	-.15	-.18	-.15	.16	.18	.13	-.11	-.12	.32	-.04
DS	/	/	/	/	/	/	1.0	/	/	/	/	/	/	/	/	/	/	/
R	.72	.48	/	/	.46	.25	/	1.0	-.74	-.68	-.74	.21	-.29	-.13	-.52	.01	.11	.57
C	-.80	-.71	/	/	-.38	-.15	/	-.74	1.0	.64	1.0	-.32	-.32	-.01	.43	-.02	-.10	-.53
TA	-.43	-.26	/	/	-.13	-.18	/	-.68	.64	1.0	.64	.40	-.11	.27	.57	-.13	-.26	-.22
RCTA	-.80	-.71	/	/	-.38	-.15	/	-.74	1.0	.64	1.0	-.32	-.32	-.01	.43	-.02	-.10	-.53
L	.45	.31	/	/	.41	.16	/	.21	-.32	.40	-.32	1.0	.24	.25	.09	-.18	-.19	.53
RW	.51	.14	/	/	.47	.18	/	.29	-.32	-.11	-.32	.24	1.0	.09	.05	.25	-.28	.42
VW	.30	.29	/	/	.33	.13	/	-.13	-.01	.27	-.01	.25	.09	1.0	.37	-.21	-.09	-.21
E	-.22	-.24	/	/	-.03	-.11	/	-.52	.43	.57	.43	.09	.05	.37	1.0	-.09	-.33	-.27
GRA	-.03	-.21	/	/	-.03	-.12	/	.01	-.02	-.13	-.02	-.18	.25	-.21	-.09	1.0	-.09	-.33
SD	.09	.26	/	/	.07	.32	/	.11	-.10	-.26	-.10	-.19	-.28	-.09	-.33	-.09	1.0	-.26
FL	.45	.11	/	/	.32	-.04	/	.57	-.53	-.22	-.53	.53	.42	-.21	-.27	.33	-.26	1.0

TABLE D9 : CORRELATIONS BETWEEN MIDDLE SPEED AND LATERAL ACCELERATION AND INDEPENDENT VARIABLES FOR ALL STUDY SITES SINGLE AND DUAL CARRIAGEWAYS (85TH PERCENTILE)

V_{PCM}	V_{HGM}	A_{PCM}	A_{HGM}	AS_{PC}	AS_{HG}	DS	R	C	TA	RCTA	L	RW	VW	E	GRA	SD	FL
1.0	/	-.63	/	.69	/	/	.77	-.85	-.51	-.85	.40	.48	.23	-.30	-.04	.11	.48
/	1.0	/	-.37	/	.50	/	.59	-.76	-.36	-.76	.16	.18	.13	-.11	-.12	.32	-.04
-.63	/	1.0	/	-.21	/	/	-.86	.85	.74	.85	-.18	-.19	.25	.58	-.05	-.13	-.58
/	-.37	/	1.0	/	-.06	/	-.90	.77	.53	.77	-.15	-.03	.14	.60	.11	-.12	-.34
.69	/	-.21	/	1.0	/	/	.46	-.38	-.13	-.38	.41	.47	.33	-.03	-.03	.07	.32
/	.50	/	-.06	/	1.0	/	.26	-.25	-.18	-.15	.16	.18	.13	-.11	-.12	.32	-.04
/	/	/	/	/	/	1.0	/	/	/	/	/	/	/	/	/	/	/
.77	.59	-.86	-.90	.46	.25	/	1.0	-.74	-.68	-.74	.29	-.13	-.52	.01	.11	.57	-.03
-.85	-.76	.85	.77	-.38	-.15	/	-.74	1.0	.64	1.0	-.32	-.32	-.09	.43	-.02	-.10	-.53
-.51	-.36	.74	.53	-.13	-.18	/	-.68	.64	1.0	.64	.40	-.11	.27	.57	-.13	-.26	-.22
-.85	-.76	.85	.77	-.38	-.15	/	-.74	1.0	.64	1.0	-.32	-.32	-.09	.43	-.02	-.10	-.53
.40	.16	-.18	-.25	.41	.16	/	.29	-.32	.40	-.32	1.0	.24	.25	.09	-.18	-.19	.53
.48	.18	-.19	-.03	.47	.18	/	-.13	-.32	-.11	-.32	.24	1.0	.09	.05	.25	-.28	.42
.23	.13	.25	.14	.33	.13	/	-.52	-.09	.27	-.09	.25	-.09	1.0	.38	-.21	-.08	-.21
-.30	-.11	.58	.60	-.03	-.11	/	.01	.43	.57	.43	.09	.05	.38	1.0	-.09	-.33	-.27
-.04	-.12	-.05	.11	-.03	-.12	/	.11	-.02	-.13	-.02	-.18	.25	-.21	-.09	1.0	-.09	.03
.11	.32	-.13	-.12	.07	.32	/	.57	-.10	-.26	-.10	-.19	-.28	-.08	-.33	-.09	1.0	-.26
.48	-.04	-.58	-.34	.32	-.04	/	-.03	-.53	-.22	-.53	.53	.43	-.21	-.27	.03	-.26	1.0

TABLE D10 : CORRELATIONS BETWEEN MIDDLE SPEED AND LATERAL ACCELERATION AND INDEPENDENT VARIABLES FOR ALL STUDY SITES SINGLE CARRIAGEWAYS (85TH PERCENTILE)

	V_{PCM}	V_{HGM}	A_{PCM}	A_{HGM}	AS_{PC}	AS_{HG}	DS	R	C	TA	RCTA	L	RW	VW	E	GRA	SD	FL
V_{PCM}	1.0	/	-.72	/	.56	/	.72	.78	-.90	-.65	-.90	.48	.28	-0.1	-.40	-.02	.23	.52
V_{HGM}	/	1.0	/	-.40	/	.33	.44	.56	-.78	-.43	-.78	.17	.03	-.05	-.51	-.08	.38	.21
A_{PCM}	-.72	/	1.0	/	-.27	/	-.71	-.88	.87	.86	.87	-.25	-.31	.28	.58	-.02	-.14	-.70
A_{HGM}	/	-.40	/	1.0	/	-.11	-.67	-.93	.77	.71	.77	-.03	-.26	.20	.63	.12	.03	-.70
AS_{PC}	.56	/	-.27	/	1.0	/	/	.46	-.35	-.29	-.35	.31	.02	.08	-.21	.12	.26	.21
AS_{HG}	/	.33	/	-.11	/	1.0	/	.22	-.06	-.35	-.06	-.14	-.14	-.30	-.41	-.02	.49	-.17
DS	.72	.44	-.71	-.67	/	/	1.0	.66	-.79	-.50	-.79	.44	.42	-.14	-.24	0.0	0.0	.63
R	.78	.56	-.88	-.93	.46	.22	.66	1.0	-.75	-.79	-.75	.21	.25	-.25	-.55	0.0	.16	.69
C	-.90	-.78	.87	.77	-.35	-.06	-.79	-.75	1.0	.74	1.0	-.44	-.32	.04	.47	0.0	-.15	-.60
TA	-.65	-.43	.86	.71	-.29	-.35	-.50	-.79	.74	1.0	.74	.18	-.20	.38	.60	0.0	-.30	-.62
RCTA	-.90	-.78	.87	.77	-.35	-.06	-.79	-.75	1.0	.74	1.0	-.44	-.32	.04	.47	0.0	-.15	-.60
L	.48	.17	-.25	-.03	.31	-.14	.44	.21	-.44	.18	-.44	1.0	.20	.37	.03	0.0	-.22	.19
RW	.28	.03	-.31	-.26	.02	-.14	.42	.25	-.32	-.20	-.32	.20	1.0	-.09	-.12	.34	-.21	.38
VW	.10	-.05	.28	.20	.08	-.30	-.14	-.25	.04	.38	.04	.37	-.09	1.0	.39	0.0	-.09	-.32
E	-.40	-.51	.58	.63	-.21	-.41	-.24	-.55	.47	.60	.47	.03	-.12	.39	1.0	0.0	-.35	-.42
GRA	-.02	-.08	-.02	.12	.12	.01	0.0	0.0	0.0	0.0	0.0	0.0	.34	0.0	0.0	1.0	-.09	.06
SD	.23	.38	-.14	.03	.26	.49	0.0	.16	-.15	-.30	-.15	-.22	-.21	-.09	-.35	-.09	1.0	-.22
FL	.52	.21	-.70	-.70	.21	-.17	.63	.69	-.60	-.62	-.60	.19	.38	-.32	-.42	.06	-.22	1.0

TABLE D11 : CORRELATIONS BETWEEN MIDDLE SPEED AND LATERAL ACCELERATION AND INDEPENDENT VARIABLES FOR ALL STUDY SITES DUAL CARRIAGEWAYS (85TH PERCENTILE)

V_{PCM}	V_{HGM}	A_{PCM}	A_{HGM}	AS_{PC}	AS_{HG}	DS	R	C	TA	RCTA	L	RW	VW	E	CRA	SD	FL
1.0	/	-.49	/	.72	/	.26	.77	-.82	-.40	-.82	.19	.21	.44	-.32	-.30	.44	.01
/	1.0	/	-.32	/	.82	.08	.73	-.75	-.39	-.78	.32	.03	.50	-.20	-.50	.17	.05
-.49	/	1.0	/	-.04	/	-.33	-.87	.80	.45	.80	-.14	.18	.21	.68	-.15	-.31	-.36
/	-.32	/	1.0	/	.01	-.25	-.82	.79	.23	.79	-.43	.59	.02	.59	.09	-.45	-.40
.72	/	-.04	/	1.0	/	/	.38	-.36	.09	-.35	.34	.35	.74	.15	-.54	.22	.02
/	.82	/	.01	/	1.0	/	.44	-.43	-.20	-.43	.51	-.29	.19	-.39	-.38	.41	.28
.26	.08	-.35	-.25	/	/	1.0	.44	-.23	.14	-.23	.40	.06	.12	-.16	-.20	-.17	.54
.77	.73	-.87	-.82	.38	.44	.44	1.0	-.82	-.47	-.82	.13	.14	.05	-.57	-.03	.36	.21
-.82	-.75	.80	.79	-.36	-.43	-.23	-.82	1.0	.52	1.0	-.19	.07	-.14	.64	.03	-.42	-.20
-.40	-.39	.45	.23	.09	-.20	.14	-.47	.52	1.0	.52	.71	-.25	.08	.52	-.39	-.40	.49
-.82	-.76	.80	.79	-.35	-.43	-.23	-.82	1.0	.52	1.0	-.19	.07	-.24	.64	.03	-.42	-.20
.19	.32	-.14	-.43	.34	.51	.40	.13	-.19	.71	-.19	1.0	-.37	.12	.09	-.46	-.14	.80
.21	.03	.18	.59	.35	-.29	.06	.14	.07	-.25	.07	-.37	1.0	.23	.18	.05	.27	-.44
.44	.50	.21	.02	.74	.19	.12	.05	-.14	.08	-.14	.12	.23	1.0	.33	-.59	.08	-.22
-.32	-.20	.68	.59	.15	-.39	-.16	-.57	.64	.52	.64	.09	.18	.33	1.0	-.33	-.30	-.13
-.30	-.50	-.15	.09	-.54	-.38	-.20	-.03	.03	-.39	.03	-.46	.05	-.59	-.33	1.0	-.13	-.16
.44	.17	-.31	-.45	.22	.41	-.17	.36	-.42	-.40	-.42	-.14	.27	.08	-.30	.13	1.0	-.22
.01	-.05	-.36	-.40	.02	.28	.54	.21	-.20	.49	-.20	.80	-.44	-.22	-.13	-.16	-.22	1.0

TABLE D12 : CORRELATIONS BETWEEN MIDDLE SPEED AND LATERAL ACCELERATION AND INDEPENDENT VARIABLES FOR SELECTED SITES SINGLE CARRIAGEWAYS (85TH PERCENTILE)

	V_{PCM}	V_{HGM}	A_{PCM}	A_{HGM}	AS_{PC}	AS_{HG}	DS	R	C	TA	RCTA	L	RW	VW	E	GRA	SD	FL
V_{PCM}	1.0	/	-.81	/	.58	/	/	.83	-.93	-.73	-.93	.58	.21	-.01	-.51	-.04	.30	.53
V_{HGM}	/	1.0	/	-.56	/	.41	/	.67	-.87	-.52	-.87	.21	.09	.27	-.62	-.25	.51	.07
A_{PCM}	-.81	/	1.0	/	-.38	/	/	-.77	.90	.85	.90	-.52	-.30	.23	.62	0.0	-.17	-.61
A_{HGM}	/	-.56	/	1.0	/	-.23	/	-.82	.81	.78	.81	-.11	-.35	-.45	.51	-.10	.01	-.56
AS_{PC}	.58	/	-.38	/	1.0	/	/	.54	-.41	-.44	-.41	.32	-.08	.02	-.42	.05	.28	.28
AS_{HG}	/	.41	/	-.23	/	1.0	/	-.36	-.11	-.53	-.11	-.18	-.09	-.30	-.61	.08	.58	-.23
DS	/	/	/	/	/	/	1.0	/	/	/	/	/	/	/	/	/	/	/
R	.83	.67	-.77	-.82	.54	.36	/	1.0	-.77	-.77	-.77	.50	.18	-.23	-.64	-.04	.20	.69
C	-.93	-.87	.90	.81	-.41	-.11	/	-.77	1.0	.76	1.0	-.60	-.31	.09	.51	0.0	-.18	-.61
TA	-.73	-.52	.85	.78	-.44	-.53	/	-.77	.76	1.0	.76	-.07	-.08	.32	.64	0.0	-.35	-.64
RCTA	-.93	-.87	.90	.81	-.41	-.11	/	-.77	1.0	.76	1.0	-.60	-.31	.09	.51	0.0	-.18	-.61
L	.58	.21	-.52	-.11	.32	-.18	/	.50	-.60	-.07	-.60	1.0	.41	.16	-.15	-.02	-.22	.31
RW	.21	.09	-.30	-.35	-.08	-.09	/	.18	-.31	-.08	-.31	.41	1.0	-.06	-.04	.33	-.31	.39
VW	-.01	.27	.23	-.45	.02	-.30	/	-.23	.09	.32	.09	.16	-.06	1.0	.44	-.11	-.06	-.32
E	-.51	-.62	.62	.51	-.42	-.61	/	-.64	.51	.64	.51	-.15	-.04	.44	1.0	-.12	-.40	-.40
GRA	-.04	-.25	0.0	-.10	.05	.08	/	-.04	0.0	0.0	0.0	-.02	.33	-.22	-.12	1.0	-.15	.20
SD	.30	.51	-.17	.01	.28	.58	/	.20	-.18	-.35	-.18	-.22	-.31	-.06	-.40	-.15	1.0	-.21
FL	.53	.07	-.61	-.56	.28	-.23	/	.69	-.61	-.64	-.61	.31	.39	-.32	-.40	.20	-.21	1.0

TABLE D13 : CORRELATIONS BETWEEN MIDDLE SPEED AND LATERAL ACCELERATION AND INDEPENDENT VARIABLES FOR SELECTED SITES DUAL CARRIAGEWAYS (85TH PERCENTILE)

V_{PCM}	V_{HGM}	A_{PCM}	A_{HGM}	AS_{PC}	AS_{HG}	DS	R	C	TA	RCTA	L	RW	VW	E	GRA	SD	FL
1.0	/	-.38	/	.74	/	/	.65	-.84	-.27	-.84	.36	.08	.59	-.38	-.42	.83	.15
/	1.0	/	-.34	/	.86	/	.64	-.83	-.46	-.83	.26	-.07	.52	-.49	-.20	.05	.02
-.38	/	1.0	/	0.0	/	/	-.89	.76	.35	.76	-.25	.43	.17	.76	-.22	-.34	-.52
/	-.34	/	1.0	/	-.13	/	-.90	.77	.18	.77	-.48	.59	-.10	.63	-.03	-.59	-.45
.74	/	0.0	/	1.0	/	/	.30	-.39	.13	-.39	.38	.41	.77	.18	-.60	.68	.09
/	.86	/	-.13	/	1.0	/	.49	-.56	-.37	-.56	.18	.20	.62	-.09	-.26	-.10	.06
/	/	/	/	/	/	1.0	/	/	/	/	/	/	/	/	/	/	/
.65	.64	-.89	-.90	.30	.49	/	1.0	-.82	-.39	-.82	.25	-.10	.08	-.70	.10	.64	.39
-.84	-.83	.76	.77	-.39	-.56	/	-.82	1.0	.44	1.0	-.32	.25	-.24	.73	.08	.63	-.32
-.27	-.46	.35	.18	.13	-.37	/	-.39	.44	1.0	.44	.67	-.05	-.03	.54	-.35	-.24	.44
-.84	-.83	.76	.77	-.39	-.56	/	-.82	1.0	.44	1.0	-.32	.25	-.24	.73	.08	-.63	-.32
.36	.26	-.25	-.48	.38	.28	/	.25	-.32	.67	-.32	1.0	-.29	.06	.06	-.36	.27	.80
.08	-.07	.43	.59	.41	.20	/	-.10	.25	-.05	.25	-.29	1.0	.31	.37	.05	.13	-.47
.59	.52	.17	-.10	.77	.62	/	.08	-.24	-.03	-.24	.06	.31	1.0	.42	-.65	.53	-.31
-.38	-.49	.76	.63	.18	-.09	/	-.70	.73	.54	.73	.06	.37	.42	1.0	-.39	-.29	-.29
-.42	-.20	-.22	-.03	-.60	-.26	/	.10	.08	-.35	.08	-.36	.05	-.65	-.39	1.0	-.45	-.08
.83	.05	-.34	-.59	.68	-.10	/	.64	.63	-.24	-.63	.27	.13	.53	-.29	-.45	1.0	.05
.15	.02	-.52	-.45	.09	.06	/	.39	-.32	.44	-.32	.80	-.47	-.31	-.29	-.08	.05	1.0

TABLE D14 . REGRESSION RELATIONSHIPS FOR ALL CAR ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{CE}(85)$	R	33.23+0.05R+0.047L+0.27AS+1.0VW+0.005SD r^2 = 0.79/s = 4.96	10.76+0.644AS+0.034R+0.04L r^2 = 0.82/s = 4.78	52.69+0.053R+1.07VW+0.06L+0.009SD r^2 = 0.79/s = 5.11
	C	43.28-0.65C+0.49AS+0.824VW r^2 = 0.89/s = 3.51	29.80-0.51C+0.64AS+0.63VW r^2 = 0.90/s = 3.60	45.32-0.726C+10.476AS+0.95VW r^2 = 0.91/s = 3.24
$V_{CE}(85)$	TA	24.88+0.615AS-10.81TA+1.73VW+1.59RW r^2 = 0.68/s = 6.10	6.08+0.91AS-7.80TA+1.14VW r^2 = 0.80/s = 5.14	85.83-14.73TA+2.245VW r^2 = 0.55/s = 7.14
	RCTA	43.28-1.126RCTA+0.49AS+0.824VW r^2 = 0.89/s = 3.51	29.80-0.886RCTA+0.64AS+0.63VW r^2 = 0.90/s = 3.60	45.32-1.27RCTA+0.476DS+0.95VW r^2 = 0.91/s = 3.24

* 56 Curves ** 28 Curves *** 28 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{CE}(85)$	R	58.87+0.06R+0.04L+1.10VW r^2 = 0.80/s = 4.65	16.78+0.56AS+0.036R+0.046L r^2 = 0.76/s = 5.86
	C	51.20-0.67C+0.37AS+0.95VW+0.009SD r^2 = 0.89/s = 3.60	37.93-0.606C+0.556AS+0.683VW r^2 = 0.92/s = 3.38
$V_{CE}(85)$	TA	39.43-11.55TA+1.98VW+2.13RW+0.41AS r^2 = 0.64/s = 6.41	22.74+0.73AS-10.23TA+1.32TA r^2 = 0.74/s = 6.06
	RCTA	51.20-1.17RCTA+0.37AS+0.95VW+0.009SD r^2 = 0.89/s = 3.60	37.93-1.06RCTA+0.556AS+0.683VW r^2 = 0.92/s = 3.38

* 29 Curves ** 27 Curves

TABLE D15 : REGRESSION RELATIONSHIPS FOR ALL CAR ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$V_{CE}(85)$	R	8.38+0.75AS+0.03R+0.026SD r^2 = 0.87/s = 3.65	16.25+0.038R+0.667AS r^2 = 0.81/s = 4.35
	C	32.34+0.744AS-1.096C-0.005FL r^2 = 0.92/s = 2.80	26.90-1.06C+0.82AS-0.008FL r^2 = 0.95/s = 2.37
$V_{CE}(85)$	TA	0.635+1.005AS-5.396TA r^2 = 0.81/s = 4.28	-3.983+1.064AS-6.97TA r^2 = 0.83/s = 4.06
	RCTA	32.34+0.744AS-1.914RCTA-0.005FL r^2 = 0.92/s = 2.80	26.90-1.85RCTA+0.82AS-0.008FL r^2 = 0.95/s = 2.37

* 22 Curves ** 14 Curves

TABLE D16 : REGRESSION RELATIONSHIPS FOR FREE CAR ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{FCE}(85)$	R	25.714+0.05R+0.04L+0.31AS+1.02VW+0.006SD +1.26RW r^2 = 0.80/s = 5.21	7.07+0.696AS+0.037R+0.035L r^2 = 0.83/s = 5.03	52.48+0.056R+1.085VW+0.01SD +0.056L r^2 = 0.79/s = 5.31
	C	42.64-0.68C+0.515AS+0.73VW r^2 = 0.90/s = 3.65	26.35-0.523C+0.71AS r^2 = 0.90/s = 3.72	46.15-0.75C+0.476AS+0.914VW r^2 = 0.91/s = 3.48
$V_{FCE}(85)$	TA	32.74+0.626AS-12.23TA+1.70VW r^2 = 0.67/s = 6.48	-3.42+0.94AS-7.82TA+1.14VW+ 1.56RW r^2 = 0.83/s = 5.05	87.12-15.63TA+2.955VW r^2 = 0.57/s = 7.28
	RCTA	42.64-1.183RCTA+0.515AS+0.73VW r^2 = 0.90/s = 3.65	26.35-0.91RCTA+0.71AS r^2 = 0.90/s = 3.72	46.15-1.313RCTA+0.476AS+ 0.914VW r^2 = 0.91/s = 3.48

* 56Curves ** 28 Curves *** 28 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{FCE}(85)$	R	56.43+0.065R+0.036L+1.012VW r^2 = 0.78/s = 5.13	14.60+0.585AS+0.04R+0.044L r^2 = 0.76/s = 6.11
	C	50.31-0.70C+0.40AS+0.84VW+0.01SD r^2 = 0.88/s = 3.79	36.87-0.637C+0.583AS+0.61VW r^2 = 0.93/s = 3.43
$V_{FCE}(85)$	TA	39.23-12.16TA+1.93VW+2.34RW+0.415AS r^2 = 0.65/s = 6.64	22.26+0.75AS-11.02TA+1.324VW r^2 = 0.76/s = 6.17
	RCTA	50.31-1.22RCTA+0.40AS+0.84VW+0.01SD r^2 = 0.88/s = 3.79	36.87-1.113RCTA+0.583AS+0.61VW r^2 = 0.93/s = 3.43

* 29 Curves ** 27 Curves

TABLE D17 : REGRESSION RELATIONSHIPS FOR FREE CAR ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		All Curves *	Uphill Curves**
$V_{FCE}(85)$	R	11.32+0.746AS+0.032R r^2 = 0.83/s = 3.93	23.53+0.04R+0.593AS r^2 = 0.81/s = 4.20
	C	30.41+0.726AS-1.028C r^2 = 0.91/s = 2.97	34.02-1.023C+0.687AS r^2 = 0.94/s = 2.41
$V_{FCE}(85)$	TA	2.65+0.98AS-4.83TA r^2 = 0.79/s = 4.46	1.55+1.004AS-6.53TA r^2 = 0.81/s = 4.20
	RCTA	30.41+0.726AS-1.796RCTA r^2 = 0.91/s = 2.97	34.02-1.786RCTA+0.687AS r^2 = 0.94/s = 2.41

* 22 Curves ** 14 Curves

TABLE D18 : REGRESSION RELATIONSHIPS FOR GOODS VEHICLE ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
V_{GE} (85)	R	58.11+0.03R+0.007SD+1.01VW r^2 = 0.41/s = 5.37	68.57+0.007SD r^2 = 0.31/s = 5.50	61.96+0.032R r^2 = 0.36/s = 5.82
	C	85.53-0.894C-0.014FL r^2 = 0.63/s = 4.17	68.57+0.007SD r^2 = 0.31/s = 5.50	77.80-0.76C r^2 = 0.81/s = 3.18
V_{GE} (85)	TA	69.08+0.006SD r^2 = 0.16/s = 6.20	68.57+0.007SD r^2 = 0.31/s = 5.50	————
	RCTA	85.53-1.56RCTA-0.014FL r^2 = 0.63/s = 4.17	68.57+0.007SD r^2 = 0.31/s = 5.50	77.80-1.32RCTA r^2 = 0.81/s = 3.18

* 31 Curves ** 14 Curves *** 17 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
V_{GE} (85)	R	22.52+0.66AS r^2 = 0.48/s = 3.84	————
	C	22.52+0.66AS r^2 = 0.48/s = 3.84	88.67-0.897C-0.02FL r^2 = 0.69/s = 5.03
V_{GE} (85)	TA	22.52+0.66AS r^2 = 0.48/s = 3.84	————
	RCTA	22.52+0.66AS r^2 = 0.48/s = 3.84	88.67-1.57RCTA-0.02FL r^2 = 0.69/s = 5.03

* 17 Curves ** 14 Curves

TABLE D19 : REGRESSION RELATIONSHIPS FOR GOODS VEHICLE ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
V_{GE} (85)	R	-14.67+0.86AS+0.045R r^2 = 0.91/s = 3.00	51.46+0.078R r^2 = 0.67/s = 6.61
	C	17.303+0.83AS-0.945C r^2 = 0.96/s = 1.89	18.85-0.915C+0.805AS r^2 = 1.00/s = 0.72
V_{GE} (85)	TA	-16.64+1.17AS r^2 = 0.70/s = 5.17	————
	RCTA	17.303+0.83AS-1.65RCTA r^2 = 0.96/s = 1.89	18.85-1.60RCTA+0.605AS r^2 = 1.00/s = 0.72

* 12 Curves ** 6 Curves

TABLE D20 : REGRESSION RELATIONSHIPS FOR ALL CAR ENTRY SPEEDS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{CE}(85)$	R	8.98+0.046R+0.04L+1.253VW+0.006SD+0.52DS r^2 = 0.79/s = 4.97	54.11+0.06R+0.05L+1.07VW r^2 = 0.75/s = 5.68	-24.49+0.056R+1.58VW+1.00DS -0.013FL r^2 = 0.77/s = 5.30
	C	80.46-0.666C+0.74VW+0.005SD+0.025L r^2 = 0.82/s = 4.57	82.28-0.66C+0.034L r^2 = 0.77/s = 5.31	85.57-0.74C+1.026VW r^2 = 0.82/s = 4.55
$V_{CE}(85)$	TA	-23.77+1.146DS-9.61TA+2.046VW r^2 = 0.69/s = 5.99	-24.50+1.154DS-9.29TA+1.975VW r^2 = 0.64/s = 6.83	-23.03+1.14DS-9.93TA+2.116VW r^2 = 0.74/s = 5.58
	RCTA	84.58-1.28RCTA+1.03VW+0.004SD r^2 = 0.81/s = 4.71	85.96-1.314RCTA+0.945VW r^2 = 0.77/s = 5.32	85.57-1.29RCTA+1.026VW r^2 = 0.82/s = 4.55

* 56 Curves ** 28 Curves *** 28 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{CE}(85)$	R	65.034+0.062R r^2 = 0.64/s = 6.07	-4.42+0.04R+0.05L+0.007SD+1.36VW+0.66DS r^2 = 0.78/s = 5.78
	C	83.19-0.712C+0.866VW+0.012SD r^2 = 0.85/s = 4.12	85.24-0.768C+1.22VW r^2 = 0.78/s = 5.39
$V_{CE}(85)$	TA	-14.01+1.05DS-9.85TA+1.805VW r^2 = = 0.71/s = 5.68	-34.93+1.256DS+2.305VW-9.32TA r^2 = 0.68/s = 6.72
	RCTA	83.19-1.244RCTA+0.866VW+0.012SD r^2 = 0.85/s = 4.12	85.24-1.342RCTA+1.22VW r^2 = 0.78/s = 5.39

* 29 Curves ** 27 Curves

TABLE D21 : REGRESSION RELATIONSHIPS FOR ALL CAR ENTRY SPEEDS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$V_{CE}(85)$	R	69.97+0.05R+1.82VW r^2 = 0.76/s = 4.81	67.89+0.005R+2.71VW r^2 = 0.80/s = 4.49
	C	73.60-1.422C+1.41VW+3.27RW r^2 = 0.82/s = 4.25	74.39-1.315C+2.48VW+2.67RW r^2 = 0.90/s = 3.33
$V_{CE}(85)$	TA	78.00+1.82VW+0.06SD r^2 = 0.49/s = 7.02	———
	RCTA	73.60-2.48RCTA+1.41VW+3.27RW r^2 = 0.82/s = 4.25	74.39-2.30RCTA+2.48VW+2.67RW r^2 = 0.90/s = 3.33

* 22 Curves ** 14 Curves

TABLE D22 : REGRESSION RELATIONSHIPS FOR FREE CAR ENTRY SPEEDS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{FCE}(85)$	R	-1.78+0.05R+0.04L+0.007SD+1.26VW+0.65DS r^2 = 0.79/s = 5.28	56.18+0.06R+0.066L r^2 = 0.72/s = 6.27	4.7+0.046R+1.285VW+0.57DS+ 0.009SD+0.04L r^2 = 0.81/s = 5.10
	C	82.54-0.72C+0.693VW+0.005SD+0.02L r^2 = 0.81/s = 4.90	90.36-0.80C r^2 = 0.76/s = 5.74	84.96-0.75C+1.04VW+0.005SD r^2 = 0.84/s = 4.59
$V_{FCE}(85)$	TA	-30.63+1.24DS-10.23TA+2.034VW r^2 = 0.70/s = 6.12	-81.36+1.76DS r^2 = 0.47/s = 8.43	-25.76+1.18DS-10.65TA+2.16VW r^2 = 0.75/s = 5.63
	RCTA	86.15-1.35RCTA+0.944VW+0.004SD r^2 = 0.80/s = 4.98	90.36-1.40RCTA r^2 = 0.76/s = 5.74	84.96-1.304RCTA+1.04VW+ 0.005SD r^2 = 0.84/s = 4.59

* 56 Curves ** 28 Curves *** 28 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{FCE}(85)$	R	56.43+0.065R+0.036L+1.01VW r^2 = 0.78/s = 5.13	40.6+0.062R+0.082L+0.01SD+168.47E r^2 = 0.75/s = 6.41
	C	89.71-0.754C r^2 = 0.79/s = 4.79	86.90-0.82C+1.173VW r^2 = 0.79/s = 5.69
$V_{FCE}(85)$	TA	-19.51+1.126DS-10.21TA+1.725VW r^2 = 0.71/s = 5.87	-43.58+1.366DS+2.37VW-10.19TA r^2 = 0.71/s = 6.77
	RCTA	89.71-1.316RCTA r^2 = 0.79/s = 4.79	86.90-1.43RCTA+1.73VW r^2 = 0.79/s = 5.69

* 29 Curves ** 27 Curves

TABLE D23 : REGRESSION RELATIONSHIPS FOR FREE CAR ENTRY SPEEDS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$V_{FCE}(85)$	R	71.18+0.05R+1.72VW r^2 = 0.75/s = 4.80	69.67+0.05R+2.333VW r^2 = 0.79/s = 4.42
	C	68.44-1.366C+1.20VW+3.76RW+0.012L r^2 = 0.84/s = 4.07	93.44-1.264C+2.69VW r^2 = 0.87/s = 3.48
$V_{FCE}(85)$	TA	85.81+1.82VW r^2 = 0.30/s = 7.86	———
	RCTA	76.96-2.54RCTA+0.865VW+3.27RW+0.59GRA r^2 = 0.84/s = 4.13	93.44-2.21RCTA+2.69VW r^2 = 0.87/s = 3.48

* 22 Curves ** 14 Curves

TABLE D24 : REGRESSION RELATIONSHIPS FOR GOODS VEHICLE ENTRY SPEEDS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{GE}(85)$	R	58.11+0.03R+0.007SD+1.01VW r^2 = 0.41/s = 5.37	68.57+0.007SD r^2 = 0.31/s = 5.50	-36.08+1.154DS r^2 = 0.50/s = 5.18
	C	85.53-0.894C-0.014FL r^2 = 0.63/s = 4.17	68.57+0.007SD r^2 = 0.31/s = 5.50	77.80-0.757C r^2 = 0.81/s = 3.18
$V_{GE}(85)$	TA	-0.746+0.007SD+0.75DS r^2 = 0.32/s = 5.66	68.57+0.007SD r^2 = 0.31/s = 5.50	-36.08+1.154DS r^2 = 0.50/s = 5.18
	RCTA	85.53-1.56RCTA-0.014FL r^2 = 0.63/s = 4.17	68.57+0.007SD r^2 = 0.31/s = 5.50	77.80-1.32RCTA r^2 = 0.81/s = 3.18

* 31 Curves ** 14 Curves *** 17 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
V_{GE} (85)	R	69.014+0.007SD r^2 = 0.35/s = 4.30	-49.09+1.29DS r^2 = 0.46/s = 6.33
	C	77.37-0.785C r^2 = 0.40/s = 4.12	88.67-0.90C-0.02FL r^2 = 0.69/s = 5.03
V_{GE} (85)	TA	69.014+0.007SD r^2 = 0.35/s = 4.30	-49.09+1.29DS r^2 = 0.46/s = 6.33
	RCTA	77.37-1.37RCTA r^2 = 0.40/s = 4.12	88.67-1.57RCTA-0.002FL r^2 = 0.69/s = 5.03

* 17 Curves ** 14 Curves

TABLE D25 : REGRESSION RELATIONSHIPS FOR GOODS VEHICLE ENTRY SPEEDS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
V_{GE} (85)	R	55.83+0.07R r^2 = 0.60/s = 5.95	51.46+0.078R r^2 = 0.67/s = 6.61
	C	50.07-2.03C+214.96E+3.82RW r^2 = 0.89/s = 3.45	70.86-1.04C+5.62VW r^2 = 0.98/s = 2.02
V_{GE} (85)	TA	———	———
	RCTA	50.07-3.55RCTA+214.96E+8.82RW r^2 = 0.89/s = 3.45	70.86-1.82RCTA+5.62VW r^2 = 0.98/s = 2.02

* 12 Curves ** 6 Curves

TABLE D26 : REGRESSION RELATIONSHIPS FOR ALL SELECTED CAR ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves	Left-Hand Curves**	Right-Hand Curves***
$V_{CE}(85)$	R	30.54+0.04R+0.07L+0.006SD+0.314AS r^2 = 0.77/s = 5.74	-21.68+1.064AS+0.06L r^2 = 0.87/s = 4.42	63.12+0.07R r^2 = 0.61/s = 7.33
	C	46.06-0.64C+0.456AS+0.71VW r^2 = 0.93/s = 3.19	21.76-0.393C+0.67AS+0.03L r^2 = 0.97/s = 2.28	45.79-0.734C+0.435AS+2.12VW r^2 = 0.95/s = 2.91
$V_{CE}(85)$	TA	22.86-11.67TA+0.594AS+1.48VW+2.78RW r^2 = 0.70/s = 6.56	-38.29+1.3AS r^2 = 0.79/s = 5.31	91.93-16.07TA-1.05GRA r^2 = 0.66/s = 7.03
	RCTA	46.06-1.115RCTA+0.456AS+0.71VW r^2 = 0.93/s = 3.19	21.18-0.79RCTA+0.74AS r^2 = 0.95/s = 2.68	45.79-1.28RCTA+0.435AS+2.12VW r^2 = 0.95/s = 2.91

* 37 Curves ** 19 Curves *** 18 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{CE}(85)$	R	57.55+0.05R+0.06L r^2 = 0.74/s = 5.83	6.63+0.73AS+0.043R r^2 = 0.72/s = 6.85
	C	59.05-0.644C+0.294AS+0.01SD r^2 = 0.91/s = 3.46	38.05+0.59C+0.57AS r^2 = 0.94/s = 3.13
$V_{CE}(85)$	TA	90.36-13.69TA r^2 = 0.50/s = 7.77	10.46+0.89AS-8.55TA r^2 = 0.72/s = 6.78
	RCTA	59.05-1.125RCTA+0.294AS+0.01SD r^2 = 0.91/s = 3.46	38.05-1.034RCTA+0.57AS r^2 = 0.94/s = 3.13

* 19 Curves ** 18 Curves

TABLE D27 : REGRESSION RELATIONSHIPS FOR ALL SELECTED CAR ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$V_{CE}(85)$	R	0.247+0.93AS r^2 = 0.72/s = 5.22	61.28+0.274SD r^2 = 0.84/s = 3.86
	C	27.08+0.726AS-0.855C r^2 = 0.92/s = 3.00	61.28+0.274SD r^2 = 0.84/s = 3.86
$V_{CE}(85)$	TA	0.247+0.93AS r^2 = 0.72/s = 5.22	61.28+0.274SD r^2 = 0.84/s = 3.86
	RCTA	27.08+0.726AS-1.494RCTA r^2 = 0.92/s = 3.00	61.28+0.274SD r^2 = 0.84/s = 3.86

* 13 Curves ** 8 Curves

TABLE D28 : REGRESSION RELATIONSHIPS FOR SELECTED FREE CAR ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{FCE}(85)$	R	30.54+0.04R+0.07L+0.006SD+0.314AS r^2 = 0.77/s = 5.74	-21.68+1.064AS+0.06L r^2 = 0.87/s = 4.42	63.12+0.07R r^2 = 0.61/s = 7.33
	C	46.06-0.64C+0.456AS+0.71VW r^2 = 0.93/s = 3.19	21.76-0.39C+0.67AS+0.03L r^2 = 0.97/s = 2.28	45.8-0.73C+0.435AS+2.12VW r^2 = 0.95/s = 2.91
$V_{FCE}(85)$	TA	22.86-11.67TA+0.59AS+1.48VW+2.78RW r^2 = 0.70/s = 6.56	-38.29+1.37AS r^2 = 0.79/s = 5.31	91.93-16.07TA-1.05GRA r^2 = 0.66/s = 7.03
	RCTA	46.06-1.115RCTA+0.456AS+0.71VW r^2 = 0.93/s = 3.19	21.18-0.79RCTA+0.74AS r^2 = 0.95/s = 2.68	45.8-1.28RCTA+0.435AS+2.12VW r^2 = 0.95/s = 2.91

* 37 Curves ** 19 Curves *** 18 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{FCE}(85)$	R	57.55+0.05R+0.06L r^2 = 0.74/s = 5.83	6.63+0.73AS+0.043R r^2 = 0.72/s = 6.85
	C	59.05-0.644C+0.294AS+0.01SD r^2 = 0.91/s = 3.46	38.05-0.59C+0.57AS r^2 = 0.94/s = 3.13
$V_{FCE}(85)$	TA	90.36-13.69TA r^2 = 0.50/s = 7.77	10.46+0.89AS-8.55TA r^2 = 0.72/s = 6.78
	RCTA	59.05-1.125RCTA+0.294AS+0.01SD r^2 = 0.91/s = 3.46	38.05-1.034RCTA+0.57AS r^2 = 0.94/s = 3.13

* 19 Curves ** 18 Curves

TABLE D29 : REGRESSION RELATIONSHIPS FOR SELECTED FREE CAR ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$V_{FCE}(85)$	R	4.21+0.89AS r^2 = 0.70/s = 5.24	63.33+0.263SD r^2 = 0.80/s = 4.23
	C	33.03+0.673AS-0.866C r^2 = 0.92/s = 2.83	63.33+0.263SD r^2 = 0.80/s = 4.23
$V_{FCE}(85)$	TA	4.21+0.89AS r^2 = 0.70/s = 5.24	63.33+0.263SD r^2 = 0.80/s = 4.23
	RCTA	33.03+0.673AS-1.55RCTA r^2 = 0.92/s = 2.83	63.33+0.26SD r^2 = 0.80/s = 4.23

* 13 Curves ** 8 Curves

TABLE D30 : REGRESSION RELATIONSHIPS FOR SELECTED GOODS VEHICLE ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
V_{GE} (85)	R	46.26+0.04R+0.01SD+0.06L r^2 = 0.76/s = 4.48	-41.03+1.49AS r^2 = 0.88/s = 2.88	———
	C	72.90-0.68C+0.006SD r^2 = 0.80/s = 3.95	-41.03+1.49AS r^2 = 0.88/s = 2.88	76.58-0.74C r^2 = 0.87/s = 3.60
V_{GE} (85)	TA	———	-41.03+1.49AS r^2 = 0.88/s = 2.88	———
	RCTA	72.90-1.19RCTA+0.006SD r^2 = 0.80/s = 3.95	-41.03+1.49AS r^2 = 0.88/s = 2.88	76.58-1.293RCTA r^2 = 0.87/s = 3.60

* 16 Curves ** 8 Curves *** 8 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
V_{GE} (85)	R	7.89+0.814AS+0.004SD r^2 = 0.90/s = 2.09	———
	C	7.89+0.814AS+0.004SD r^2 = 0.90/s = 2.09	———
V_{GE} (85)	TA	7.89+0.814AS+0.004SD r^2 = 0.90/s = 2.09	85.63-36.66TA r^2 = 0.92/s = 3.97
	RCTA	7.89+0.814AS+0.004SD r^2 = 0.90/s = 2.09	———

* 11 Curves ** 5 Curves

TABLE D31 : REGRESSION RELATIONSHIPS FOR SELECTED GOODS VEHICLE ENTRY SPEEDS AGAINST APPROACH SPEED, CURVE GEOMETRY AND FLOW DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
V_{GE} (85)	R	-28.18+1.294AS r^2 = 0.75/s = 4.71	———
	C	17.96-0.865C+0.805AS r^2 = 0.98/s = 1.32	———
V_{GE} (85)	TA	-28.18+1.294AS r^2 = 0.75/s = 4.72	———
	RCTA	17.96-1.51RCTA+0.805AS r^2 = 0.98/s = 1.32	———

* 9 Curves ** 5 Curves

TABLE D32 : REGRESSION RELATIONSHIPS FOR ALL CAR ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{CE}(85)$	R	25.74+0.035AS+0.05R+1.18VW+1.48RW+0.015L +0.004SD r^2 = 0.83/s = 4.92	7.42+0.71AS+0.04R+0.79VW r^2 = 0.87/s = 4.70	48.18+0.05R+1.50VW+2.48RW+ 0.009SD+0.02L r^2 = 0.80/s = 5.06
	C	34.86-0.64C+0.56AS+0.735VW+0.69RW r^2 = 0.91/s = 3.60	23.89+0.714AS-0.52C+0.555VW r^2 = 0.91/s = 3.95	36.25-0.753C+0.60AS+0.795VW r^2 = 0.91/s = 3.27
$V_{CE}(85)$	TA	14.30+0.828AS-8.16TA+1.01VW r^2 = 0.71/s = 6.27	-3.514+1.04AS-6.00TA r^2 = 0.83/s = 5.17	22.57+0.764AS-7.49TA r^2 = 0.49/s = 7.70
	RCTA	34.86-1.12RCTA+0.56AS+0.735VW+0.69RW r^2 = 0.91/s = 3.60	23.89+0.714AS-0.91RCTA+0.555VW r^2 = 0.91/s = 3.95	36.25-1.315RCTA+0.60AS+ 0.795VW r^2 = 0.91/s = 3.27

* 78 Curves ** 38 Curves *** 40 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{CE}(85)$	R	-3.42+0.054R+1.75RW+1.55VW+0.25AS r^2 = 0.81/s = 4.78	12.42+0.645AS+0.04R+0.93VW r^2 = 0.83/s = 5.57
	C	33.15-0.70C+0.625AS+0.88VW r^2 = 0.87/s = 3.85	31.28+0.596AS-0.59C+0.91RW+0.46VW r^2 = 0.93/s = 3.49
$V_{CE}(85)$	TA	18.45+0.78AS-9.71TA+1.60VW r^2 = 0.64/s = 6.37	2.62+0.98AS-5.935TA r^2 = 0.78/s = 6.22
	RCTA	33.15-1.23RCTA+0.625AS+0.88VW r^2 = 0.87/s = 3.85	31.28+0.596AS-1.03RCTA+0.91RW+0.46VW r^2 = 0.93/s = 3.49

* 43 Curves ** 35 Curves

TABLE D33 : REGRESSION EQUATIONS FOR ALL FREE CAR ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{FCE}(85)$	R	26.51+0.34AS+0.05R+1.09VW+1.54RW+0.02L+0.005SD r^2 = 0.82/s = 5.13	-0.24+0.843AS+0.04R r^2 = 0.85/s = 5.01	47.71+0.05R+1.39VW+2.52RW+0.01SD+0.02L r^2 = 0.81/s = 5.12
	C	35.88-0.675C+0.565AS+0.63VW+0.66RW r^2 = 0.91/s = = 3.64	19.97+0.79AS-0.53C r^2 = 0.91/s = 3.95	38.07-0.78C+0.59AS+0.74VW r^2 = 0.91/s = 3.41
$V_{FCE}(85)$	TA	7.87+0.93AS-7.20TA r^2 = 0.67/s = 6.76	-4.19+1.06AS-6.5TA r^2 = 0.84/s = 5.17	23.85+0.755AS-7.67TA r^2 = 0.49/s = 7.99
	RCTA	35.88-1.18RCTA+0.565AS+0.63VW+0.66RW r^2 = 0.91/s = 3.64	19.97+0.79AS-0.93RCTA r^2 = 0.91/s = 3.95	38.07-1.36RCTA+0.59AS+0.74VW r^2 = 0.91/s = 3.41

* 78 Curves ** 38 Curves *** 40 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{FCE}(85)$	R	52.53+0.06R+2.11RW+1.50VW r^2 = 0.77/s = 5.17	11.39+0.66AS+0.044R+0.835VW r^2 = 0.82/s = 5.81
	C	36.64-0.735C+0.60AS+0.72VW r^2 = 0.87/s = 3.86	28.04+0.65AS-0.60C+1.05RW r^2 = 0.93/s = 3.59
$V_{FCE}(85)$	TA	20.08+0.77AS-9.90TA+1.443VW r^2 = 0.62/s = 6.69	2.32+0.99AS-6.293TA r^2 = 0.78/s = 6.41
	RCTA	36.64-1.28RCTA+0.60AS+0.72VW r^2 = 0.87/s = 3.86	28.04+0.65AS-1.05RCTA+1.05RW r^2 = 0.93/s = 3.59

* 43 Curves ** 35 Curves

TABLE D34 : REGRESSION RELATIONSHIPS FOR GOODS VEHICLE ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{GE}(85)$	R	26.72+0.45AS+0.03R+0.94VW r^2 = 0.49/s = 5.53	-2.64+0.984AS r^2 = 0.53/s = 6.02	51.06+0.035R+1.01VW+1.47RW+0.005SD r^2 = 0.58/s = 4.66
	C	39.25-0.753C+0.49AS+0.524VW r^2 = 0.70/s = 4.23	20.71+0.74AS-0.62C r^2 = 0.63/s = 5.51	48.85-0.87C+0.315AS+123.23E r^2 = 0.85/s = 2.70
$V_{GE}(85)$	TA	22.92+0.65AS r^2 = 0.25/s = 6.49	-2.64+0.984AS r^2 = 0.53/s = 6.02	————
	RCTA	39.25-1.32RCTA+0.49AS+0.524VW r^2 = 0.70/s = 4.23	20.71+0.74AS-1.084RCTA r^2 = 0.63/s = 5.51	48.85-1.52RCTA+0.315AS+123.23E r^2 = 0.85/s = 2.70

* 43 Curves   ** 20 Curves   *** 23 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{GE}(85)$	R	9.88+0.823AS r^2 = 0.51/s = 4.73	59.07-1.82GRA+2.20RW r^2 = 0.46/s = 6.45
	C	30.04-0.68C+0.61AS+0.59VW r^2 = 0.78/s = 3.30	58.35-0.71C+307.45E-1.35GRA r^2 = 0.77/s = 4.36
$V_{GE}(85)$	TA	9.88+0.823AS r^2 = 0.51/s = 4.73	59.07-1.82GRA+2.20RW r^2 = 0.46/s = 6.45
	RCTA	30.04-1.19RCTA+0.61AS+0.59VW r^2 = 0.78/s = 3.30	58.35-1.244RCTA+307.45E-1.35GRA r^2 = 0.77/s = 4.36

* 23 Curves   ** 20 Curves

TABLE D35 : REGRESSION RELATIONSHIPS FOR ALL SELECTED CAR ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{CE}(85)$	R	26.95+0.31AS+0.05R+1.06VW+1.65RW+0.005SD +0.02L r^2 = 0.81/s = 5.45	-6.214+0.89AS+0.04R r^2 = 0.89/s = 4.43	57.93+0.07R+2.74VW r^2 = 0.63/s = 6.99
	C	40.74-0.645C+0.52AS+0.784VW r^2 = 0.93/s = 3.11	25.16+0.684AS-0.50C+0.49VW r^2 = 0.95/s = 2.98	47.26-0.734C+0.45AS+1.26VW r^2 = 0.94/s = 2.79
$V_{CE}(85)$	TA	5.05+0.936AS-6.83TA r^2 = 0.66/s = 7.02	-10.91+1.10AS-5.30TA r^2 = 0.86/s = 4.94	37.21-9.91TA+3.00RW-1.18GRA +0.44AS r^2 = 0.64/s = 7.31
	RCTA	40.74-1.13RCTA+0.52AS+0.784VW r^2 = 0.93/s = 3.11	25.16+0.648AS-0.87RCTA +0.49VW r^2 = 0.95/s = 2.98	47.26-1.28RCTA+0.45AS+1.26VW r^2 = 0.94/s = 2.79

* 50 Curves ** 25 Curves *** 25 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{CE}(85)$	R	52.39+0.06R+1.956RW+1.59VW r^2 = 0.72/s = 5.93	-3.16+0.863AS+0.04R r^2 = 0.79/s = 6.31
	C	41.19-0.68C+0.51AS+1.24VW r^2 = 0.91/s = 3.33	35.89-0.60C+0.58AS+0.61VW r^2 = 0.96/s = 2.98
$V_{CE}(85)$	TA	26.87+0.57AS-8.00TA+2.03RW r^2 = 0.59/s = 7.15	-2.90+1.03AS-6.08TA r^2 = 0.79/s = 6.44
	RCTA	41.19-1.19RCTA+0.51AS+1.24VW r^2 = 0.91/s = 3.33	35.89-1.04RCTA+0.58AS+0.61VW r^2 = 0.96/s = 2.98

* 27 Curves ** 23 Curves

TABLE D36 : REGRESSION RELATIONSHIPS FOR SELECTED FREE CAR ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{FCE}(85)$	R	27.07+0.30AS+0.05R+1.80RW+0.99VW+0.02L +0.005SD r^2 = 0.81/s = 5.46	-6.42+0.90AS+0.036R r^2 = 0.89/s = 4.40	46.97+0.05R+1.43VW+2.47RW +0.001SD+0.03L r^2 = 0.78/s = 5.94
	C	39.90-0.65C+0.535AS+0.72VW r^2 = 0.93/s = 3.21	18.11+0.78AS-0.464C r^2 = 0.95/s = 3.07	45.86-0.74C+0.47AS+1.19VW r^2 = 0.94/s = 3.00
$V_{FCE}(85)$	TA	4.15+0.945AS-6.60TA r^2 = 0.65/s = 7.13	-11.04+1.10AS-5.08TA r^2 = 0.86/s = 4.96	———
	RCTA	39.90-1.13RCTA+0.535AS+0.72VW r^2 = 0.93/s = 3.21	18.11+0.78AS-0.81RCTA r^2 = 0.95/s = 3.07	45.86-1.294RCTA+0.47AS+1.19VW r^2 = 0.94/s = 3.00

* 50 Curves   ** 25 Curves   *** 25 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{FCE}(85)$	R	56.22+0.06R+2.13RW r^2 = 0.69/s = 6.17	-4.10+0.88AS+0.04R r^2 = 0.79/s = 6.36
	C	41.39-0.69C+0.516AS+1.01VW r^2 = 0.91/s = 3.47	33.98-0.64C+0.58AS+1.72RW-0.006FL r^2 = 0.96/s = 2.92
$V_{FCE}(85)$	TA	19.27+0.776AS-7.50TA r^2 = 0.51/s = 7.77	-3.98+1.03AS-5.70TA r^2 = 0.78/s = 6.58
	RCTA	41.39-1.20RCTA+0.516AS+1.01VW r^2 = 0.91/s = 3.47	33.98-1.12RCTA+0.58AS+1.72RW-0.006FL r^2 = 0.96/s = 2.92

* 27 Curves   ** 23 Curves

TABLE D37 : REGRESSION RELATIONSHIPS FOR SELECTED GOODS VEHICLE ENTRY SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{GE}(85)$	R	2.61+0.77AS+0.035R r^2 = 0.59/s = 5.27	-42.14+1.49AS r^2 = 0.84/s = 3.92	63.96+2.25VW r^2 = 0.31/s = 7.00
	C	19.27-0.74C+0.76AS r^2 = 0.85/s = 3.43	-42.14+1.49AS r^2 = 0.84/s = 3.92	32.25-0.85C+0.50AS+147.42E r^2 = 0.92/s = 2.59
$V_{GE}(85)$	TA	32.41+0.61AS-218.28E+1.30VW r^2 = 0.59/s = 5.81	-42.14+1.49AS r^2 = 0.84/s = 3.92	63.96+2.25VW r^2 = 0.31/s = 7.00
	RCTA	19.27-1.29RCTA+0.76AS r^2 = 0.85/s = 3.43	-42.14+1.49AS r^2 = 0.84/s = 3.92	32.25-1.48RCTA+0.50AS+147.42E r^2 = 0.92/s = 2.59

* 25 Curves ** 12 Curves *** 13 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{GE}(85)$	R	-14.53+1.126AS r^2 = 0.74/s = 4.06	———
	C	18.60+0.76AS-0.59C r^2 = 0.85/s = 3.19	-17.76-0.84C+1.23AS r^2 = 0.93/s = 3.16
$V_{GE}(85)$	TA	-14.53+1.126AS r^2 = 0.74/s = 4.06	———
	RCTA	18.60+0.76AS-1.03RCTA r^2 = 0.85/s = 3.19	-17.76-1.46RCTA+1.23AS r^2 = 0.93/s = 3.16

* 16 Curves ** 9 Curves

TABLE D38 : CURVILINEAR REGRESSION RELATIONSHIPS FOR ENTRY SPEEDS AGAINST APPROACH SPEEDS AND CURVE GEOMETRY ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Cars*	Free Cars*	Goods Vehicles**
V(85)	R	$17.65+0.17R-0.0004R^2+0.46AS$ $r^2 = 0.80/s = 4.76$	$16.29+0.176R-0.0004R^2+0.47AS$ $r^2 = 0.81/s = 4.93$	$35.92+0.134R-0.0004R^2+0.213AS$ $r^2 = 0.39/s = 5.46$
	C	$48.69-0.86C+0.475AS+0.0004C^3$ $r^2 = 0.87/s = 3.84$	$48.04-0.89C+0.495AS+0.0004C^3$ $r^2 = 0.88/s = 3.88$	$41.98-0.023C^2+0.40AS+0.18C$ $r^2 = 0.62/s = 4.30$
V(85)	R	$52.96+0.19R-0.0004R^2$ $r^2 = 0.73/s = 5.55$	$52.60+0.196R-0.0004R^2$ $r^2 = 0.73/s = 5.79$	$51.15+0.137R-0.0004R^2$ $r^2 = 0.36/s = 5.49$
	C	$91.90-1.194C+0.0004C^3$ $r^2 = 0.79/s = 4.87$	$93.39-1.25C+0.0004C^3$ $r^2 = 0.80/s = 5.05$	$73.91-0.036C^2+0.0004C^4$ $r^2 = 0.55/s = 4.59$

* 56 Curves   ** 31 Curves

TABLE D39 : CURVILINEAR REGRESSION RELATIONSHIPS FOR ENTRY SPEEDS AGAINST APPROACH SPEEDS AND CURVE GEOMETRY ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Cars*	Free Cars*	Goods Vehicles**
V(85)	R	$1.53+0.754AS+0.096R-0.0004R^2$ $r^2 = 0.87/s = 3.60$	$3.813+0.73AS+0.102R-0.0004R^2$ $r^2 = 0.87/s = 3.54$	$-15.30+0.893AS+0.117R-0.0004R^2$ $r^2 = 0.95/s = 2.46$
	C	$26.62+0.757AS-0.96C-0.0004C^3$ $r^2 = 0.90/s = 3.11$	$29.77+0.73AS-0.967C-0.0004C^3$ $r^2 = 0.91/s = 3.05$	$18.75+0.833AS-1.23C+0.012C^2$ $r^2 = 0.97/s = 1.96$
V(85)	R	$65.45+0.13R-0.0004R^2$ $r^2 = 0.52/s = 6.80$	$65.68+0.136R-0.0004R^2$ $r^2 = 0.54/s = 6.52$	$50.35+0.117R-0.0004R^2$ $r^2 = 0.62/s = 6.14$
	C	$105.55-2.22C+0.03C^2$ $r^2 = 0.55/s = 6.57$	$106.43-2.24C+0.03C^2$ $r^2 = 0.58/s = 6.27$	$84.57-1.24C-0.0004C^4$ $r^2 = 0.68/s = 5.67$

* 22 Curves   ** 12 Curves

TABLE D40 : CURVILINEAR REGRESSION RELATIONSHIPS FOR SELECTED ENTRY SPEEDS AGAINST APPROACH SPEEDS AND CURVE GEOMETRY ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Cars*	Free Cars*	Goods Vehicles**
V(85)	R	$19.46+0.192R-0.0004R^2+0.41AS$ $r^2 = 0.85/s = 4.55$	$19.46+0.192R-0.0004R^2+0.41AS$ $r^2 = 0.85/s = 4.55$	$2.71+0.20R-0.0004R^2+0.553AS$ $r^2 = 0.70/s = 5.02$
	C	$53.06-0.83C+0.414AS+\underline{0.0004C^3}$ $r^2 = 0.92/s = 3.37$	$53.06-0.83C+0.414AS+\underline{0.0004C^3}$ $r^2 = 0.92/s = 3.37$	$-6.18+0.747C+0.973AS-0.035C^2$ $r^2 = 0.88/s = 3.18$
V(85)	R	$51.39+0.207R-0.0004R^2$ $r^2 = 0.80/s = 5.12$	$51.39+0.207R-0.0004R^2$ $r^2 = 0.80/s = 5.12$	$43.11+0.195R-0.0004R^2$ $r^2 = 0.59/s = 5.66$
	C	$91.30-1.13C+0.0004C^3$ $r^2 = 0.87/s = 4.17$	$91.30-1.13C+0.0004C^3$ $r^2 = 0.87/s = 4.17$	$76.32-0.816C+0.0004C^4$ $r^2 = 0.64/s = 5.33$

* 37 Curves ** 16 Curves

TABLE D41 : CURVILINEAR REGRESSION RELATIONSHIPS FOR SELECTED ENTRY SPEEDS AGAINST APPROACH SPEEDS AND CURVE GEOMETRY ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Cars*	Free Cars*	Goods Vehicles**
V(85)	R	$3.53+0.716AS+0.112R-0.0004R^2$ $r^2 = 0.86/s = 4.08$	$8.31+0.65AS+0.13R-0.0004R^2$ $r^2 = 0.87/s = 3.82$	$-23.39+0.96AS+0.16R-0.0004R^2$ $r^2 = 0.97/s = 1.97$
	C	$20.18+0.754AS-0.001C^3-\underline{0.20C}$ $r^2 = 0.94/s = 2.76$	$26.01+0.697AS-0.03C^2-\underline{0.0004C^3}$ $r^2 = 0.94/s = 2.68$	$17.73-0.001C^3+0.77AS-\underline{0.40C}$ $r^2 = 0.99/s = 1.16$
V(85)	R	$57.09+0.217R-0.0004R^2$ $r^2 = 0.53/s = 7.09$	$57.28+0.222R-0.0004R^2$ $r^2 = 0.59/s = 6.46$	$43.08+0.204R-\underline{0.0004R^2}$ $r^2 = 0.66/s = 5.93$
	C	$98.23-0.96C-\underline{0.013C^2}$ $r^2 = 0.54/s = 7.01$	$99.68-1.06C-\underline{0.01C^2}$ $r^2 = 0.59/s = 6.45$	$78.40-0.0004C^4-\underline{0.34C}$ $r^2 = 0.82/s = 4.29$

* 13 Curves ** 9 Curves

TABLE D42 : CURVILINEAR REGRESSION RELATIONSHIPS FOR ENTRY SPEEDS AGAINST APPROACH SPEEDS AND CURVE GEOMETRY ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Cars*	Free Cars*	Goods Vehicles**
V(85)	R	$3.87+0.656AS+0.144R-0.0004R^2$ $r^2 = 0.83/s = 4.81$	$4.24+0.645AS+0.152R-0.0004R^2$ $r^2 = 0.83/s = 4.85$	$13.75+0.504AS+0.137R-0.0004R^2$ $r^2 = 0.53/s = 5.25$
	C	$34.14-0.87C+0.654AS+0.0004C^3$ $r^2 = 0.87/s = 3.92$	$35.75-0.90C+0.646AS+0.0004C^3$ $r^2 = 0.90/s = 3.86$	$29.06-0.05C+0.60AS-0.02C^2$ $r^2 = 0.70/s = 4.22$
V(85)	R	$54.72+0.18R-0.0004R^2$ $r^2 = 0.64/s = 6.97$	$54.35+0.187R-0.0004R^2$ $r^2 = 0.66/s = 6.95$	$49.38+0.15R-0.0004R^2$ $r^2 = 0.39/s = 5.93$
	C	$97.56-1.767C+0.02C^2$ $r^2 = 0.69/s = 6.40$	$98.85-1.81C+0.02C^2$ $r^2 = 0.71/s = 6.33$	$77.89-0.68C-0.004C^2$ $r^2 = 0.51/s = 5.33$

* 78 Curves   ** 43 Curves

TABLE D43 : CURVILINEAR REGRESSION RELATIONSHIPS FOR SELECTED ENTRY SPEEDS AGAINST APPROACH SPEEDS AND CURVE GEOMETRY ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Cars*	Free Cars*	Goods Vehicles**
V(85)	R	$6.73+0.58AS+0.18R-0.0004R^2$ $r^2 = 0.86/s = 4.54$	$5.98+0.59AS+0.183R-0.0004R^2$ $r^2 = 0.86/s = 4.54$	$-11.30+0.75AS+0.20R-0.0004R^2$ $r^2 = 0.79/s = 4.17$
	C	$37.20-0.77C+0.60AS+\underline{0.0004C^3}$ $r^2 = 0.92/s = 3.51$	$36.76-0.765C+0.605AS+\underline{0.0004C^3}$ $r^2 = 0.92/s = 3.52$	$0.05+0.276C+0.933AS-0.025C^2$ $r^2 = 0.90/s = 2.92$
V(85)	R	$51.09+0.226R-0.0004R^2$ $r^2 = 0.73/s = 6.28$	$60.00+0.23R-0.0004R^2$ $r^2 = 0.73/s = 6.34$	$41.90+0.217R-0.0004R^2$ $r^2 = 0.58/s = 5.77$
	C	$94.24-1.233C+0.0004C^3$ $r^2 = 0.77/s = 5.71$	$94.56-1.24C+0.0004C^3$ $r^2 = 0.77/s = 5.78$	$79.49-1.017C+\underline{0.0004C^4}$ $r^2 = 0.62/s = 5.46$

* 50 Curves ** 25 Curves

TABLE D44 : REGRESSION RELATIONSHIPS FOR ALL CAR MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{CM}(85)$	R	44.87+0.069R+0.054L+1.06VW+0.0075SD r^2 = 0.77/s = 6.02	12.82+0.05R+0.482AS+0.045L r^2 = 0.80/s = 5.95	51.64+0.077R+1.799VW r^2 = 0.68/s = 7.00
	C	43.63-0.804C+0.46AS+0.627VW r^2 = 0.89/s = 4.12	37.68-0.713C+0.526AS r^2 = 0.88/s = 4.42	40.60-0.864C+0.51AS+0.764VW r^2 = 0.92/s = 3.69
$V_{CM}(85)$	TA	16.45-13.76TA+0.631AS+1.81VW+2.61RW-0.051GRA r^2 = 0.70/s = 6.99	-1.41+0.978AS-9.098TA r^2 = 0.71/s = 7.04	84.37-18.09TA+2.35VW r^2 = 0.60/s = 7.87
	RCTA	43.63-1.404RCTA+0.46AS+0.627VW r^2 = 0.89/s = 4.12	37.68-1.246RCTA+0.526AS r^2 = 0.88/s = 4.42	40.60-1.509RCTA+0.51AS+0.764VW r^2 = 0.92/s = 3.69

* 56 Curves ** 28 Curves *** 28 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{CM}(85)$	R	46.43+0.075R+0.045L+1.173VW r^2 = 0.79/s = 5.78	8.061+0.053R+0.634AS r^2 = 0.72/s = 7.00
	C	48.55-0.796C+0.331AS+0.017L+0.757VW+0.012SD r^2 = 0.90/s = 4.26	36.31-0.739C+0.559AS r^2 = 0.91/s = 3.84
$V_{CM}(85)$	TA	69.54-16.51TA+2.356VW+2.786RW r^2 = 0.64/s = 7.59	13.48+0.838AS-11.268TA r^2 = 0.70/s = 7.19
	RCTA	49.29-1.465RCTA+0.359AS+0.964VW+0.01SD r^2 = 0.89/s = 4.27	36.33-1.29RCTA+0.559AS r^2 = 0.91/s = 3.84

* 29 Curves ** 27 Curves

TABLE D45 : REGRESSION RELATIONSHIPS FOR ALL CAR MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$V_{CM}(85)$	R	7.43+0.051R+0.673AS r^2 = 0.80/s = 5.04	63.17+0.07R r^2 = 0.70/s = 6.20
	C	35.30-1.526C+0.657AS r^2 = 0.88/s = 3.85	37.95-1.488C+0.626AS r^2 = 0.90/s = 3.78
$V_{CM}(85)$	TA	-4.14+1.03AS-7.98TA r^2 = 0.73/s=5.89	-6.081+1.06AS-10.34TA r^2 = 0.77/s = 5.66
	RCTA	35.30-2.666RCTA+0.657AS r^2 = 0.85/s = 3.85	39.95-2.60RCTA+0.626AS r^2 = 0.90/s = 5.48

* 22 Curves ** 14 Curves

TABLE D46 : REGRESSION RELATIONSHIPS FOR FREE CAR MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{FCM}(85)$	R	39.60+0.07R+0.05L+0.008SD+1.12VW+1.49RW r^2 = 0.78/s = 6.17	5.75+0.063R+0.59AS+1.17VW r^2 = 0.79/s = 6.31	52.24+0.08R+1.72NW r^2 = 0.69/s = 7.04
	C	45.87-0.83C+0.446AS+0.565VW r^2 = 0.88/s = 4.39	35.33-0.724C+0.564AS r^2 = 0.87/s = 4.83	47.41-0.881C+0.44AS+0.67VW r^2 = 0.91/s = 3.93
$V_{FCM}(85)$	TA	35.22-15.49TA+0.57AS+1.80VW r^2 = 0.65/s = 7.63	2.91+0.92AS-11.86TA+1.22VW r^2 = 0.75/s = 6.92	85.61-18.41TA+2.28VW r^2 = 0.60/s = 7.97
	RCTA	45.87-1.445RCTA+0.446AS+0.565VW r^2 = 0.88/s = 4.39	35.33-1.264RCTA+0.564AS r^2 = 0.87/s = 4.83	47.41-1.54RCTA+0.44AS+0.67VW r^2 = 0.91/s = 3.93

* 56 Curves ** 28 Curves *** 28 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{FCM}(85)$	R	47.235+0.08R+1.214VW+0.04L r^2 = 0.79/s = 5.87	13.254+0.054R+0.506AS+0.04L r^2 = 0.75/s = 6.96
	C	53.92-0.866C+0.32AS+0.86VW+0.01SD r^2 = 0.88/s = 4.60	37.06+0.756C+0.56AS r^2 = 0.91/s = 4.04
$V_{FCM}(85)$	TA	70.024-17.186TA+2.33VW+3.033RW r^2 = 0.67/s = 7.47	13.88+0.84AS-11.19TA r^2 = 0.69/s = 7.54
	RCTA	53.92-1.51RCTA+0.32AS+0.86VW+0.01SD r^2 = 0.88/s = 4.60	37.06-1.32RCTA+0.56AS r^2 = 0.91/s = 4.04

* 29 Curves ** 27 Curves

TABLE D47 : REGRESSION RELATIONSHIPS FOR FREE CAR MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$V_{FCM}(85)$	R	9.83-0.05R+0.065AS r^2 = 0.80/s = 5.06	63.38+0.07R r^2 = 0.73/s = 6.02
	C	43.42-1.624C+0.625AS-0.006FL r^2 = 0.91/s = 3.41	44.45-1.55C+0.565AS r^2 = 0.91/s = 3.64
$V_{FCM}(85)$	TA	-3.73+1.03AS-8.01TA r^2 = 0.73/s = 5.82	-4.36+1.05AS-10.80TA r^2 = 0.78/s = 5.57
	RCTA	43.42-2.836RCTA+0.625AS-0.00FL r^2 = 0.91/s = 3.41	44.45-2.704RCTA+0.565AS r^2 = 0.91/s = 3.64

* 22 Curves ** 14 Curves

TABLE D48 : REGRESSION RELATIONSHIPS FOR GOODS VEHICLE MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{GM}(85)$	R	49.39+0.034R+0.008SD+0.039L r^2 = 0.54/s = 5.44	7.53+0.828AS r^2 = 0.40/s = 5.68	56.12+0.04R r^2 = 0.43/s = 6.38
	C	73.55-0.856C+0.005SD r^2 = 0.70/s = 4.33	7.53+0.828AS r^2 = 0.40/s = 5.68	52.46-0.924C+0.312AS r^2 = 0.92/s = 2.54
$V_{GM}(85)$	TA	————	7.53+0.828AS r^2 = 0.40/s = 5.68	73.25-7.908TA r^2 = 0.23/s = 7.38
	RCTA	73.55-1.494RCTA+0.005SD r^2 = 0.70/s = 4.33	7.53+0.828AS r^2 = 0.40/s = 5.68	52.46-1.613RCTA+0.312AS r^2 = 0.92/s = 2.54

* 31 Curves ** 14 Curves *** 17 Curves

DEPENDENT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{GM}(85)$	R	83.68-285.63E r^2 = 0.54/s = 4.59	64.85-1.863GRA r^2 = 0.34/s = 7.58
	C	83.68-285.63E r^2= 0.54/s = 4.59	87.34-1.062C-0.019FL r^2 = 0.84/s = 3.88
$V_{GM}(85)$	TA	83.68-285.63E r^2= 0.54/s = 4.59	64.85-1.863GRA r^2 = 0.34/s = 7.58
	RCTA	83.68-285.63E r^2 = 0.54/s = 4.59	87.34-1.855RCTA-0.019FL r^2 = 0.84/s = 3.88

* 17 Curves ** 14 Curves

TABLE D49 : REGRESSION RELATIONSHIPS FOR GOODS VEHICLE MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$V_{GM}(85)$	R	-9.52+0.871AS+0.041R r^2 = 0.85/s = 3.82	-13.40+1.044AS r^2 = 0.63/s = 6.33
	C	9.16+0.858AS-0.824C r^2 = 0.88/s = 3.45	-13.40+1.044AS r^2 = 0.63/s = 6.33
$V_{GM}(85)$	TA	-20.42+1.15AS r^2 = 0.68/s = 5.35	-13.40+1.044AS r^2 = 0.63/s = 6.33
	RCTA	9.16+0.858AS-1.438RCTA r^2 = 0.88/s = 3.45	-13.40+1.044AS r^2 = 0.63/s = 6.33

* 12 Curves ** 6 Curves

TABLE D50 : REGRESSION RELATIONSHIPS FOR ALL CAR MIDDLE SPEEDS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{CM}(85)$	R	-22.40+0.054R+0.034L+0.007SD+0.793DS +1.30VW r^2 = 0.81/s = 5.55	46.86+0.069R+0.065L r^2 = 0.75/s = 6.44	-7.57+0.053R+1.23VW+0.63DS+ 0.01L+0.041L r^2 = 0.81/s = 6.01
	C	81.88-0.88C+0.827VW+0.004SD r^2 = 0.84/s = 4.99	84.73-0.913C r^2 = 0.82/s = 5.43	82.00-0.857C+0.89VW+0.006SD r^2 = 0.86/s = 4.78
$V_{CM}(85)$	TA	-51.88+1.45DS-8.61TA r^2 = 0.63/s = 7.56	-60.14+1.50DS-11.31TA+1.99VW r^2 = 0.73/s = 6.89	-38.23+1.28DS-12.68TA+ 2.21VW r^2 = 0.77/s = 6.06
	RCTA	81.88-1.54RCTA+0.827VW+0.004SD r^2 = 0.84/ s = 4.99	84.73-1.60RCTA r^2 = 0.82/s = 5.43	82.00-1.497RCTA+0.89VW +0.006SD r^2 = 0.86/s = 4.78

* 56 Curves   ** 28 Curves   *** 28 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{CM}(85)$	R	46.43+0.075R+0.045L+1.17VW r^2 = 0.79/s = 5.78	-66.40+0.046R+1.33DS+1.76VW+0.006SD r^2 = 0,81/s = 5.99
	C	85.49-0.888C r^2 = 0.82/s = 5.14	85.28-0.897C r^2 = 0.80/s = 5.74
$V_{CM}(85)$	TA	-31.82+1.21DS-12.86TA+2.11VW r^2 = 0.73/s = 6.58	-67.98+1.58DS-11.08TA+2.10VW r^2 = 0.77/s = 6.49
	RCTA	85.49-1.55RCTA r^2 = 0.82/s = 5.14	85.28-1.566RCTA r^2 = 0.80/s = 5.74

* 29 Curves   ** 27 Curves

TABLE D51 : REGRESSION RELATIONSHIPS FOR ALL CAR MIDDLE SPEEDS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$V_{CM}(85)$	R	61.35+0.066R+1.60VW r^2 = 0.76/s = 5.59	63.17+0.07R r^2 = 0.70/s = 6.20
	C	74.26-1.876C+1.12VW+3.10RW r^2 = 0.83/s = 4.83	92.79-1.70C+1.95VW r^2 = 0.83/s = 4.91
$V_{CM}(85)$	TA	80.51+1.734VW r^2 = 0.20/s = 9.90	72.04+3.33GRA r^2 = 0.36/s = 9.10
	RCTA	74.26-3.28RCTA+1.12VW+3.10RW r^2 = 0.83/s = 4.83	92.79-2.97RCTA+1.95VW r^2 = 0.8

* 22 Curves   ** 14 Curves

TABLE D52 : REGRESSION RELATIONSHIPS FOR FREE CAR MIDDLE SPEEDS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves**
$V_{FCM}(85)$	R	-29.04+0.056R+0.03L+0.007SD+0.88DS+1.30VW r^2 = 0.81/s = 5.68	47.17+0.73R+0.064L r^2 = 0.75/s = 6.82	-10.67+0.054R+1.156VW+0.674DS+0.009SD+0.04L r^2 = 0.81/s = 5.80
	C	76.83-0.814C+1.03VW+0.006SD+0.009VW r^2 = 0.84/s = 5.14	86.14-0.945C r^2 = 0.80/s = 5.89	87.04-0.89C r^2 = 0.83/s = 5.17
$V_{FCM}(85)$	TA	-54.95+1.464DS-12.24TA+2.07VW r^2 = 0.75/s = 6.38	-68.60+1.60DS-11.66TA+2.01VW r^2 = 0.74/s = 7.05	-41.3+1.33DS-12.81TA+2.13VW r^2 = 0.78/s = 6.04
	RCTA	76.83-1.42RCTA+1.03VW+0.0006SD+0.009VW r^2 = 0.84/s = 5.14	86.14-1.65RCTA r^2 = 0.80/s = 5.89	87.04-1.554RCTA r^2 = 0.83/s = 5.17

* 56 Curves ** 28 Curves *** 28 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{FCM}(85)$	R	-14.95+0.07R+1.170VW+0.75DS r^2 = 0.80/s = 5.73	-72.90+1.413DS+0.046R+1.75VW+0.006SD r^2 = 0.80/s = 6.27
	C	86.72-0.91C r^2 = 0.83/s = 5.24	86.44-0.924C r^2 = 0.80/s = 5.98
$V_{FCM}(85)$	TA	-35.61+1.27DS-13.43TA+2.07VW r^2 = 0.75/s = 6.41	-75.80+1.68DS-10.99TA+2.083VW r^2 = 0.76/s = 6.77
	RCTA	86.72-1.59RCTA r^2 = 0.82/s = 5.24	86.44-1.614RCTA r^2 = 0.80/s = 5.98

* 29 Curves ** 27 Curves

TABLE D53 : REGRESSION RELATIONSHIPS FOR FREE CAR MIDDLE SPEEDS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$V_{FCM}(85)$	R	61.95+0.066R+1.535VW r^2 = 0.76/s = 5.23	63.38+0.072R r^2 = 0.73/s = 6.02
	C	77.08-1.914C+1.07VW+2.86RW r^2 = 0.84/s = 4.61	98.37-1.793C r^2 = 0.80/s = 5.12
$V_{FCM}(85)$	TA	73.67+0.70SD+1.55VW r^2 = 0.35/s = 9.09	91.71-10.32TA r^2 = 0.37/s = 9.14
	RCTA	77.08-3.343RCTA+1.07VW+2.86RW r^2 = 0.84/s = 4.61	98.37-3.13RCTA r^2 = 0.80/s = 5.12

* 22 Curves ** 14 Curves

TABLE D54 : REGRESSION RELATIONSHIPS FOR GOODS VEHICLE MIDDLE SPEEDS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{GM}(85)$	R	49.39+0.034R+0.008SD+0.039L r^2 = 0.54/s = 5.44	———	-65.55+1.434DS r^2 = 0.57/s = 5.51
	C	73.55-0.856C+0.005SD r^2 = 0.70/s = 4.33	———	74.27-0.889C+0.004SD r^2 = 0.91/s = 2.61
$V_{GM}(85)$	TA	———	———	-65.55+1.434DS r^2 = 0.57/s = 5.51
	RCTA	73.55-1.494RCTA+0.005SD r^2 = 0.70/s = 4.33	———	74.27-1.585RCTA+0.004SD r^2 = 0.91/s = 2.61

* 31 Curves ** 14 Curves *** 17 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{GM}(85)$	R	———	-111.88+1.675DS+395.98E-2.067GRA r^2 = 0.83/s = 4.19
	C	———	87.34-1.062C-0.019FL r^2 = 0.84/s = 3.88
$V_{GM}(85)$	TA	———	-111.88+1.675DS+395.98E-2.067GRA r^2 = 0.83/s = 4.19
	RCTA	———	87.34-1.855RCTA-0.019FL r^2 = 0.84/s = 3.88

* 17 Curves ** 14 Curves

TABLE D55 : REGRESSION RELATIONSHIPS FOR GOODS VEHICLE MIDDLE SPEEDS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$V_{GM}(85)$	R	51.78+0.065R r^2 = 0.54/s = 6.42	———
	C	67.36-1.835C+261.12E r^2 = 0.73/s = 5.17	———
$V_{GM}(85)$	TA	———	———
	RCTA	67.36-3.204RCTA+261.12E r^2 = 0.73/s = 5.17	———

* 12 Curves ** 6 Curves

TABLE D56 : REGRESSION RELATIONSHIPS FOR ALL SELECTED CAR MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{CM}(85)$	R	46.07+0.06R+0.065L+0.008SD r^2 = 0.78/s = 6.21	10.09+0.05R+0.06L+0.47AS r^2 = 0.87/s = 4.98	55.23+0.08R r^2 = 0.67/s = 7.41
	C	47.72-0.73C+0.39AS+0.003SD r^2 = 0.92/s = 3.60	41.35-0.674C+0.455AS r^2 = 0.91/s = 4.08	47.03-0.78C+0.416AS+0.004SD r^2 = 0.95/s = 2.94
$V_{CM}(85)$	TA	20.64-14.21TA+0.57AS+2.95RW+1.36VW r^2 = 0.69/s = 7.45	-12.54+1.07AS-7.65TA r^2 = 0.71/s = 7.36	87.98-19.21TA r^2 = 0.65/s = 7.67
	RCTA	47.72-1.28RCTA+0.39AS+0.003SD r^2 = 0.92/s = 3.60	41.35-1.176RCTA+0.455AS r^2 = 0.91/s = 4.08	47.03-1.36RCTA+0.416AS+0.004SD r^2 = 0.95/s = 2.94

* 37 Curves ** 19 Curves *** 18 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{CM}(85)$	R	53.83+0.08R r^2 = 0.73/s = 6.54	3.74+0.06R+0.65AS r^2 = 0.74/s = 7.19
	C	78.76-0.794C+0.016SD r^2 = 0.93/s = 3.43	33.18-0.68C+0.567AS r^2 = 0.94/s = 3.58
$V_{CM}(85)$	TA	86.99-17.1TA r^2 = 0.60/s = 7.95	3.24+0.924-10.21TA r^2 = 0.71/s = 7.64
	RCTA	78.76-1.39RCTA+0.016SD r^2 = 0.93/s = 3.43	33.18-1.183RCTA+0.567AS r^2 = 0.94/s = 3.58

* 19 Curves ** 18 Curves

TABLE D57 : REGRESSION RELATIONSHIPS FOR ALL SELECTED CAR MIDDLE SPEEDS AGAINST APPROACH SPEED, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$V_{CM}(85)$	R	60.25+0.243SD r^2 = 0.68/s = 6.23	50.47+0.33SD r^2 = 0.85/s = 4.48
	C	37.55-1.303C+0.60AS r^2 = 0.90/s = 3.64	50.47+0.33SD r^2 = 0.85/s = 4.48
$V_{CM}(85)$	TA	60.25+0.243SD r^2 = 0.68/s = 6.23	50.47+0.33SD r^2 = 0.85/s = 4.48
	RCTA	37.55-2.275RCTA+0.60AS r^2 = 0.90/s = 3.64	50.47+0.33SD r^2 = 0.85/s = 4.48

* 13 Curves ** 8 Curves

TABLE D58 : REGRESSION RELATIONSHIPS FOR SELECTED FREE CAR MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{FCM}(85)$	R	46.48+0.06R+0.065L+0.007SD r^2 = 0.77/s = 6.37	6.27+0.005R+0.06L+0.525AS r^2 = 0.87/s = 5.09	55.51+0.08R r^2 = 0.69/s = 7.36
	C	47.94-0.756C+0.41AS r^2 = 0.92/s = 3.79	38.99-0.67C+0.49AS r^2 = 0.91/s = 4.06	49.95-0.816C+0.406AS r^2 = 0.94/s = 3.28
$V_{FCM}(85)$	TA	23.90-14.53TA+0.54AS+2.96RW+1.30VW r^2 = 0.68/s = 7.66	-16.99+1.123AS-7.42TA r^2 = 0.73/s = 7.21	89.28-17.69TA r^2 = 0.66/s = 7.74
	RCTA	47.94-1.32RCTA+0.41AS r^2 = 0.92/s = 3.79	38.99-1.17RCTA+0.49AS r^2 = 0.91/s = 4.06	49.95-1.425RCTA+0.406AS r^2 = 0.94/s = 3.28

* 37 Curves ** 19 Curves *** 18 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{FCM}(85)$	R	54.43+0.08R r^2 = 0.73/s = 6.60	4.164+0.06R+0.645AS r^2 = 0.74/s = 7.37
	C	79.89-0.803C+0.014SD r^2 = 0.93/s = 3.46	35.33-0.70C+0.55AS r^2 = 0.93/s = 3.78
$V_{FCM}(85)$	TA	71.24-16.12TA+3.59RW r^2 = 0.68/s = 7.39	3.88+0.923AS-10.45TA r^2 = 0.70/s = 7.92
	RCTA	79.89-1.403RCTA+0.014SD r^2 = 0.93/s = 3.46	35.33-1.224RCTA+0.55AS r^2 = 0.93/s = 3.78

* 19 Curves ** 18 Curves

TABLE D59 : REGRESSION RELATIONSHIPS FOR SELECTED FREE CAR MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$V_{FCM}(85)$	R	60.66+0.246SD r^2 = 0.68/s = 6.36	50.25+0.344SD r^2 = 0.85/s = 4.67
	C	41.13-1.38C+0.57AS r^2 = 0.92/s = 3.42	54.24-1.42C+0.43AS r^2 = 0.94/s = 3.32
$V_{FCM}(85)$	TA	60.66+0.246SD r^2 = 0.68/s = 6.36	50.25+0.344SD r^2 = 0.85/s = 4.67
	RCTA	41.13-2.41RCTA+0.57AS r^2 = 0.92/s = 3.42	54.24-2.474RCTA+0.43AS r^2 = 0.94/s = 3.32

* 13 Curves ** 8 Curves

TABLE D60 : REGRESSION RELATIONSHIPS FOR SELECTED GOODS VEHICLE MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
V_{GM} (85)	R	40.56+0.044R+0.01SD+0.065L r^2 = 0.80/s = 4.44	-25.68+1.25AS r^2 = 0.88/s = 2.36	49.57+0.063R r^2 = 0.54/s = 8.01
	C	71.18-0.807C+0.006SD r^2 = 0.88/s = 3.24	-25.68+1.25AS r^2 = 0.88/s = 2.36	74.94-0.90C r^2 = 0.90/s = 3.81
V_{GM} (85)	TA	———	-25.68+1.25AS r^2 = 0.88/s = 2.36	———
	RCTA	71.18-1.41RCTA+0.006SD r^2 = 0.88/s = 3.24	-25.68+1.25AS r^2 = 0.88/s = 2.36	74.94-1.57RCTA r^2 = 0.90/s = 3.81

* 16 Curves ** 8 Curves *** 8 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
V_{GM} (85)	R	4.40+0.82AS+0.003SD r^2 = 0.94/s = 1.54	———
	C	4.40+0.82AS+0.003SD r^2 = 0.94/s = 1.54	72.62-0.84C r^2 = 0.83/s = 6.58
V_{GM}(85)	TA	4.40+0.82AS+0.003SD r^2 = 0.94/s = 1.54	86.01-42.91TA r^2 = 0.98/s = 2.33
	RCTA	4.40+0.82AS+0.003SD r^2 = 0.94/s = 1.54	72.62-1.46RCTA r^2 = 0.83/s = 6.58

* 11 Curves ** 5 Curves

TABLE D61 : REGRESSION RELATIONSHIPS FOR SELECTED GOODS VEHICLE MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
V_{GM} (85)	R	25.67+1.194AS r^2 = 0.73/s = 4.50	———
	C	11.67+0.80AS-0.70C r^2 = 0.91/s = 2.79	———
V_{GM} (85)	TA	25.67+1.194AS r^2 = 0.73/s = 4.50	———
	RCTA	11.67+0.80AS-1.223RCTA r^2 = 0.91/s = 2.79	———

* 9 Curves ** 5 Curves

TABLE D62 : REGRESSION RELATIONSHIPS FOR ALL CAR MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{CM}(85)$	R	23.83+0.06R+0.254AS+1.19VW+1.64RW+0.006SD +0.02L r^2 = 0.81/s = 5.88	3.904+0.62AS+0.06R+0.904VW r^2 = 0.84/s = 5.87	41.99+0.06R+2.37RW+1.26VW+ 0.01SD+0.02L r^2 = 0.80/s = 5.65
	C	35.06-0.815C+0.533AS+0.546VW+0.65RW r^2 = 0.89/s = 4.46	20.33-0.706C+0.734AS r^2 = 0.87/s = 5.19	35.83-0.884C+0.60AS r^2 = 0.90/s = 3.87
$V_{CM}(85)$	TA	4.49+0.936AS-9.85TA r^2 = 0.65/s = 7.71	-10.37+1.09AS-9.19TA r^2 = 0.80/s = 6.62	24.26-10.21TA+0.722AS r^2 = 0.49/s = 8.52
	RCTA	35.06-1.423RCTA+0.533AS+0.546VW+o.65RW r^2 = 0.89/s = 4.46	20.33-1.23RCTA+0.734AS r^2 = 0.87/s = 5.19	35.83-1.544RCTA+0.60AS r^2 = 0.90/s = 3.87

* 78 Curves ** 38 Curves *** 40 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{CM}(85)$	R	43.60+0.07R+1.63VW+2.04RW r^2 = 0.77/s = 6.05	-0.435+0.75AS+0.05R r^2 = 0.81/s = 6.33
	C	35.37+0.90C+0.57AS+0.766VW r^2 = 0.86/s = 4.77	27.78-0.723C+0.60AS+1.24RW r^2 = 0.93/s = 3.97
$V_{CM}(85)$	TA	18.42-13.19TA+0.75AS+1.76VW r^2 = 0.63/s = 7.65	-1.46+1.00AS-8.74TA r^2 = 0.75/s = 7.15
	RCTA	35.37-1.564RCTA+0.57AS+0.766VW r^2 = 0.86/s = 4.77	27.78-1.26RCTA+0.60AS+1.24RW r^2 = 0.93/s = 3.97

* 43 Curves ** 35 Curves

TABLE D63 : REGRESSION RELATIONSHIPS FOR FREE CAR MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{FCM}(85)$	R	26.93+0.065R+0.22AS+1.17VW+1.66RW+ 0.006SD+0.015L r^2 = 0.80/s = 6.03	4.03+0.63AS+0.06R+0.83VW r^2 = 0.84/s = 6.09	42.80+0.064R+2.31RW+1.18VW+ 0.01SD+0.02L r^2 = 0.80/s = 5.67
	C	37.87-0.84C+0.513AS+0.494VW+0.62RW r^2 = 0.88/s = 4.60	21.21-0.73C+0.73AS r^2 = 0.87/s = 5.27	41.66-0.904C+0.54AS r^2 = 0.89/s = 4.02
$V_{FCM}(85)$	TA	6.89+0.916AS-10.20TA r^2 = 0.64/s = 7.89	-10.81+1.10AS-9.40TA r^2 = 0.79/s = 6.74	29.40-10.59TA+0.67AS r^2 = 0.48/s = 8.68
	RCTA	37.87-1.47RCTA+0.513AS+0.494VW+0.62RW r^2 = 0.88/s = 4.60	21.21-1.27RCTA+0.73AS r^2 = 0.87/s = 5.27	41.66-1.58RCTA+0.54AS r^2 = 0.89/s = 4.02

* 78 Curves   ** 38 Curves   *** 40 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{FCM}(85)$	R	44.28+0.075R+1.99RW+1.56VW r^2 = 0.79/s = 5.92	0.37+0.744AS+0.05R r^2 = 0.80/s = 6.53
	C	41.19-0.93C+0.52AS+0.67VW r^2 = 0.85/s = 4.96	29.18-0.74C+0.60AS+1.07RW r^2 = 0.92/s = 4.06
$V_{FCM}(85)$	TA	23.46-13.98TA+0.706AS+1.725VW r^2 = 0.63/s = 7.76	-0.996+0.993AS-8.44TA r^2 = 0.74/s = 7.38
	RCTA	41.19-1.62RCTA+0.52AS+0.67VW r^2 = 0.85/s = 4.96	29.18-1.29RCTA+0.60AS+1.07RW r^2 = 0.92/s = 4.06

* 43 Curves   ** 35 Curves

TABLE D64 : REGRESSION RELATIONSHIPS FOR GOODS VEHICLE MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{GM}(85)$	R	26.70+0.04R+0.36AS+0.83VW+0.004SD r^2 = 0.57/s = 5.47	-7.16+1.01AS r^2 = 0.53/s = 6.15	58.61+0.034R r^2 = 0.32/s = 6.17
	C	34.96-0.89C+0.54AS r^2 = 0.73/s = 4.19	19.46+0.73AS-0.71C r^2 = 0.65/s = 5.45	45.26-0.906C+0.405AS r^2 = 0.86/s = 2.87
$V_{GM}(85)$	TA	16.50+0.69AS r^2 = 0.25/s = 6.95	1.71+0.95AS-5.30TA r^2 = 0.64/s = 5.54	————
	RCTA	34.96-1.553RCTA+0.54AS r^2 = 0.73/s = 4.19	19.46+0.73AS-1.24RCTA r^2 = 0.65/s = 5.45	45.26-1.58RCTA+0.405AS r^2 = 0.86/s = 2.87

* 43 Curves ** 20 Curves *** 23 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{GM}(85)$	R	————	56.24-2.19GRA+1.96RW r^2 = 0.52/s = 6.27
	C	————	37.62-0.95C+0.51AS r^2 = 0.76/s = 4.42
$V_{GM}(85)$	TA	————	56.24-2.19GRA+1.96RW r^2 = 0.52/s = 6.27
	RCTA	————	37.62-1.65RCTA+0.51AS r^2 = 0.76/s = 4.42

* 23 Curves ** 20 Curves

TABLE D65 : REGRESSION RELATIONSHIPS FOR ALL SELECTED CAR MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{CM}(85)$	R	19.57+0.07R+0.30AS+1.04VW+1.93RW+0.005SD r^2 = 0.80/s = 6.22	1.19+0.625AS+0.065R+0.84VW r^2 = 0.88/s = 5.24	42.05+0.05R+2.89RW+0.01SD+0.03L r^2 = 0.76/s = 6.39
	C	38.09-0.763C+0.505AS+0.563VW r^2 = 0.92/s = 3.89	30.16-0.68C+0.57AS+0.65VW r^2 = 0.92/s = 4.34	39.46-0.815C+0.53AS r^2 = 0.94/s = 3.12
$V_{CM}(85)$	TA	0.883+0.94AS-9.25TA r^2 = 0.64/s = 7.99	-16.76+1.12AS-7.403TA r^2 = 0.78/s = 6.91	85.95-11.95TA r^2 = 0.35/s = 9.86
	RCTA	38.09-1.333RCTA+0.505AS+0.563VW r^2 = 0.92/s = 3.89	30.16-1.184RCTA+0.57AS+0.65VW r^2 = 0.92/s = 4.34	39.46-1.423RCTA+0.53AS r^2 = 0.94/s 3.12

* 50 Curves ** 25 Curves *** 25 Curves

DEPENDNAT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{CM}(85)$	R	48.27+0.07R+1.73RW r^2 = 0.73/s = 6.51	-9.804+0.835AS+0.05R r^2 = 0.80/s = 6.64
	C	46.55-0.814C+0.43AS r^2 = 0.89/s = 4.20	22.34-0.65C+0.69AS r^2 = 0.94/s = 3.62
$V_{CM}(85)$	TA	84.98-12.43TA r^2 = 0.38/s = 9.69	-11.23+1.07AS-7.31TA r^2 = 0.76/s = 7.29
	RCTA	46.55-1.42RCTA+0.43AS r^2 = 0.89/s = 4.20	22.34-1.14RCTA+0.69AS r^2 = 0.94/s = 3.62

* 27 Curves ** 23 Curves

TABLE D66 : REGRESSION RELATIONSHIPS FOR SELECTED FREE CAR MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{FCM}(85)$	R	21.44+0.07R+0.273AS+1.98RW+1.00VW+ 0.005SD r^2 = 0.79/s = 6.37	-10.53+0.82AS+0.06R r^2 = 0.86/s = 5.56	42.68+0.06R+2.8RW+0.01SD +0.03L r^2 = 0.77/s = 6.37
	C	39.85-0.78C+0.495AS+0.50VW r^2 = 0.91/s = 4.03	19.96-0.64C+0.71AS r^2 = 0.91/s = 4.52	45.54-0.84C+0.466AS r^2 = 0.93/s = 3.33
$V_{FCM}(85)$	TA	1.942+0.935AS-9.405TA r^2 = 0.63/s = 8.18	-19.42+1.15AS-7.22TA r^2 = 0.79/s = 6.89	87.15-12.37TA r^2 = 0.36/s = 9.95
	RCTA	39.85-1.36RCTA+0.495AS+0.50VW r^2 = 0.91/s = 4.03	19.96-1.11RCTA+0.71AS r^2 = 0.91/s = 4.52	45.54-1.46RCTA+0.466AS r^2 = 0.93/s = 3.33

* 50 Curves ** 25 Curves *** 25 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{FCM}(85)$	R	48.46+0.074R+1.76RW r^2 = 0.74/s = 6.44	-9.53+0.83AS+0.053R r^2 = 0.80/s = 6.77
	C	49.42-0.83C+0.403AS r^2 = 0.89/s = 4.27	23.90-0.67C+0.69AS r^2 = 0.94/s = 3.70
$V_{FCM}(85)$	TA	86.02-12.76TA r^2 = 0.39/s = 9.74	-11.39+1.07AS-7.18TA r^2 = 0.75/s = 7.59
	RCTA	49.42-1.45RCTA+0.403AS r^2 = 0.89/s = 4.27	23.90-1.17RCTA+0.69AS r^2 = 0.94/s = 3.70

* 27 Curves ** 23 Curves

TABLE D67 : REGRESSION RELATIONSHIPS FOR SELECTED GOODS VEHICLE MIDDLE SPEEDS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$V_{GM}(85)$	R	9.63+0.04R+0.61AS $r^2 = 0.54/s = 5.97$	-25.14+1.216AS $r^2 = 0.74/s = 4.40$	54.27+0.05R $r^2 = 0.33/s = 7.72$
	C	27.94-0.824C+0.604AS $r^2 = 0.87/s = 3.24$	-25.14+1.216AS $r^2 = 0.74/s = 4.40$	33.86-0.86C+0.534AS $r^2 = 0.88/s = 3.39$
$V_{GM}(85)$	TA	-0.293+0.87AS $r^2 = 0.33/s = 7.08$	-23.90+1.36AS-2.144RW $r^2 = 0.91/s = 2.67$	———
	RCTA	27.94-1.44RCTA+0.604AS $r^2 = 0.87/s = 3.24$	-25.14+1.216AS $r^2 = 0.74/s = 4.40$	33.86-1.51RCTA+0.534AS $r^2 = 0.88/s = 3.39$

* 25 Curves ** 12 Curves *** 13 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$V_{GM}(85)$	R	-12.74+1.05AS $r^2 = 0.73/s = 3.91$	-97.72+0.11R+1.68AS+0.02L $r^2 = 0.96/s = 2.73$
	C	-12.74+1.05AS $r^2 = 0.73/s = 3.91$	-1.35-0.95C+0.98AS $r^2 = 0.97/s = 2.08$
$V_{GM}(85)$	TA	-12.74+1.05AS $r^2 = 0.73/s = 3.91$	65.33-2.86GRA $r^2 = 0.45/s = 8.60$
	RCTA	-12.74+1.05AS $r^2 = 0.73/s = 3.91$	-1.35-1.66RCTA+0.98AS $r^2 = 0.97/s = 2.08$

* 16 Curves ** 9 Curves

TABLE D68 : CURVILINEAR REGRESSION RELATIONSHIPS FOR MIDDLE SPEEDS AGAINST APPROACH SPEEDS AND CURVE GEOMETRY ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Cars*	Free Cars*	Goods Vehicles**
V(85)	R	$13.45+0.212R-0.0004R^2+0.374AS$ $r^2 = 0.83/s = 5.09$	$15.73+0.215R-0.0004R^2+0.35AS$ $r^2 = 0.83/s = 5.31$	$24.04+0.134R-0.0004R^2+0.31AS$ $r^2 = 0.48/s = 5.81$
	C	$54.58-1.24C+0.39AS+0.0004C^3$ $r^2 = 0.90/s = 3.95$	$57.77-1.31C+0.37AS+0.0003C^3$ $r^2 = 0.90/s = 4.12$	$32.64-0.133C+0.52AS-0.02C^2$ $r^2 = 0.73/s = 4.20$
V(85)	R	$42.34+0.23R-0.0004R^2$ $r^2 = 0.80/s = 5.58$	$42.61+0.23R-0.0004R^2$ $r^2 = 0.80/s = 5.74$	$46.04+0.14R-0.0004R^2$ $r^2 = 0.43/s = 5.94$
	C	$90.06-1.52C+0.0003C^3$ $r^2 = 0.86/s = 4.65$	$91.51-1.58C+0.0004C^3$ $r^2 = 0.86/s = 4.75$	$74.38-0.682C-\underline{0.006C^2}$ $r^2 = 0.62/s = 4.89$

* 56 Curves ** 31 Curves

TABLE D69 : CURVILINEAR REGRESSION RELATIONSHIPS FOR MIDDLE SPEEDS AGAINST APPROACH SPEEDS AND CURVE GEOMETRY ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Cars*	Free Cars*	Goods Vehicles**
V(85)	R	$-2.207+0.14R+0.65AS-0.0004R^2$ $r^2 = 0.85/s = 4.52$	$-1.026+0.152R+0.626AS-0.0004R^2$ $r^2 = 0.86/s = 4.38$	$-15.70+0.89AS+0.083R-\underline{0.0004R^2}$ $r^2 = 0.67/s = 3.88$
	C	$38.01-1.904C+0.646AS+0.015C^2$ $r^2 = 0.87/s = 3.92$	$40.60-1.884C+0.623AS+0.013C^2$ $r^2 = 0.90/s = 3.70$	$10.40+0.86AS-1.117C+\underline{0.01C^2}$ $r^2 = 0.88/s = 3.64$
V(85)	R	$52.78+0.172R-\underline{0.0004R^2}$ $r^2 = 0.65/s = 6.67$	$52.10+0.18R-0.0004R^2$ $r^2 = 0.67/s = 6.39$	$53.75+0.053R+\underline{0.000R^4}$ $r^2 = 0.54/s = 6.73$
	C	$105.22-2.95C+\underline{0.04C^2}$ $r^2 = 0.69/s = 6.28$	$105.96-2.96C+\underline{0.04C^2}$ $r^2 = 0.72/s = 5.94$	$78.133-1.05C-\underline{0.0004C^4}$ $r^2 = 0.57/s = 6.50$

* 22 Curves ** 12 Curves

TABLE D70 : CURVILINEAR REGRESSION RELATIONSHIPS FOR SELECTED MIDDLE SPEEDS AGAINST APPROACH SPEEDS AND CURVE GEOMETRY ON SINGLE CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Cars*	Free Cars*	Goods Vehicles**
V(85)	R	$17.92+0.22R-0.0004R^2+0.30AS$ $r^2 = 0.88/s = 4.50$	$20.23+0.223R-0.0004R^2+0.273AS$ $r^2 = 0.88/s = 4.66$	$5.19+0.224R-0.0004R^2+0.43AS$ $r^2 = 0.73/s = 5.14$
	C	$59.93-1.21C+0.0004C^3+0.304AS$ $r^2 = 0.94/s = 3.18$	$63.15-1.244C+0.0004C^3+0.277AS$ $r^2 = 0.94/s = 3.22$	$-2.82+0.18C+0.923AS-0.001C^3$ $r^2 = 0.94/s = 2.47$
V(85)	R	$41.32+0.23R-0.0004R^2$ $r^2 = 0.86/s = 4.78$	$41.58+0.233R-0.0004R^2$ $r^2 = 0.86/s = 4.88$	$36.55+0.222R-0.0004R^2$ $r^2 = 0.67/s = 5.44$
	C	$86.89-1.29C+0.0004C^4$ $r^2 = 0.92/s = 3.62$	$87.88-1.313C+0.0004C^4$ $r^2 = 0.93/s = 3.58$	$73.19-0.725C-0.004C^2$ $r^2 = 0.75/s = 4.71$

* 37 Curves ** 16 Curves

TABLE D71 : CURVILINEAR REGRESSION RELATIONSHIPS FOR SELECTED MIDDLE SPEEDS AGAINST APPROACH SPEEDS AND CURVE GEOMETRY ON DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Cars*	Free Cars*	Goods Vehicles**
V(85)	R	$2.04+0.56AS+0.18R-0.0004R^2$ $r^2 = 0.83/s = 5.01$	$3.51+0.536AS+0.19R-0.0004R^2$ $r^2 = 0.85/s = 4.83$	$-27.13+0.964AS+0.16R-0.0004R^2$ $r^2 = 0.92/s = 2.87$
	C	$32.64-0.836C+0.615AS-0.001C^3$ $r^2 = 0.91/s = 3.68$	$37.55-1.05C+0.585AS-0.0004C^3$ $r^2 = 0.92/s = 3.52$	$11.14-0.002C^3+0.717AS+0.39C$ $r^2 = 0.95/s = 2.27$
V(85)	R	$44.04+0.26R-0.0004R^2$ $r^2 = 0.67/s = 6.65$	$43.79+0.264R-0.0004R^2$ $r^2 = 0.71/s = 6.35$	$39.80+0.204R-0.0004R^2$ $r^2 = 0.59/s = 6.26$
	C	$96.33-1.473C-0.007C^2$ $r^2 = 0.70/s = 6.35$	$98.74-1.75C$ $r^2 = 0.74/s = 5.72$	$68.66-0.0004C^4+0.037C^2$ $r^2 = 0.79/s = 4.31$

* 13 Curves ** 9 Curves

TABLE D72 : CURVILINEAR REGRESSION RELATIONSHIPS FOR MIDDLE SPEEDS AGAINST APPROACH SPEEDS AND CURVE GEOMETRY ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Cars*	Free Cars*	Goods Vehicles**
V(85)	R	$0.036+0.184R+0.57AS-0.0004R^2$ $r^2 = 0.84/s = 5.29$	$2.74+0.19R-0.0004R^2+0.534AS$ $r^2 = 0.84/s = 5.36$	$10.69+0.123R+0.50AS-0.0004R^2$ $r^2 = 0.56/s = 5.45$
	C	$40.65-1.306C+0.567AS+0.0004C^3$ $r^2 = 0.90/s = 4.25$	$44.67-1.37C+0.534AS+0.0004C^3$ $r^2 = 0.90/s = 4.28$	$26.86-0.297C+0.606AS-0.016C^2$ $r^2 = 0.75/s = 4.09$
V(85)	R	$44.12+0.213R-0.0004R^2$ $r^2 = 0.72/s = 6.86$	$44.21+0.217R-0.0004R^2$ $r^2 = 0.74/s = 6.75$	$46.08+0.134R-0.0004R^2$ $r^2 = 0.44/s = 6.09$
	C	$96.24-2.24C+0.025C^2$ $r^2 = 0.78/s = 6.10$	$97.55-2.305C+0.026C^2$ $r^2 = 0.80/s = 5.95$	$76.54-0.994C+\underline{0.0004C^4}$ $r^2 = 0.58/s = 5.24$

* 78 Curves ** 43 Curves

TABLE D73 : CURVILINEAR REGRESSION RELATIONSHIPS FOR SELECTED MIDDLE SPEEDS AGAINST APPROACH SPEEDS AND CURVE GEOMETRY ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Cars*	Free Cars*	Goods Vehicles**
V(85)	R	$2.91+0.212R-0.0004R^2+0.50AS$ $r^2 = 0.88/s = 4.71$	$4.73+0.216R-0.0004R^2+0.475AS$ $r^2 = 0.87/s = 4.84$	$-4.71+0.21R-0.0004R^2+0.59AS$ $r^2 = 0.76/s = 4.40$
	C	$42.65-1.17C+0.51AS+0.0004C^3$ $r^2 = 0.93/s = 3.64$	$45.74-1.22C+0.486AS+0.0004C^3$ $r^2 = 0.93/s = 3.69$	$6.61+0.30C+0.80AS-0.028C^2$ $r^2 = 0.92/s = 2.51$
V(85)	R	$40.72+0.25R-0.0004R^2$ $r^2 = 0.80/s = 6.01$	$40.99+0.253R-0.0004R^2$ $r^2 = 0.80/s = 5.99$	$37.10+0.223R-0.0004R^2$ $r^2 = 0.63/s = 5.36$
	C	$91.06-1.563C+0.0004C^3$ $r^2 = 0.84/s = 5.31$	$92.16-1.60C+0.0004C^3$ $r^2 = 0.85/s = 5.20$	$74.39-0.795C-0.003C^2$ $r^2 = 0.72/s = 4.71$

* 50 Curves ** 25 Curves

TABLE D74 : REGRESSION RELATIONSHIPS FOR ALL CAR MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$A_{CM}(85)$	None	3.88-0.003FL r^2 = 0.49/s = 0.73	2.30-0.002FL+18.01E r^2 = 0.56/s = 0.66	4.18-0.004FL r^2 = 0.54/s = 0.74
$A_{CM}(85)$	R	2.12-0.007R+0.023AS r^2 = 0.80/s = 0.46	3.76-0.006R r^2 = 0.77/s = 0.46	1.40-0.008R+0.034AS r^2 = 0.84/s = 0.45
	C	1.73+0.062C+0.089VW-0.001FL r^2 = 0.84/s = 0.41	1.10+0.065C+0.115VW r^2 = 0.80/s = 0.44	1.91+0.065C-0.001FL+0.081VW r^2 = 0.88/s = 0.39
$A_{CM}(85)$	TA	1.83+1.27TA-0.001FL r^2 = 0.78/s = 0.48	0.89+1.54TA r^2 = 0.78/s = 0.45	2.16+1.22TA-0.002FL r^2 = 0.77/s = 0.54
	RCTA	1.73+0.108RCTA+0.089VW-0.001FL r^2 = 0.84/s = 0.41	1.10+0.113RCTA+0.115VW r^2 = 0.80/s = 0.44	1.91+0.114RCTA-0.001FL+0.081VW r^2 = 0.88/s = 0.39

* 56 Curves ** 28 Curves *** 28 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$A_{CM}(85)$	None	2.49-0.003FL+17.61E r^2 = 0.55/s = 0.69	3.964-0.004FL r^2 = 0.53/s = 0.73
$A_{CM}(85)$	R	3.96-0.007R r^2 = 0.81/s = 0.44	3.95-0.007R r^2 = 0.75/s = 0.53
	C	1.12+0.072C+0.108VW r^2 = 0.86/s = 0.38	1.87+0.058C+0.091VW-0.001FL r^2 = 0.82/s = 0.48
$A_{CM}(85)$	TA	2.04+1.438TA-0.217RW r^2 = 0.78/s = 0.48	1.90+1.263TA-0.001FL r^2 = 0.80/s = 0.49
	RCTA	1.12+0.126RCTA+0.108VW r^2 = 0.86/s = 0.38	1.87+0.101RCTA+0.091VW-0.001FL r^2 = 0.82/s = 48

* 28 Curves ** 27 Curves

TABLE D75 : REGRESSION RELATIONSHIPS FOR ALL CAR MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$A_{CM}(85)$	None	0.625+25.64E r^2 = 0.47/s = 0.49	0.656+26.44E r^2 = 0.50/s = 0.54
$A_{CM}(85)$	R	0.219-0.005R+0.022AS+0.209RW r^2 = 0.90/s = 0.22	-0.295-0.006R+0.048AS-0.001L r^2 = 0.93/s = 0.22
	C	1.03+0.122C+0.077VW r^2 = 0.75/s = 0.35	1.256+0.114C r^2 = 0.73/s = 0.40
$A_{CM}(85)$	TA	0.625+25.64E r^2 = 0.47/s = 0.49	0.656+26.44E r^2 = 0.50/s = 0.54
	RCTA	1.029+0.213+0.077VW r^2 = 0.75/s = 0.35	1.256+0.20RCTA r^2 = 0.73/s = 0.40

* 22 Curves ** 14 Curves

TABLE D76 : REGRESSION RELATIONSHIPS FOR FREE CAR MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$A_{FCM}(85)$	None	3.905-0.003FL r^2 = 0.48/s = 0.74	2.33-0.002FL+17.83E r^2 = 0.53/s = 0.68	4.21-0.004FL r^2 = 0.53/s = 0.75
$A_{FCM}(85)$	R	2.314-0.007R+0.02AS r^2 = 0.80/s = 0.46	3.81-0.006R r^2 = 0.76/s = 0.48	1.97-0.008R+0.03AS r^2 = 0.84/s = 0.45
	C	1.47+0.06C+0.07VW-0.001FL+6.18E r^2 = 0.84/s = 0.42	1.16+0.065C+0.12VW r^2 = 0.79/s = 0.46	1.75+0.06C-0.001FL+10.06E r^2 = 0.88/s = 0.39
$A_{FCM}(85)$	TA	1.82+1.293TA-0.001FL r^2 = 0.77/s = 0.49	0.94+1.54TA r^2 = 0.78/s = 0.46	2.17+1.12TA-0.002FL r^2 = 0.77/s = 0.534
	RCTA	1.47+0.1RCTA+0.07VW-0.001FL+6.18E r^2 = 0.84/s = 0.42	1.6+0.113RCTA+0.115VW r^2 = 0.79/s = 0.46	1.75+0.101RCTA-0.001FL+10.06E r^2 = 0.88/s = 0.39

* 56 Curves ** 28 Curves *** 28 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$A_{FCM}(85)$	None	2.53-0.002FL+17.53E r^2 = 0.52/s = 0.71	3.98-0.004FL r^2 = 0.52/s = 0.74
$A_{FCM}(85)$	R	4.02-0.007R r^2 = 0.80/s = 0.45	3.98-0.007R r^2 = 0.75/s = 0.53
	C	1.17+0.07C+0.10VW r^2 = 0.86/s = 0.39	1.144+0.07C+0.123VW r^2 = 0.77/s = 0.52
$A_{FCM}(85)$	TA	2.05+1.44TA-0.21RW r^2 = 0.77/s = 0.50	1.87+1.29TA-0.001FL r^2 = 0.80/s = 0.49
	RCTA	1.17+0.13RCTA+0.103VW r^2 = 0.86/s = 0.39	1.144+0.12RCTA+0.123VW r^2 = 0.77/s = 0.52

* 29 Curves ** 27 Curves

TABLE D77 : REGRESSION RELATIONSHIPS FOR ALL FREE CAR MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$A_{FCM}(85)$	None	0.68+25.144E r^2 = 0.45/s = 0.50	0.723+25.79E r^2 = 0.49/s = 0.54
$A_{FCM}(85)$	R	0.393-0.005R+0.02AS+0.19RW r^2 = 0.91/s = 0.22	0.527-0.006R+0.037AS r^2 = 0.90/s = 0.25
	C	1.074+0.12C+0.074VW r^2 = 0.74/s = 0.35	1.30+0.113C r^2 = 0.73/s = 0.39
$A_{FCM}(85)$	TA	0.68 + 25.144E r^2 = 0.45/s = 0.50	0.723+25.79E r^2 = 0.49/s = 0.54
	RCTA	1.074+0.21RCTA+0.074VW r^2 = 0.74/s = 0.35	1.30+0.20RCTA r^2 = 0.73/s = 0.39

* 22 Curves ** 14 Curves

TABLE D78 : REGRESSION RELATIONSHIPS FOR GOODS VEHICLE MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$A_{GM}(85)$	None	1.44-0.002FL+19.57E r^2 = 0.71/s = 0.34	1.81-0.002FL+18.09E r^2 = 0.67/s = 0.37	0.843+26.067E-0.001FL r^2 = 0.78/s = 0.32
$A_{GM}(85)$	R	2.83-0.005R r^2 = 0.86/s = 0.23	2.87-0.005R r^2 = 0.77/s = 0.29	2.80-0.005R r^2 = 0.92/s = 0.19
	C	1.25+0.037C-0.001FL+12.70E r^2 = 0.82/s = 0.27		0.80+0.032C+18.26E-0.001FL r^2 = 0.90/s = 0.22
$A_{GM}(85)$	TA	1.28+0.41TA-0.002FL+13.80E r^2 = 0.77/s = 0.31		0.843+26.067E-0.001FL r^2 = 0.78/s = 0.32
	RCTA	1.25+0.065-0.001FL+12.70E r^2 = 0.82/s = 0.27		0.80+0.055RCTA+18.26E-0.001FL r^2 = 0.90/s = 0.22

* 31 Curves ** 14 Curves *** 17 Curves

DEPENDENT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$A_{GM}(85)$	None	1.42-0.002FL+17.30E r^2 = 0.62/s = 0.39	3.02-0.003FL r^2 = 0.65/s = 0.39
$A_{GM}(85)$	R	2.82-0.005R r^2 = 0.85/s = 0.23	2.95-0.005R-0.062GRA r^2 = 0.92/s = 0.20
	C	-1.47+0.149C+o.025AS r^2 = 0.92/s = 0.18	3.02-0.003FL r^2 = 0.65/s = 0.39
$A_{GM}(85)$	TA	0.822+0.896TA r^2 = 0.64/s = 0.36	3.02-0.003FL r^2 = 0.65/s = 0.39
	RCTA	-1.47+0.26RCTA+0.025AS r^2 = 0.92/s = 0.18	3.02-0.003FL r^2 = 0.65/s = 0.39

* 17 Curves ** 14 Curves

TABLE D79 : REGRESSION RELATIONSHIPS FOR GOODS VEHICLE MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves
$A_{GM}(85)$	None	-1.43+0.423RW r^2 = 0.35/s = 0.45	—
$A_{GM}(85)$	R	0.066-0.005R+0.038AS r^2 = 0.84/s = 0.23	-0.54-0.007R+0.052SD r^2 = 0.99/s = 0.08
	C	-1.935+0.095C+0.035AS r^2 = 0.76/s = 0.29	—
$A_{GM}(85)$	TA	-1.43+0.423RW r^2 = 0.35/s = 0.45	—
	RCTA	-1.935+0.167RCTA+0.035AS r^2 = 0.76/s = 0.29	—

*12 Curves ** 6 Curves

TABLE D80 : REGRESSION RELATIONSHIPS FOR ALL CAR MIDDLE LATERAL ACCELERATIONS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRESENTATION	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$A_{CM}(85)$	None	11.58-0.106DS+19.38E-0.001FL r^2 = 0.72/s = 0.55	13.48-0.14DS+22.84E+0.07GRA r^2 = 0.69/s = 0.56	16.38-0.17DS+26.76E-0.084GRA r^2 = 0.79/s = 0.53
$A_{CM}(85)$	R	8.57-0.005R-0.06DS+9.72E r^2 = 0.83/s = 0.43	3.76-0.006R r^2 = 0.77/s = 0.46	9.88-0.005R-0.08DS+11.48E r^2 = 0.87/s = 0.42
	C	1.47+0.06C+0.07VW-0.001FL+6.02E r^2 = 0.85/s = 0.41	1.1+0.065C+0.12VW r^2 = 0.80/s = 0.44	1.91+0.065C-0.001FL+0.08VW r^2 = 0.88/s = 0.39
$A_{CM}(85)$	TA	9.22+1.08TA-0.09DS+7.41E r^2 = 0.85/s = 0.40	7.6+1.26TA-0.07DS r^2 = 0.87/s = 0.36	10.18+1.13TA-0.103DS-0.001SD +10.69E r^2 = 0.89/s = 0.39
	RCTA	1.47+0.1RCTA+0.07VW-0.001FL+6.02E r^2 = 0.85/s = 0.41	1.1+0.113RCTA+0.12VW r^2 = 0.80/s = 0.44	1.91+0.114RCTA-0.001FL+ 0.08VW r^2 = 0.88/s = 0.39

* 56 Curves ** 28 Curves *** 28 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$A_{CM}(85)$	None	14.34-0.15DS+26.21E+0.09GRA r^2 = 0.80/s = 0.47	3.964-0.004FL r^2 = 0.53/s = 0.73
$A_{CM}(85)$	R	10.68-0.004R-0.085DS+9.16E r^2 = 0.89/s = 0.34	3.95-0.007R r^2 = 0.75/s = 0.53
	C	1.12+0.07C+0.11VW r^2 = 0.86/s = 0.38	1.87+0.058C+0.09VW-0.001FL r^2 = 0.82/s = 0.48
$A_{CM}(85)$	TA	11.23+ 0.97TA-0.11DS+7.324E r^2 = 0.91/s = 0.31	7.25+1.354TA-0.066DS r^2 = 0.80/s = 0.49
	RCTA	1.12+0.13RCTA+0.11VW r^2 = 0.86/s = 0.38	1.87+0.1RCTA+0.09VW-0.001FL r^2 = 0.82/s = 0.48

* 29 Curves ** 27 Curves

TABLE D81 : REGRESSION RELATIONSHIPS FOR ALL CAR MIDDLE LATERAL ACCELERATIONS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$A_{CM}(85)$	None	0.625+25.64E r^2 = 0.47/s = 0.49	0.656+26.435E r^2 = 0.50/s = 0.54
$A_{CM}(85)$	R	1.584-0.005R+0.30RW-0.033GRA r^2 = 0.89/s = 0.24	1.78-0.005R+0.26RW r^2 = 0.87/s = 0.28
	C	1.03+0.122+0.08VW r^2 = 0.75/s = 0.35	1.256+0.114C r^2 = 0.73/s = 0.40
$A_{CM}(85)$	TA	0.625+25.64E r^2 = 0.47/s = 0.49	0.656+26.44E r^2 = 0.50/s = 0.54
	RCTA	1.03+0.213RCTA+0.08VW r^2 = 0.75/s = 0.35	1.256+0.20RCTA r^2 = 0.73/s = 0.40

* 22 Curves ** 14 Curves

TABLE D82 : REGRESSION RELATIONSHIPS FOR FREE CAR MIDDLE LATERAL ACCELERATION AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$A_{FCM}(85)$	None	11.47-0.105DS+19.58E-0.001FL r^2 = 0.70/s = 0.57	12.15-0.12AS+21.37E r^2 = 0.61/s = 0.62	16.28-0.17DS+27.13E-0.082GRA r^2 = 0.79/s = 0.52
$A_{FCM}(85)$	R	8.23-0.005R-0.06DS+9.37E r^2 = 0.82/s = 0.44	3.81-0.006R r^2 = 0.76/s = 0.48	9.716-0.005R-0.074DS+11.65E r^2 = 0.87/s = 0.40
	C	1.47+0.06C+0.07VW-0.001FL+6.18E r^2 = 0.84/s = 0.42	1.16+0.065C+0.115VW r^2 = 0.79/s = 0.46	1.75+0.058C-0.001FL+10.06E r^2 = 0.88/s = 0.39
$A_{FCM}(85)$	TA	8.96+1.10TA-0.086DS+7.2E r^2 = 0.85/s = 0.41	7.133+1.277TA-0.065DS r^2 = 0.85/s = 0.39	10.14+1.12TA-0.103DS+11.12E +0.001SD r^2 = 0.89/s = 0.38
	RCTA	1.47+0.102RCTA+0.07VW-0.001FL+6.18E r^2 = 0.84/s = 0.42	1.16+0.113RCTA+0.115VW r^2 = 0.79/s = 0.46	1.75+0.10RCTA-0.001FL+10.06E r^2 = 0.88/s = 0.39

* 56 Curves ** 28 Curves *** 28 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$A_{FCM}(85)$	None	14.31-0.15DS+26.10E+0.09GRA r^2 = 0.78/s = 0.50	4.526-0.004FL-0.001SD r^2 = 0.67/s = 0.62
$A_{FCM}(85)$	R	10.48-0.004R-0.08DS+8.32E r^2 = 0.88/s = 0.36	3.98-0.007R r^2 = 0.75/s = 0.53
	C	1.172+0.073C+0.103VW r^2 = 0.86/s = 0.39	1.903+0.057C+0.09VW-0.001FL r^2 = 0.80/s = 0.50
$A_{FCM}(85)$	TA	11.15+1.134TA-0.106DS r^2 = 0.88/s = 0.35	6.79+1.376TA-0.06DS r^2 = 0.80/s = 0.48
	RCTA	1.172+0.127RCTA+0.103VW r^2 = 0.86/s = 0.39	1.903+0.10RCTA+0.09VW-0.001FL r^2 = 0.80/s = 0.50

* 27 Curves ** 29 Curves

TABLE D83 : REGRESSION RELATIONSHIPS FOR FREE CAR MIDDLE LATERAL ACCELERATIONS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$A_{FCM}(85)$	None	0.682+25.144E r^2 = 0.45/s = 0.50	0.723+25.79E r^2 = 0.49/s = 0.54
$A_{FCM}(85)$	R	1.737-0.005R+0.28RW-0.03GRA r^2 = 0.89/s = 0.23	1.942-0.005R+0.24RW r^2 = 0.88/s = 0.27
	C	1.074+0.12C+0.074VW r^2 = 0.74/s = 0.35	1.30+0.113C r^2 = 0.73/s = 0.39
$A_{FCM}(85)$	TA	0.68+25.144E r^2 = 0.45/s = 0.50	0.723+25.79E r^2 = 0.49/s = 0.54
	RCTA	1.074+0.21RCTA+0.074VW r^2 = 0.74/s = 0.35	1.30+0.197RCTA r^2 = 0.73/s = 0.39

* 22 Curves ** 14 Curves

TABLE D84 : REGRESSION RELATIONSHIPS FOR GOODS VEHICLE MIDDLE LATERAL ACCELERATIONS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
A_{GM} (85)	None	1.44-0.002FL+19.57E r^2	14.33-0.15DS+18.57E r^2 = 0.69/s = 0.36	0.843+26.07E-0.001FL r^2 = 0.78/s = 0.32
A_{GM} (85)	R	5.434-0.004R-0.03DS-0.034VW r^2 = 0.89/s = 0.21	8.59-0.004R-0.064DS r^2 = 0.84/s = 0.26	2.80-0.005R r^2 = 0.92/s = 0.19
	C	1.25+0.037C-0.001FL+12.7E r^2 = 0.82/s = 0.27	7.78+0.124C-0.08DS r^2 = 0.89/s = 0.22	0.80+0.032C+18.26E-0.001FL r^2 = 0.90/s = 0.22
A_{GM} (85)	TA	5.60+0.72TA-0.06DS+19.7E+0.001SD-0.06VW r^2 = 0.91/s = 0.20	12.71+0.79TA-0.13DS+8.66E r^2 = 0.89/s = 0.22	0.843+26.07E-0.001FL r^2 = 0.78/s = 0.32
	RCTA	1.25+0.065RCTA-0.001FL+12.7E r^2 = 0.82/s = 0.27	7.78+0.217RCTA-0.08DS r^2 = 0.89/s = 0.22	0.80+0.055RCTA+18.26E-0.001FL r^2 = 0.90/s = 0.22

* 31 Curves ** 14 Curves *** 17 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
A_{GM} (85)	None	1.42-0.002FL+17.30E r^2 = 0.62/s = 0.39	3.02-0.003FL r^2 = 0.65/s = 0.39
A_{GM} (85)	R	2.817-0.005R r^2 = 0.85/s = 0.23	2.95-0.00R-0.062GRA r^2 = 0.92/s = 0.20
	C	4.79+0.12C-0.045DS r^2 = 0.93/s = 0.17	3.02-0.003FL r^2 = 0.65/s = 0.39
A_{GM} (85)	TA	10.65+0.72TA-0.11DS-0.10VW+11.28E r^2 = 0.93/s = 0.18	3.02-0.003FL r^2 = 0.65/s = 0.39
	RCTA	4.79+0.21RCTA-0.045DS r^2 = 0.93/s = 0.17	3.02-0.003FL r^2 = 0.65/s = 0.39

* 17 Curves ** 14 Curves

TABLE D85 : REGRESSION RELATIONSHIPS FOR GOODS VEHICLE MIDDLE LATERAL ACCELERATIONS AGAINST DESIGN SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
A_{GM} (85)	None	-1.43+0.423RW r^2 = 0.35/s = 0.45	———
A_{GM} (85)	R	0.606-0.004R+0.276RW r^2 = 0.81/s = 0.26	2.70-0.007R+0.362VW r^2 = 0.96/s = 0.17
	C	0.92+0.078C r^2 = 0.62/s = 0.35	———
A_{CM} (85)	TA	-1.43+0.423RW r^2 = 0.35/s = 0.45	———
	RCTA	0.92+0.136RCTA r^2 = 0.62/s = 0.35	———

* 12 Curves ** 6 Curves

TABLE D86 : REGRESSION RELATIONSHIPS FOR ALL SELECTED CAR MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$A_{CM}(85)$	None	3.023-0.002FL+22.04E-0.006L r^2 = 0.73/s = 0.60	7.91-0.002FL-0.054AS r^2 = 0.59/s = 0.71	1.85+34.05E-0.003FL r^2 = 0.77/s = 0.60
$A_{CM}(85)$	R	4.073-0.008R r^2 = 0.78/s = 0.52	3.85-0.007R r^2 = 0.78/s = 0.50	0.44-0.009R+0.05AS r^2 = 0.85/s = 0.49
	C	1.53+0.05C+11.04E-0.001FL r^2 = 0.88/s = 0.41	1.164+0.064C+0.09VW r^2 = 0.84/s = 0.44	1.413+0.05C+18.52E-0.002FL r^2 = 0.95/s = 0.30
$A_{CM}(85)$	TA	0.854+1.66TA r^2 = 0.72/s = 0.60	3.35+1.49TA-0.03AS r^2 = 0.86/s = 0.41	1.55+0.70TA-0.002FL+22.48E r^2 = 0.82/s = 0.55
	RCTA	1.53+0.09RCTA+11.04E-0.001FL r^2 = 0.88/s = 0.41	1.164+0.112RCTA+0.009VW r^2 = 0.84/s = 0.44	1.413+0.084RCTA+18.52E -0.002FL r^2 = 0.95/s = 0.30

* 37 Curves ** 19 Curves *** 18 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$A_{CM}(85)$	None	4.04-0.003FL r^2 = 0.48/s = 0.81	1.79-0.003FL+32.25E r^2 = 0.79/s = 0.57
$A_{CM}(85)$	R	5.16-0.007R-0.294RW r^2 = 0.87/s = 0.41	4.09-0.008R r^2 = 0.75/s = 0.60
	C	2.03+0.06C-0.001FL r^2 = 0.89/s = 0.39	1.40+0.04C+20.36E-0.002FL r^2 = 0.90/s = 0.41
$A_{CM}(85)$	TA	3.07+1.49TA-0.47RW r^2 = 0.85/s = 0.44	1.92+1.29TA-0.002FL r^2 = 0.81/s = 0.53
	RCTA	2.03+0.11RCTA-0.001FL r^2 = 0.89/s = 0.39	1.40+0.07RCTA+20.36E-0.002FL r^2 = 0.90/s = 0.41

* 19 Curves ** 18 Curves

TABLE D87 : REGRESSION RELATIONSHIPS FOR CAR MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$A_{CM}(85)$	None	0.72+27.34E r^2 = 0.58/s = 0.48	0.666+29.60E r^2 = 0.63/s = 0.58
$A_{CM}(85)$	R	1.86-0.007R+0.25RW+0.006SD r^2 = 0.95/s = 0.19	1.82-0.006R+0.28RW r^2 = 0.94/s = 0.26
	C	0.72+27.34E r^2 = 0.58/s = 0.48	1.27+0.112C r^2 = 0.70/s = 0.52
$A_{CM}(85)$	TA	0.72+27.34E r^2 = 0.58/s = 0.48	0.666+29.60E r^2 = 0.63/s = 0.58
	RCTA	0.72+27.34E r^2 = 0.58/s = 0.48	1.27+0.196RCTA r^2 = 0.70/s = 0.52

* 13 Curves ** 8 Curves

TABLE D88 : REGRESSION RELATIONSHIPS FOR SELECTED FREE CAR MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$A_{FCM}(85)$	None	2.33-0.003FL+22.84E r^2 = 0.62/s = 0.71	8.07-0.002FL+0.056AS r^2 = 0.56/s = 0.74	1.826+34.63E-0.003FL r^2 = 0.77/s = 0.60
$A_{FCM}(85)$	R	4.13-0.008R r^2 = 0.79/s = 0.52	3.90-0.007R r^2 = 0.78/s = 0.50	1.28-0.01R+0.04AS r^2 = 0.85/s = 0.49
	C	1.51+0.053C+11.18E-0.001FL r^2 = 0.87/s = 0.43	1.44+0.065C r^2 = 0.78/s = 0.50	1.385+0.05C+19.00E-0.001FL r^2 = 0.95/s = 0.30
$A_{FCM}(85)$	TA	0.89+1.667TA r^2 = 0.72/s = 0.60	3.43+1.5TA-0.03AS r^2 = 0.86/s = 0.42	1.51+0.72TA-0.002FL+22.73E r^2 = 0.82/s = 0.55
	RCTA	1.51+0.09RCTA+11.18E-0.001FL r^2 = 0.87/s = 0.43	1.44+0.114RCTA r^2 = 0.78/s = 0.50	1.385+0.085RCTA+19.00E-0.001FL r^2 = 0.95/s = 0.30

* 37 Curves ** 19 Curves *** 18 Curves

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$A_{FCM}(85)$	None	5.15-0.003FL-0.009L r^2 = 0.67/s = 0.67	1.77-0.003FL+32.59E r^2 = 0.78/s = 0.57
$A_{FCM}(85)$	R	4.14-0.008R r^2 = 0.82/s = 0.48	4.12-0.008R r^2 = 0.76/s = 0.58
	C	1.466+0.07C r^2 = 0.86/s = 0.43	1.38+0.04C+20.97E-0.002FL r^2 = 0.89/s = 0.42
$A_{FCM}(85)$	TA	0.93+1.664TA r^2 = 0.69/s = 0.63	1.91+1.30TA-0.002FL r^2 = 0.81/s = 0.53
	RCTA	1.466+0.126RCTA r^2 = 0.86/s = 0.43	1.38+0.066RCTA+20.97E-0.002FL r^2 = 0.89/s = 0.42

* 19 Curves ** 18 Curves

TABLE D89 : REGRESSION RELATIONSHIPS FOR SELECTED FREE CAR MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRESENTATIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
$A_{FCM}(85)$	None	0.81+26.42E r^2 = 0.57/s = 0.48	0.76+28.60E r^2 = 0.62/s = 0.57
$A_{FCM}(85)$	R	1.944-0.007R+0.24RW+0.005SD r^2 = 0.95/s = 0.18	1.94-0.006R+0.26RW r^2 = 0.94/s = 0.25
	C	1.59+0.10C r^2 = 0.57/s = 0.47	1.334+0.11C r^2 = 0.70/s = 0.50
$A_{FCM}(85)$	TA	0.81+26.42E r^2 = 0.57/s = 0.48	0.76+28.60E r^2 = 0.62/s = 0.57
	RCTA	1.59+0.173RCTA r^2 = 0.57/s = 0.47	1.334+0.19RCTA r^2 = 0.70/s = 0.50

* 13 Curves ** 8 Curves

TABLE D90 : REGRESSION RELATIONSHIPS FOR SELECTED GOODS VEHICLE MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
A_{GM} (85)	None	1.22-0.002FL+27.47E r^2 = 0.72/s = 0.36	———	-0.63+42.63E r^2 = 0.66/s = 0.44
A_{GM} (85)	R	2.98-0.006R r^2 = 0.92/s = 0.19	3.013-0.006R r^2 = 0.88/s = 0.21	2.96-0.005R r^2 = 0.93/s = 0.20
	C	1.13+0.033C-0.002FL+16.41E r^2 = 0.83/s = 0.29	0.474+0.123C r^2 = 0.85/s = 0.23	1.144+0.05C r^2 = 0.66/s = 0.44
A_{GM} (85)	TA	-0.57+0.94TA+0.001SD+21.34E r^2 = 0.83/s = 0.29	0.42+1.27TA+0.00SD r^2 = 0.89/s = 0.21	-0.63+42.63E r^2 = 0.66/s = 0.44
	RCTA	1.13+0.06RCTA-0.002FL+16.41E r^2 = 0.83/s = 0.29	0.474+0.215RCTA r^2 = 0.85/s = 0.23	1.144+0.086RCTA r^2 = 0.66/s = 0.44

* 16 Curves ** 8 Curves *** 8 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
A_{GM} (85)	None	6.87-0.07AS r^2 = 0.41/s = 0.50	0.744-0.01L+37.55E r^2 = 0.99/s = 0.09
A_{GM} (85)	R	2.975-0.005R r^2 = 0.92/s = 0.19	2.99-0.006R r^2 = 0.92/s = 0.25
	C	0.38+0.133C+0.004SD r^2 = 0.94/s = 0.17	———
A_{GM} (85)	TA	0.786+0.96TA r^2 = 0.75/s = 0.32	———
	RCTA	0.38+0.233RCTA+0.04SD r^2 = 0.94/s = 0.17	———

* 11 Curves ** 5 Curves

TABLE D91 : REGRESSION RELATIONSHIPS FOR SELECTED GOODS VEHICLE MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON DUAL CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		All Curves*	Uphill Curves**
A_{GM} (85)	None	———	———
A_{GM} (85)	R	3.016-0.006R r^2 = 0.81/s = 0.26	———
	C	1.01+0.073C r^2 = 0.60/s = 0.38	———
A_{GM} (85)	TA	———	———
	RCTA	1.01+0.13RCTA r^2 = 0.60/s = 0.38	———

* 9 Curves ** 5 Curves

TABLE D92 : REGRESSION RELATIONSHIPS FOR ALL CAR MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$A_{CM}(85)$	None	1.86+23.25E-0.002FL r^2 = 0.51/s = 0.63	1.72+22.37E-0.002FL r^2 = 0.51/s = 0.63	1.92-0.002FL+24.93E r^2 = 0.56/s = 0.66
$A_{CM}(85)$	R	1.62-0.006R+0.024AS-0.001FL+6.34E r^2 = 0.81/s = 0.41	1.58-0.005R+8.86E+0.02AS -0.001FL r^2 = 0.80/s = 0.41	1.39-0.007R+0.03AS r^2 = 0.83/s = 0.41
	C	1.03+0.06C+0.044VW+7.33E-0.001FL+0.06RW +0.001L r^2 = 0.83/s = 0.40	0.78+0.06C+0.07VW+9.29E r^2 = 0.80/s = 0.40	0.95+0.07C+0.05VW+9.06E-0.001FL+0.10RW r^2 = 0.87/s = 0.38
$A_{CM}(85)$	TA	1.89+0.92TA-0.002FL+7.53E r^2 = 0.74/s = 0.47	2.02+1.08TA-0.001FL r^2 = 0.78/s = 0.42	2.45+1.04TA-0.002FL r^2 = 0.71/s = 0.54
	RCTA	0.99+0.11RCTA+0.06VW+8.33E-0.001FL+ 0.055RW r^2 = 0.82/s = 0.40	0.78+0.104RCTA+0.07VW+9.29E r^2 = 0.80/s = 0.40	0.95+0.12RCTA+0.05VW+9.06E -0.001FL+0.10RW r^2 = 0.87/s = 0.38

* 78 Curves ** 38 Curves *** 40 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$A_{CM}(85)$	None	2.02-0.002FL+21.22E r^2 = 0.52/s = 0.64	1.68+25.84E-0.002FL r^2 = 0.55/s = 0.66
$A_{CM}(85)$	R	1.13-0.006R+0.04AS-0.001FL r^2 = 0.84/s = 0.37	2.01-0.01R+0.02AS r^2 = 0.75/s = 0.49
	C	1.41+0.06C+9.95E-0.001FL r^2 = 0.82/s = 0.40	1.12+0.07C+0.11VW r^2 = 0.77/s = 0.47
$A_{CM}(85)$	TA	2.41+0.98TA-0.002FL r^2 = 0.70/s = 0.51	2.08+1.16TA-0.002FL r^2 = 0.78/s = 0.46
	RCTA	1.41+1.04RCTA+9.95E-0.001FL r^2 = 0.82/s = 0.40	1.12+0.123RCTA+0.11VW r^2 = 0.77/s = 0.47

* 43 Curves ** 35 Curves

TABLE D93 : REGRESSION RELATIONSHIPS FOR FREE CAR MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$A_{FCM}(85)$	None	1.90+23.07E-0.002FL r^2 = 0.52/s = 0.64	1.79+21.79E-0.002FL r^2 = 0.49/s = 0.64	1.94-0.002FL+25.14E r^2 = 0.56/s = 0.66
$A_{FCM}(85)$	R	1.97-0.006R+0.026AS- 0.001FL r^2 = 0.80/s = 0.42	1.76-0.006R+0.02AS+8.06E r^2 = 0.77/s = 0.44	1.79-0.007R+0.03AS r^2 = 0.83/s = 0.41
	C	1.08+0.06C+0.04VW+7.29E-0.001FL+ 0.056RW+0.001L r^2 = 0.82/s = 0.41	0.86+0.06C+0.07VW+8.62E r^2 = 0.79/s = 0.42	1.05+0.07C+9.36E-0.001FL +0.12RW+0.001L r^2 = 0.87/s = 0.37
$A_{FCM}(85)$	TA	1.93+0.93TA-0.002FL+7.25E r^2 = 0.74/s = 0.48	2.05+1.08TA-0.001FL r^2 = 0.76/s = 0.44	2.47+1.05TA-0.002FL r^2 = 0.71/s = 0.53
	RCTA	1.19+0.105RCTA+0.06VW+9.18E-0.001FL r^2 = 0.81/s = 0.41	0.86-0.105RCTA+0.07VW+8.62E r^2 = 0.79/s = 0.42	0.99+0.11RCTA+12.39E r^2 = 0.86/s = 0.38

* 78 Curves ** 38 Curves *** 40 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$A_{FCM}(85)$	None	2.08-0.002FL+20.84E r^2 = 0.50/s = 0.66	1.70+25.93E-0.002FL r^2 = 0.55/s = 0.66
$A_{FCM}(85)$	R	1.47-0.006R+0.03AS-0.001FL r^2 = 0.83/s = 0.38	2.08-0.01R+0.02AS r^2 = 0.76/s = 0.48
	C	2.05+0.07C+0.06VW-0.001FL r^2 = 0 84/s = 0.38	0.45+0.06C+0.07VW+13.04E-0.06GRA r^2 = 0.80/s = 0.45
$A_{FCM}(85)$	TA	2.44+0.97TA-0.002FL r^2 = 0.69/s = 0.52	1.68+1.02TA-0.002FL+8.88E r^2 = 0.80/s = 0.45
	RCTA	2.05+0.12RCTA+0.06VW-0.001SD-0.001FL r^2 = 0.84/s = 0.38	0.45+0.12RCTA+0.07VW+13.04E-0.06GRA r^2 = 0.80/s = 0.45

* 43 Curves ** 35 Curves

TABLE D94 : REGRESSION RELATIONSHIPS FOR GOODS VEHICLE MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$A_{GM}(85)$	None	1.053+20.11E-0.001FL r^2 = 0.58/s = 0.39	-0.244+26.38E+0.001SD r^2 = 0.53/s = 0.41	0.73+25.66E-0.001FL r^2 = 0.65/s = 0.37
$A_{GM}(85)$	R	1.54-0.005R+0.02AS r^2 = 0.84/s = 0.23	1.12-0.005R+0.024AS r^2 = 0.79/s = 0.27	2.84-0.005R r^2 = 0.87/s = 0.22
	C	0.98+0.05C-0.001FL+10.05E+0.001L r^2 = 0.77/s = 0.29	1.24+0.09C-0.001FL+0.001L r^2 = 0.83/s = 0.25	0.43+0.04C+16.08E-0.001FL +0.09RW r^2 = 0.84/s = 0.27
$A_{GM}(85)$	TA	1.27+11.53E-0.001FL+0.466TA r^2 = 0.70/s = 0.33	1.82+0.808TA-0.002FL r^2 = 0.76/s = 0.29	0.87+19.62E-0.001FL+0.30TA r^2 = 0.70/s = 0.35
	RCTA	0.95+0.08RCTA-0.001FL+11.39E r^2 = 0.74/s = 0.31	1.24+0.154RCTA-0.001FL r^2 = 0.77/s = 0.28	0.43+0.07RCTA+16.08E-0.001FL +0.09RW r^2 = 0.84/s = 0.27

* 43 Curves ** 20 Curves *** 23 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$A_{GM}(85)$	None	1.11+19.76E-0.001FL r^2 = 0.58/s = 0.41	0.076+23.51E r^2 = 0.34/s = 0.46
$A_{GM}(85)$	R	1.28-0.005R+0.023AS r^2 = 0.85/s = 0.24	2.89-0.005R-0.07GRA r^2 = 0.90/s = 0.19
	C	-0.57+0.11C-0.001FL+0.02AS r^2 = 0.84/s = 0.26	0.62+0.04C+17.08E-0.001FL r^2 = 0.79/s = 0.28
$A_{GM}(85)$	TA	1.28+10.96E-0.001FL+0.42TA r^2 = 0.68/s = 0.37	0.076+23.51E r^2 = 0.34/s = 0.46
	RCTA	-0.57+0.19RCTA-0.001FL+0.02AS r^2 = 0.84/s = 0.26	0.62+0.06RCTA+17.08E-0.001FL r^2 = 0.79/s = 0.28

* 23 Curves ** 20 Curves

TABLE D95 : REGRESSION RELATIONSHIPS FOR ALL SELECTED CAR MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$A_{CM}(85)$	None	1.80+26.15E-0.002FL r^2 = 0.58/s = 0.67	1.86+21.47E-0.002FL r^2 = 0.51/s = 0.70	1.61+32.69E-0.002FL r^2 = 0.67/s = 0.64
$A_{CM}(85)$	R	2.07-0.007R+0.03AS-0.001FL r^2 = 0.81/s = 0.46	3.84-0.007R r^2 = 0.76/s = 0.48	1.48-0.008R+0.033AS r^2 = 0.83/s = 0.46
	C	-0.15+0.06C+12.01E-0.001FL+0.09RW+ 0.013AS r^2 = 0.86/s = 0.41	0.63+0.07C+0.07VW+0.12RW r^2 = 0.84/s = 0.40	0.61+0.06C+20.10E r^2 = 0.86/s = 0.42
$A_{CM}(85)$	TA	1.77+0.85TA-0.002FL+11.25E r^2 = 0.73/s = 0.54	1.83+1.174TA-0.001FL r^2 = 0.80/s = 0.45	1.60+21.32E-0.002FL+0.633TA r^2 = 0.75/s = 0.57
	RCTA	-0.15+0.10RCTA+12.01E-0.001FL+0.09RW +0.013AS r^2 = 0.86/s = 0.41	0.63+0.12RCTA+0.07VW+0.12RW r^2 = 0.84/s = 0.40	0.61+0.10RCTA+20.10E r^2 = 0.86/s = 0.42

* 50 Curves ** 25 Curves *** 25 Curves

DEPENDNAT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$A_{CM}(85)$	None	2.19+20.98E-0.002FL r^2 = 0.55/s = 0.71	1.19+36.07E-0.002FL r^2 = 0.69/s = 0.60
$A_{CM}(85)$	R	3.98-0.007R r^2 = 0.81/s = 0.45	2.20-0.01R+0.025AS r^2 = 0.77/s = 0.52
	C	1.015+0.064C+10.21E r^2 = 0.83/s =0.43	-1.10+0.06C+33.28E+0.001SD+0.002L-0.07GRA r^2 = 0.90/s = 0.37
$A_{CM}(85)$	TA	2.53+0.96TA-0.002FL r^2 = 0.67/s = 0.61	1.15+0.86TA-0.002FL+19.97E r^2 = 0.84/s = 0.44
	RCTA	1.015+0.11RCTA+10.21E r^2 = 0.83/s = 0.43	-0.27+0.09RCTA+31.65E+0.001SD r^2 = 0.85/s = 0.42

* 27 Curves ** 23 Curves

TABLE D96 : REGRESSION RELATIONSHIPS FOR SELECTED FREE CAR MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$A_{FCM}(85)$	None	1.84+25.99E-0.002FL r^2 = 0.57/s = 0.68	1.91+21.16E-0.001FL r^2 = 0.49/s = 0.72	1.63+32.77E-0.002FL r^2 = 0.67/s = 0.63
$A_{FCM}(85)$	R	2.35-0.01R+0.02AS r^2 = 0.80/s = 0.46	3.89-0.007R r^2 = 0.76/s = 0.48	2.00-0.01R+0.03AS r^2 = 0.83/s = 0.46
	C	0.86+0.06C+14.63E r^2 = 0.81/s = 0.45	0.66+0.07C+0.07VW+0.12RW r^2 = 0.83/s = 0.42	0.65+0.06C+20.10E r^2 = 0.87/s = 0.41
$A_{FCM}(85)$	TA	1.80+0.86TA-0.002FL+10.94E r^2 = 0.72/s = 0.55	1.85+1.18TA-0.001FL r^2 = 0.78/s = 0.47	1.62+21.35E-0.002FL+0.636TA r^2 = 0.75/s = 0.57
	RCTA	0.86+0.10RCTA+14.63E r^2 = 0.81/s = 0.45	0.66+0.12RCTA+0.07VW+0.12RW r^2 = 0.83/s = 0.42	0.65+0.10RCTA+20.10E r^2 = 0.87/s = 0.41

* 50 Curves ** 25 Curves *** 25 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$A_{FCM}(85)$	None	2.25+20.72E-0.002FL r^2 = 0.53/s = 0.73	1.21+36.04E-0.002FL r^2 = 0.69/s = 0.59
$A_{FCM}(85)$	R	4.04-0.007R r^2 = 0.81/s = 0.45	2.30-0.01R+0.024AS r^2 = 0.77/s = 0.51
	C	1.08+0.065C+9.50E r^2 = 0.83/s = 0.44	-1.02+0.06C+33.24E+0.001SD+0.002L-0.07GRA r^2 = 0.89/s = 0.38
$A_{FCM}(85)$	TA	2.55+0.97TA-0.002FL r^2 = 0.66/s = 0.62	1.17+0.85TA-0.002FL+20.09E r^2 = 0.84/s = 0.44
	RCTA	1.08+0.114RCTA+9.50E r^2 = 0.83/s = 0.44	-0.22+0.084RCTA+31.69E+0.001SD r^2 = 0.85/s = 0.42

* 27 Curves ** 23 Curves

TABLE D97 : REGRESSION RELATIONSHIPS FOR SELECTED GOODS VEHICLE MIDDLE LATERAL ACCELERATIONS AGAINST APPROACH SPEEDS, CURVE GEOMETRY AND FLOW ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE).

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS		
		All Curves*	Left-Hand Curves**	Right-Hand Curves***
$A_{GM}(85)$	None	1.06+21.30E-0.001FL $r^2 = 0.52/s = 0.44$	———	0.107+28.54E $r^2 = 0.43/s = 0.50$
$A_{GM}(85)$	R	1.48-0.006R+0.02AS $r^2 = 0.92/s = 0.18$	2.89-0.005R $r^2 = 0.89/s = 0.19$	3.06-0.006R $r^2 = 0.87/s = 0.24$
	C	1.01+0.06C $r^2 = 0.63/s = 0.38$	0.743+0.084C $r^2 = 0.82/s = 0.25$	0.27+0.04C+18.64E $r^2 = 0.69/s = 0.39$
$A_{GM}(85)$	TA	1.30+12.08E-0.001FL+0.51TA $r^2 = 0.69/s = 0.36$	1.73+0.864TA-0.002FL $r^2 = 0.86/s = 0.23$	0.107+28.54E $r^2 = 0.43/s = 0.50$
	RCTA	1.01+0.11RCTA $r^2 = 0.63/s = 0.38$	0.743+0.15RCTA $r^2 = 0.82/s = 0.25$	0.27+0.07RCTA+18.64E $r^2 = 0.69/s = 0.39$

* 25Curves   ** 12 Curves   *** 13 Curves

DEPENDANT VARIABLE	RADIUS REPRE-SENTA-TIONS	REGRESSION RELATIONSHIPS	
		Uphill Curves*	Downhill Curves**
$A_{GM}(85)$	None	1.08+21.89E-0.001FL $r^2 = 0.57/s = 0.45$	———
$A_{GM}(85)$	R	0.75-0.01R+0.034AS $r^2 = 0.93/s = 0.18$	0.50-0.005R+0.03AS $r^2 = 0.96/s = 0.13$
	C	0.73+0.10C $r^2 = 0.75/s = 0.33$	-3.64+0.04C+0.06AS $r^2 = 0.95/s = 0.15$
$A_{GM}(85)$	TA	1.25+13.02E-0.001FL+0.43TA $r^2 = 0.67/s = 0.41$	———
	RCTA	0.73+0.17RCTA $r^2 = 0.75/s = 0.33$	-3.64+0.07RCTA+0.06AS $r^2 = 0.95/s = 0.15$

* 16 Curves   ** 9 Curves

TABLE D98 : ANALYSIS OF VARIANCE FOR ALL CAR ENTRY SPEED LINEAR REGRESSION RELATIONSHIPS (85th PERCENTILE SPEED)

SINGLE CARRIAGEWAYS: $V_{CE}(85) = 43.28-0.65C+0.49AS+0.824VW$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	5973	55	1790		
Regression	5333	3	1778	144.2	<.01
Residual	640	52	12		

DUAL CARRIAGEWAYS: $V_{CE}(85) = 32.34+0.744AS-1.096C-0.005FL$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	1834	21	572		
Regression	1692	3	564	71.7	<.01
Residual	142	18	8		

TABLE D99 : ANALYSIS OF VARIANCE FOR GOODS VEHICLE ENTRY SPEED LINEAR REGRESSION RELATIONSHIPS (85th PERCENTILE SPEED)

SINGLE CARRIAGEWAYS: $V_{GE}(85) = 85.53-0.894C-0.014FL$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	1322	30	434		
Regression	834	2	427	23.9	<.01
Residual	488	28	17		

DUAL CARRIAGEWAYS: $V_{GE}(85) = 17.303+0.83AS-0.045C$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	891	11	434		
Regression	859	2	430	120.4	<.01
Residual	32	9	4		

TABLE D100 : ANALYSIS OF VARIANCE FOR SELECTED ALL CAR ENTRY SPEED LINEAR REGRESSION RELATIONSHIPS (85th PERCENTILE SPEED)

SINGLE CARRIAGEWAYS: $V_{CE}(85) = 46.06-0.64C+0.456AS+0.71VW$

Source	Sum of Squares	Degress of Freedom	Mean Square	F Value	Significance Level
Total	4549	36	1414		
Regression	4213	3	1404	138.0	<.01
Residual	336	33	10		

DUAL CARRIAGEWAYS: $V_{CE}(85) = 27.08+0.726AS-0.855C$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	1074	12	501		
Regression	984	2	492	54.6	<.01
Residual	90	10	9		

TABLE D101: ANALYSIS OF VARIANCE FOR SELECTED GOODS VEHICLE ENTRY SPEED LINEAR REGRESSION RELATIONSHIPS (85th PERCENTILE SPEED)

SINGLE CARRIAGEWAYS: $V_{GE}(85) = 72.90-0.68C+0.006SD$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	1016	15	423		
Regression	813	2	406	26.1	<.01
Residual	203	13	17		

DUAL CARRIAGEWAYS: $V_{GE}(85) = 17.96-0.865C+0.805AS$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	616	8	305		
Regression	605	2	303	172.9	<.01
Residual	11	6	2		

TABLE D102: ANALYSIS OF VARIANCE FOR ENTRY SPEED LINEAR REGRESSION RELATIONSHIPS ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE)

ALL CARS $V_{CE}(85) = 34.86 - 0.64C + 0.56AS + 0.735VW + 0.69RW$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	9993	77	2275		
Regression	9046	4	2262	174.4	<.01
Residual	947	73	13		

GOODS VEHICLES: $V_{GE}(85) = 39.25 - 0.753C + 0.49AS + 0.524VW$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	2313	42	556		
Regression	1614	3	538	30.0	<.01
Residual	699	39	18		

TABLE D103: ANALYSIS OF VARIANCE FOR SELECTED ENTRY SPEED LINEAR REGRESSION RELATIONSHIPS ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED)

ALL CARS: $V_{CE}(85) = 40.74 - 0.645C + 0.52AS + 0.784VW$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	6785	49	2124		
Regression	6341	3	2114	218.8	<.01
Residual	444	46	10		

GOODS VEHICLES: $V_{GE}(85) = 19.27 - 0.74C + 0.76AS$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	1744	24	755		
Regression	1485	2	743	63.0	<.01
Residual	259	22	12		

TABLE D104: ANALYSIS OF VARIANCE FOR ALL CAR ENTRY SPEED CURVILINEAR REGRESSION RELATIONSHIPS (85th PERCENTILE SPEED)

SINGLE CARRIAGEWAYS: $V_{CE}(85) = 48.69-0.86C+0.475AS+0.0004C^3$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	5974	55	1750		
Regression	5206	3	1735	117.6	<.01
Residual	768	52	15		

DUAL CARRIAGEWAYS: $V_{CE}(85) = 26.62+0.757AS-0.96C-0.0004C^3$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	1833	21	563		
Regression	1659	3	553	57.1	<.01
Residual	174	18	10		

TABLE D105 : ANALYSIS OF VARIANCE FOR GOODS VEHICLE ENTRY SPEED CURVILINEAR REGRESSION RELATIONSHIPS (85th PERCENTILE SPEED)

SINGLE CARRIAGEWAYS: $V_{GE}(85) = 41.98-0.023C^2+0.40AS+0.18C$

Source	Sum of Sqares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	1323	30	293		
Regression	823	3	274	14.8	<.01
Residual	500	27	19		

DUAL CARRIAGEWAYS: $V_{GE}(85) = 18.75+0.833AS-1.23C+0.012C^2$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	892	11	293		
Regression	861	3	289	74.6	<.01
Residual	31	8	4		

TABLE D106: ANALYSIS OF VARIANCE FOR ALL CAR MIDDLE SPEED LINEAR REGRESSION RELATIONSHIPS (85th PERCENTILE SPEED)

SINGLE CARRIAGEWAYS: $V_{CM}(85) = 43.63-0.804C+0.46AS+0.627VW$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	8120	55	2430		
Regression	7239	3	2413	142.4	<.01
Residual	881	52	17		

DUAL CARRIAGEWAYS: $V_{CM}(85) = 35.30-1.526C+0.657AS$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	2439	21	1094		
Regression	2157	2	1079	72.75	<.01
Residual	282	19	15		

TABLE D107 : ANALYSIS OF VARIANCE FOR GOODS VEHICLE MIDDLE SPEED LINEAR REGRESSION RELATIONSHIPS (85th PERCENTILE SPEED

SINGLE CARRIAGEWAYS: $V_{GM}(85) = 73.55-0.856C+0.005SD$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	1743	30	627		
Regression	1218	2	609	32.5	<.01
Residual	525	28	18		

DUAL CARRIAGEWAYS: $V_{GM}(85) = 9.16+0.858AS-0.824C$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	892	11	405		
Regression	785	2	393	32.9	<.01
Residual	107	9	12		

TABLE D108: ANALYSIS OF VARIANCE FOR SELECTED ALL CAR MIDDLE SPEED LINEAR REGRESSION RELATIONSHIPS (85th PERCENTILE SPEED)

SINGLE CARRIAGEWAYS: $V_{CM}(85) = 47.72-0.73C+0.39AS+0.003SD$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	5675	36	1761		
Regression	5246	3	1748	134.6	<.01
Residual	429	33	13		

DUAL CARRIAGEWAYS: $V_{CM}(85) = 37.55-1.303C+0.60AS$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	1351	12	622		
Regression	1219	2	609	46.0	<.01
Residual	132	10	13		

TABLE D109: ANALYSIS OF VARIANCE FOR SELECTED GOODS VEHICLE MIDDLE SPEED LINEAR REGRESSION RELATIONSHIPS (85th PERCENTILE SPEED)

SINGLE CARRIAGEWAYS: $V_{GM}(85) = 71.18-0.807C+0.006SD$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	1164	15	525		
Regression	1027	2	514	48.8	<.01
Residual	137	13	11		

DUAL CARRIAGEWAYS: $V_{GM}(85) = 11.67+0.80AS-0.70C$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	533	8	251		
Regression	486	2	243	31.3	<.01
Residual	47	6	8		

TABLE D110: ANALYSIS OF VARIANCE FOR MIDDLE SPEED LINEAR REGRESSION RELATIONSHIPS ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED)

ALL CARS: $V_{CM}(85) = 35.06-0.815C+0.533AS+0.546VW+0.65RW$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	12803	77	2858		
Regression	11352	4	2838	142.8	<.01
Residual	1451	73	20		

GOODS VEHICLES: $V_{GM}(85) = 34.96-0.89C+0.54AS$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	2645	42	989		
Regression	1942	2	971	55.2	<.01
Residual	703	40	18		

TABLE D111: ANALYSIS OF VARIANCE FOR SELECTED MIDDLE SPEED LINEAR REGRESSION RELATIONSHIPS ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE SPEED)

ALL CARS: $V_{CM}(85) = 38.09-0.763C+0.505AS+0.563VW$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	8324	49	2558		
Regression	7628	3	2543	168.2	<.01
Residual	696	46	15		

GOODS VEHICLES: $V_{GM}(85) = 27.94-0.824C+0.604AS$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	1723	24	756		
Regression	1493	2	746	71.3	<.01
Residual	230	22	10		

TABLE D112: ANALYSIS OF VARIANCE FOR ALL CAR MIDDLE SPEED CURVILINEAR REGRESSION RELATIONSHIPS (85th PERCENTILE SPEED)

SINGLE CARRIAGEWAYS: $V_{CM}(85) = 54.58-1.24C+0.39AS+0.0004C^3$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	8121	55	2452		
Regression	7309	3	2436	155.9	<.01
Residual	812	52	16		

DUAL CARRIAGEWAYS: $V_{CM}(85) = 38.01-1.904C+0.646AS+0.015C^2$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	2439	21	736		
Regression	2162	3	721	46.8	<.01
Residual	277	18	15		

TABLE D113: ANALYSIS OF VARIANCE FOR GOODS VEHICLE MIDDLE SPEED CURVILINEAR REGRESSION RELATIONSHIPS (85th PERCENTILE SPEED)

SINGLE CARRIAGEWAYS: $V_{GM}(85) = 32.64-0.133C+0.52AS-0.02C^2$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	1743	30	440		
Regression	1267	3	422	23.9	<.01
Residual	476	27	18		

DUAL CARRIAGEWAYS: $V_{GM}(85) = 10.40+0.86AS-1.117C+0.01C^2$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	894	11	275		
Regression	786	3	262	19.8	<.01
Residual	106	8	13		

TABLE D114: ANALYSIS OF VARIANCE FOR ALL CAR MIDDLE LATERAL ACCELERATION LINEAR REGRESSION RELATIONSHIPS (85th PERCENTILE LATERAL ACCELERATION)

SINGLE CARRIAGEWAYS: $A_{CM}(85) = 2.12-0.007R+0.023AS$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	56		22.5		
Regression	45	2	22.3	105.3	<.01
Residual	11	53	0.2		

DUAL CARRIAGEWAYS: $A_{CM}(85) = 0.219-0.005R+0.022AS+0.209RW$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	9.1	21	3.2		
Regression	8.2	3	2.7	55.7	<.01
Residual	0.9	18	0.5		

TABLE D115: ANALYSIS OF VARIANCE FOR GOODS VEHICLE MIDDLE LATERAL ACCELERATION LINEAR REGRESSION RELATIONSHIPS (85th PERCENTILE LATERAL ACCELERATION)

SINGLE CARRIAGEWAYS: $A_{GM}(85) = 2.83-0.005R$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	11.0	30	9.9		
Regression	9.4	1	9.4	174.0	<.01
Residual	1.6	29	0.5		

DUAL CARRIAGEWAYS: $A_{GM}(85) = 0.066-0.005R+0.038AS$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	3.1	11	1.4		
Regression	2.6	2	1.3	24.1	<.01
Residaul	0.5	9	0.1		

TABLE D116: ANALYSIS OF VARIANCE FOR MIDDLE LATERAL ACCELERATION LINEAR REGRESSION RELATIONSHIPS ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE LATERAL ACCELERATION)

ALL CARS: $A_{CM}(85) = 1.62-0.006R+0.024AS-0.001FL+6.34E$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	65	77	13.5		
Regression	53	4	13.3	80.2	<.01
Residual	12	73	0.2		

GOODS VEHICLES: $A_{GM}(85) = 1.54-0.005R+0.02AS$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	14	42	6.0		
Regression	12	2	5.9	108.4	<.01
Residual	2	40	0.1		

TABLE D117: ANALYSIS OF VARIANCE FOR SELECTED MIDDLE LATERAL ACCELERATION LINEAR REGRESSION RELATIONSHIPS ON SINGLE AND DUAL CARRIAGEWAYS (85th PERCENTILE ACCELERATION)

ALL CARS: $A_{CM}(85) = 2.07-0.007R+0.03AS-0.001FL$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	51	49	13.8		
Regression	41	3	13.6	65.5	<.01
Residual	10	46	0.2		

GOODS VEHICLES: $A_{GM}(85) = 1.48-0.006R+0.02AS$

Source	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance Level
Total	8.8	24	4.09		
Regression	8.1	2	4.06	123.5	<.01
Residual	0.7	22	0.03		

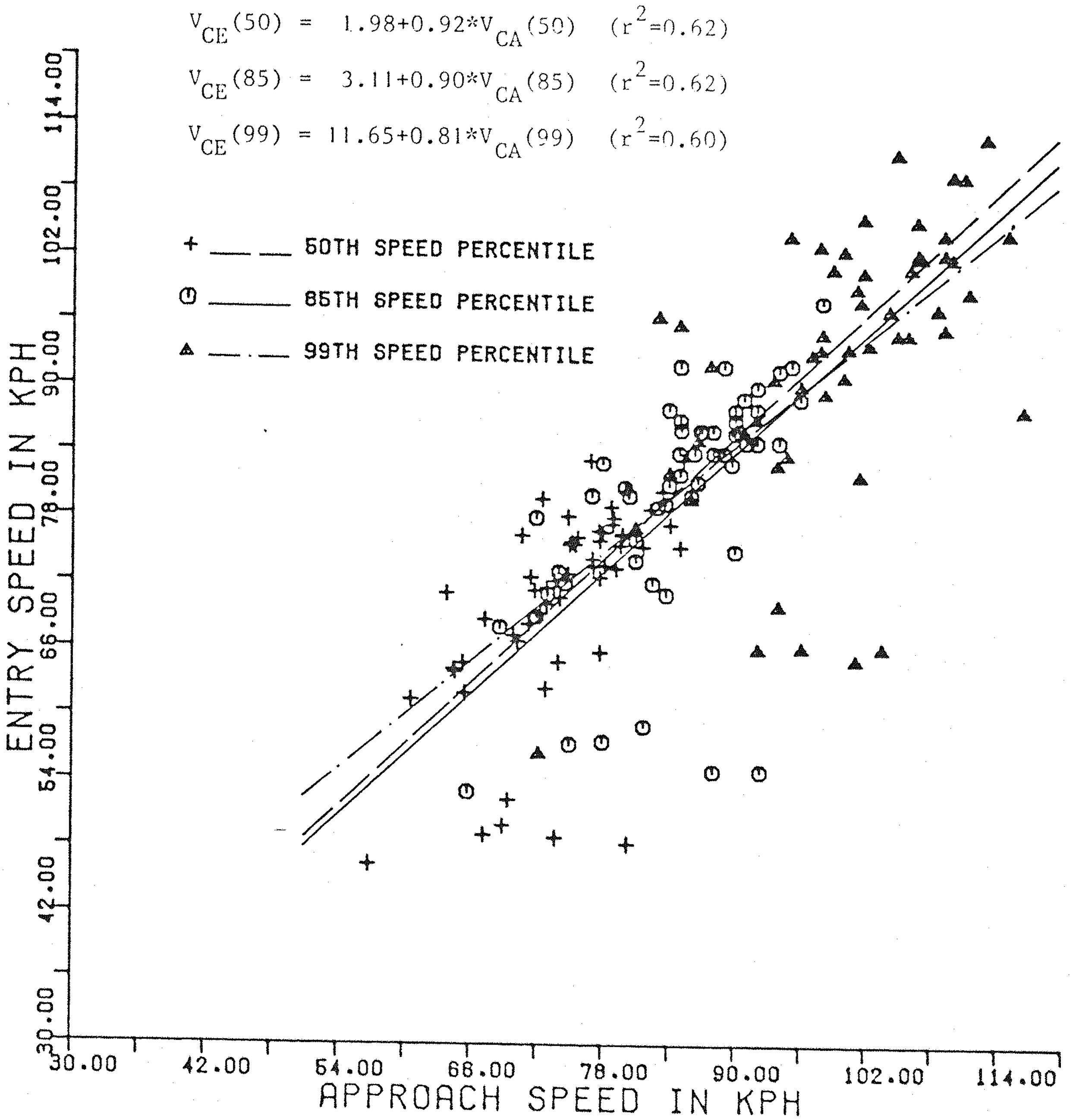


Figure D1(a): Relationship between Entry Speed and Approach Speed
(Single Carriageway - All Cars)

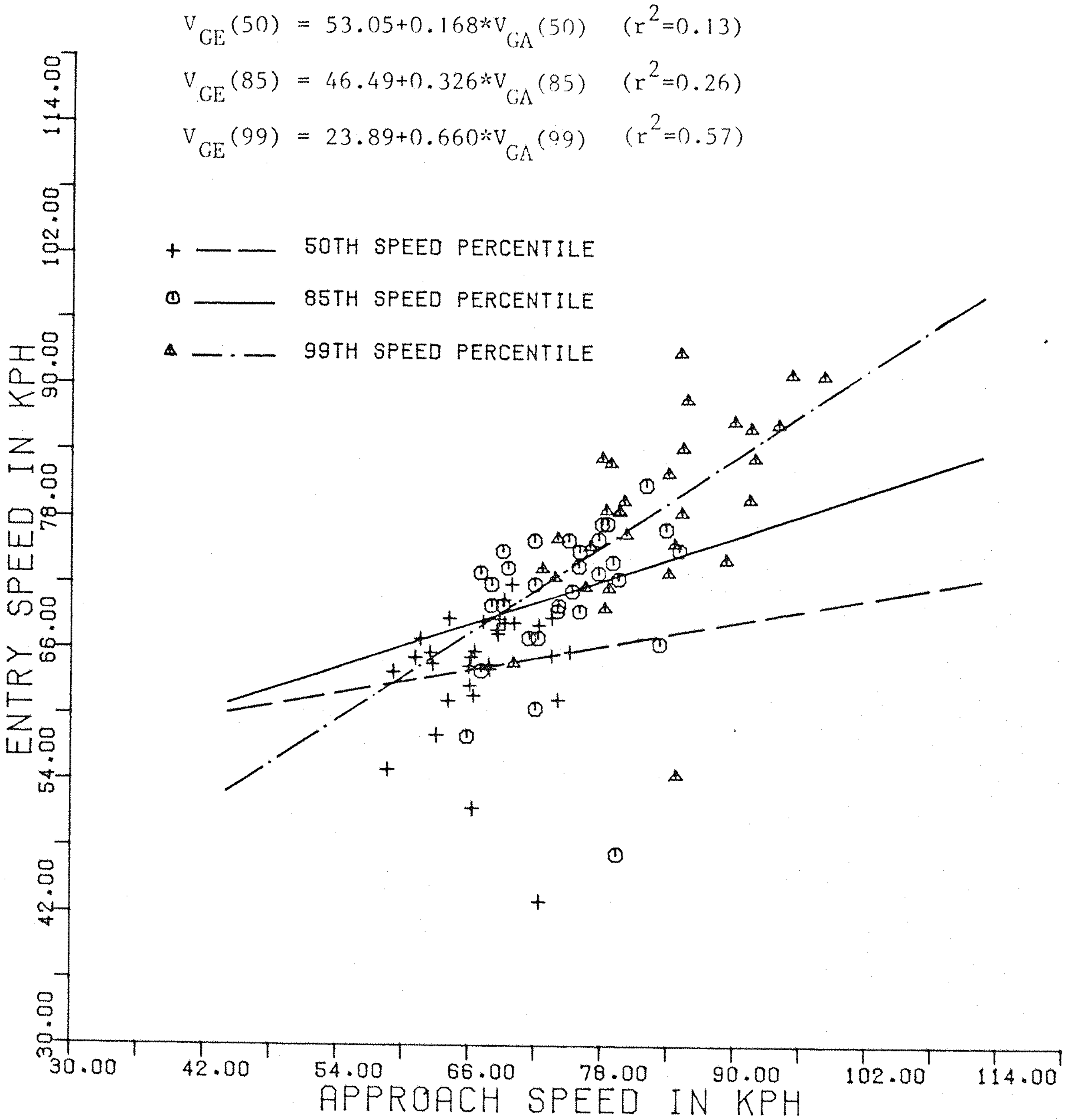


Figure D1(b): Relationship between Entry Speed and Approach Speed
(Single Carriageways - Goods Vehicles)

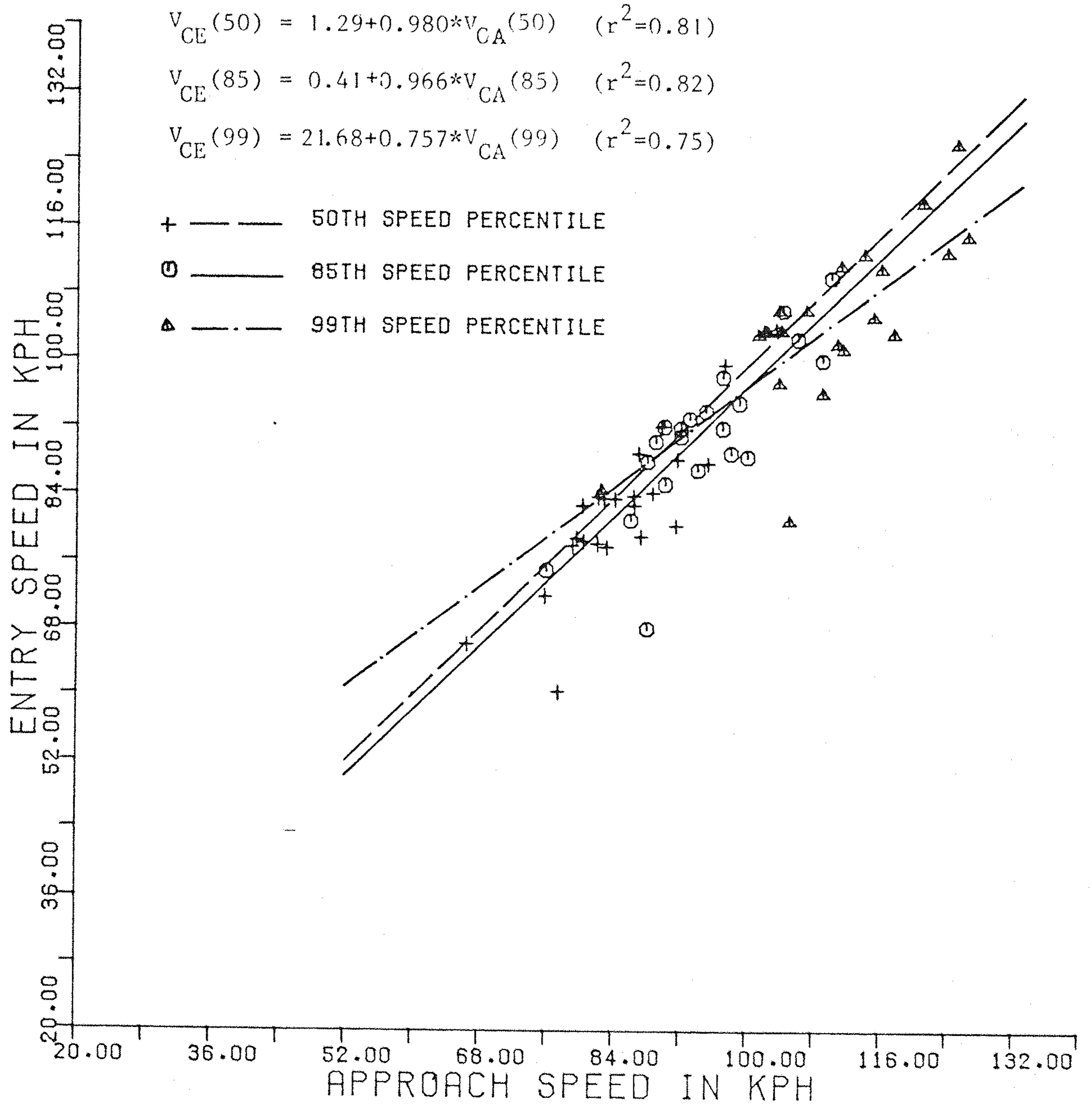


Figure D2(a) : Relationship between Entry Speed and Approach Speed
(Dual Carriageways - All Cars)

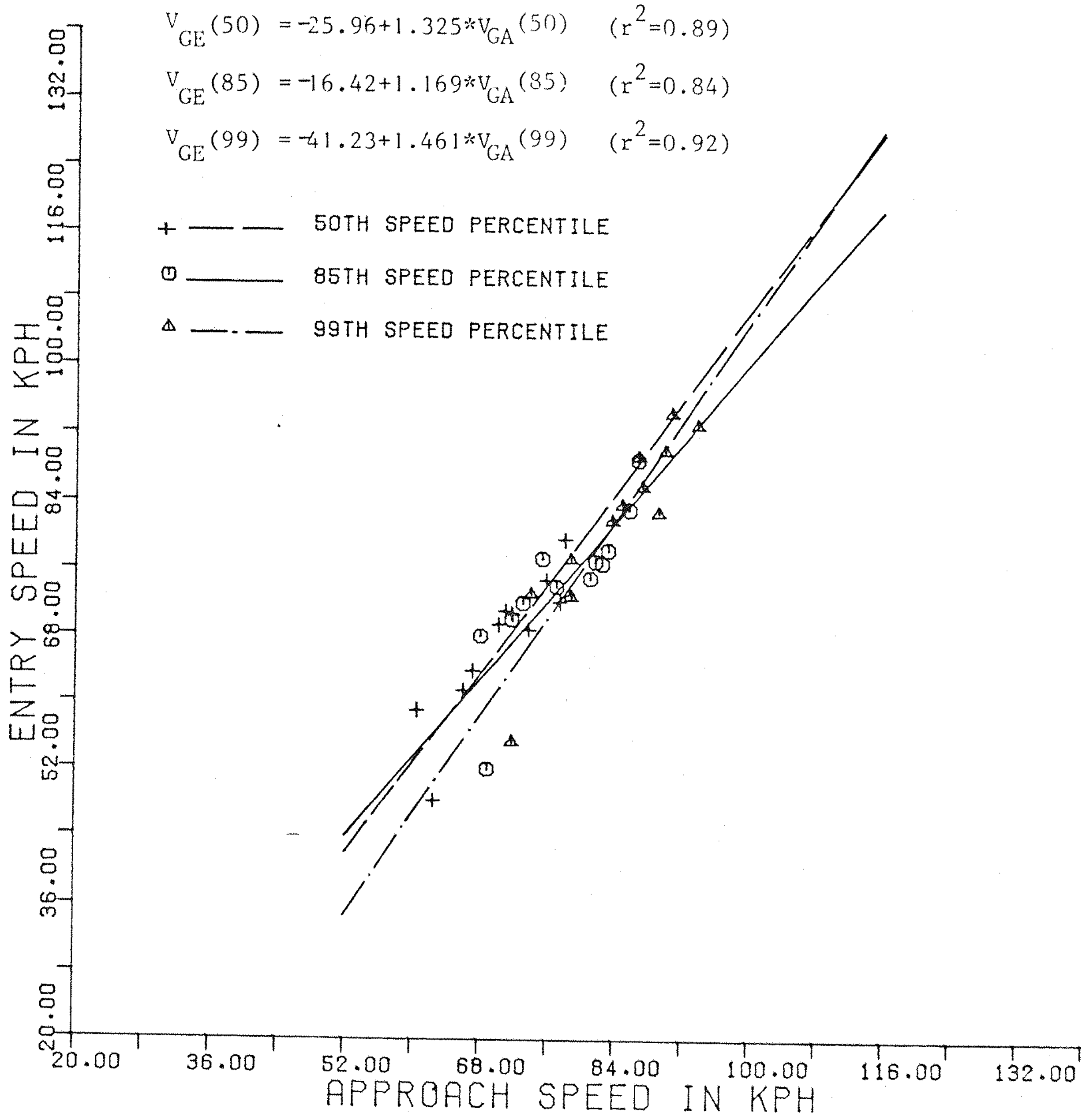


Figure D2(b): Relationship between Entry Speeds and Approach Speeds (Dual Carriageways - Goods Vehicles)

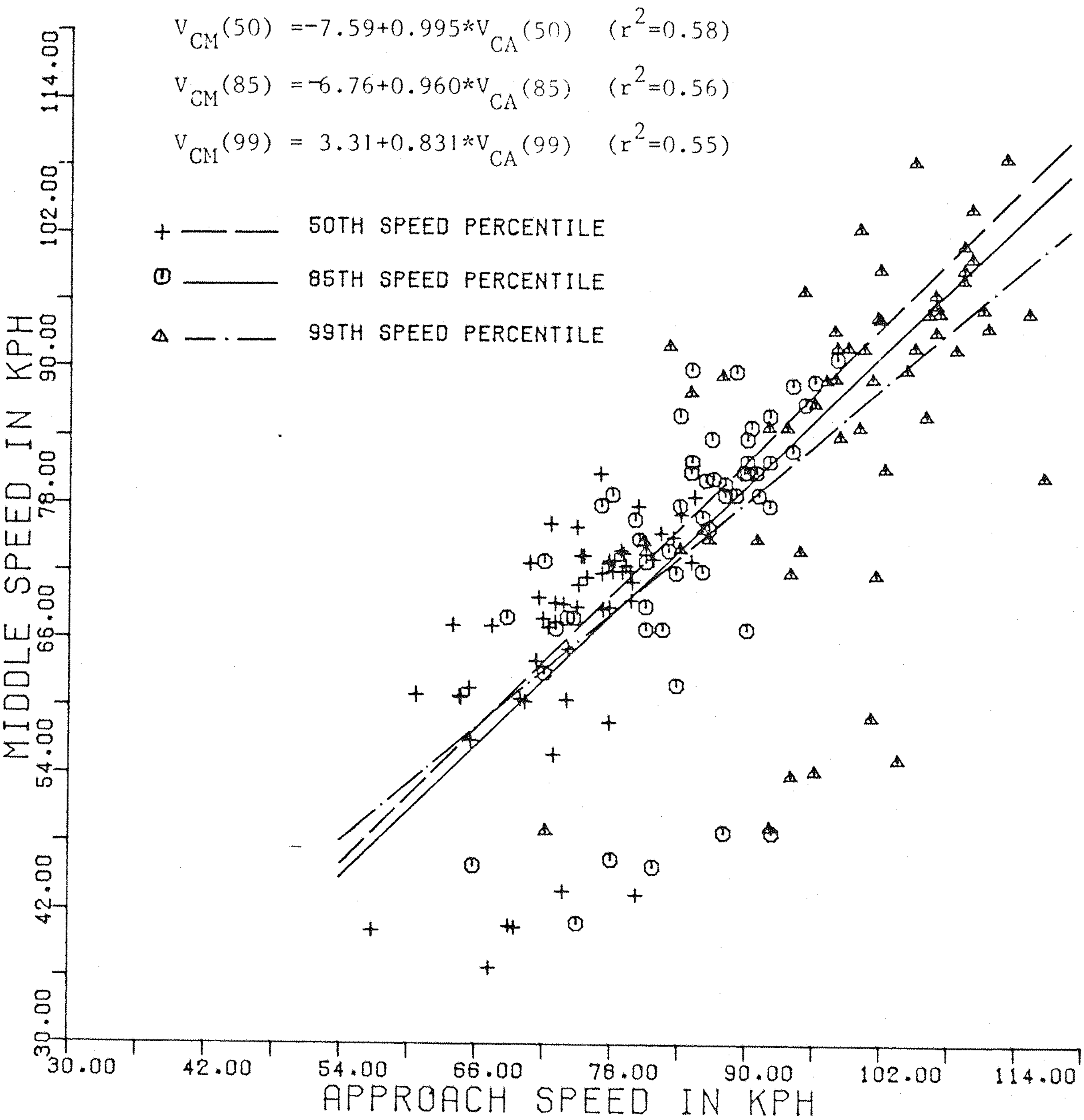


Figure D3(a): Relationship between Middle Speed and Approach Speed
(Single Carriageways - All Cars)

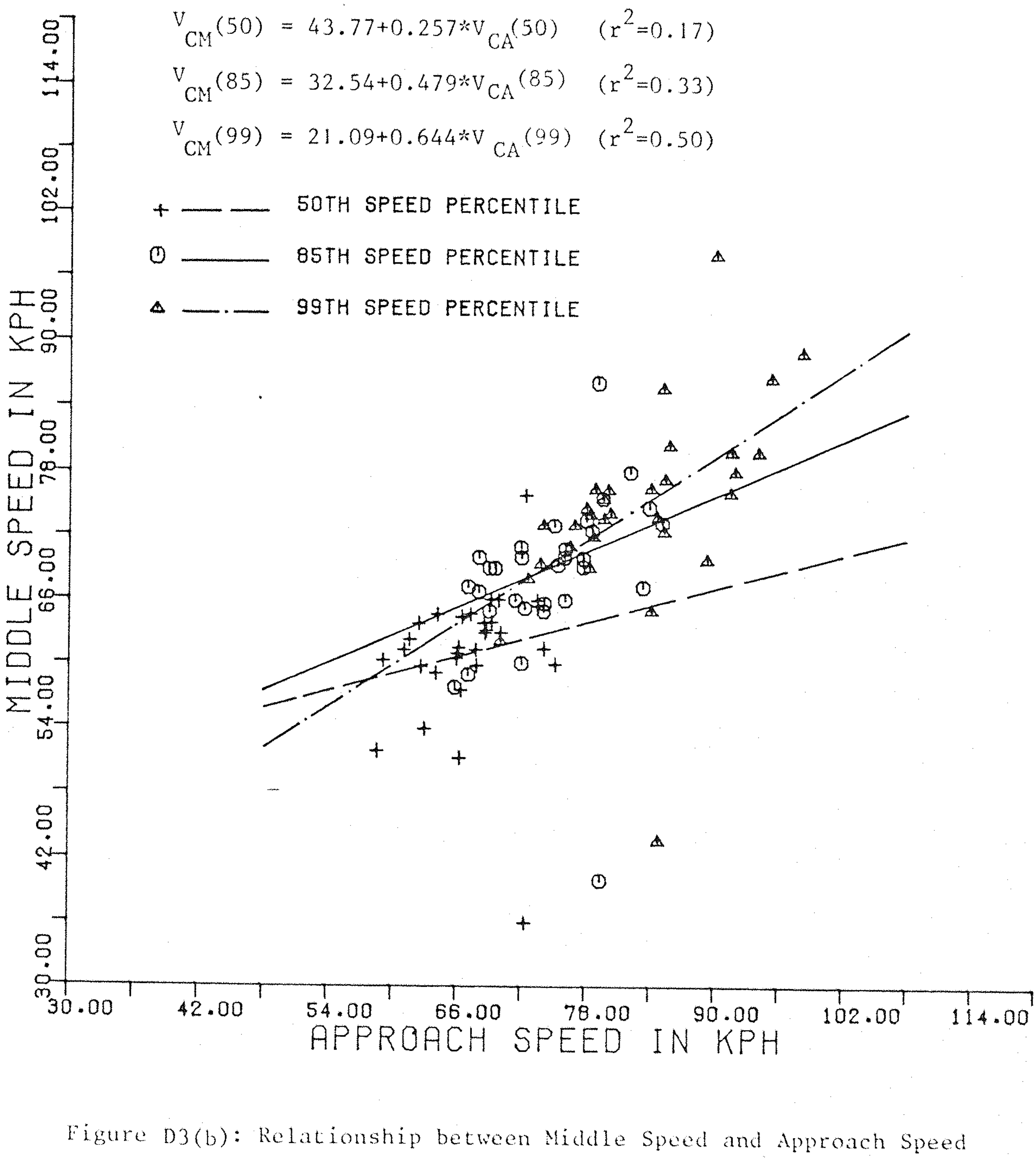


Figure D3(b): Relationship between Middle Speed and Approach Speed
(Single Carriageways - Goods Vehicles)

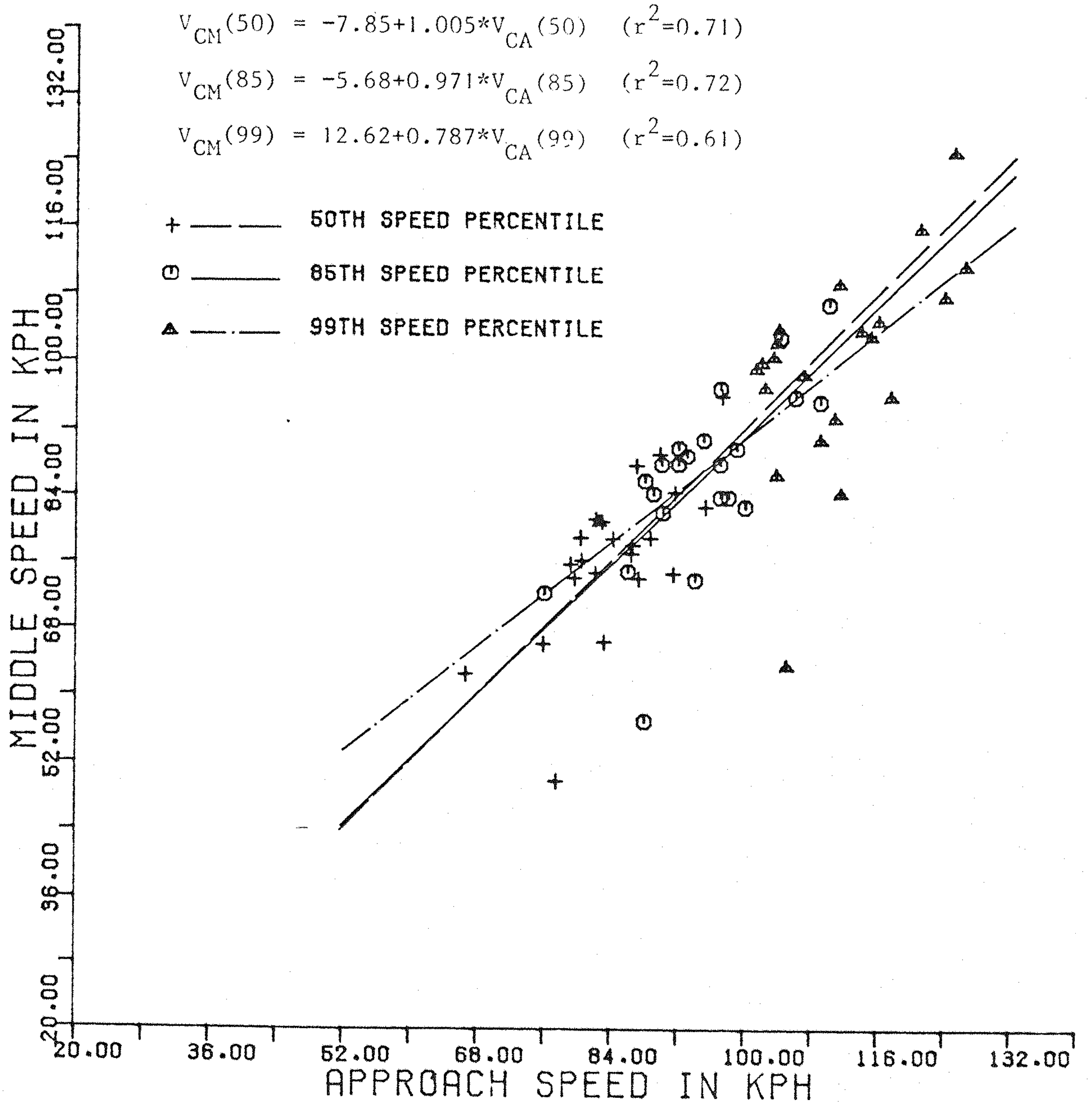


Figure D4(a): Relationship between Middle Speed and Approach Speed (Dual Carriageways - All Cars)

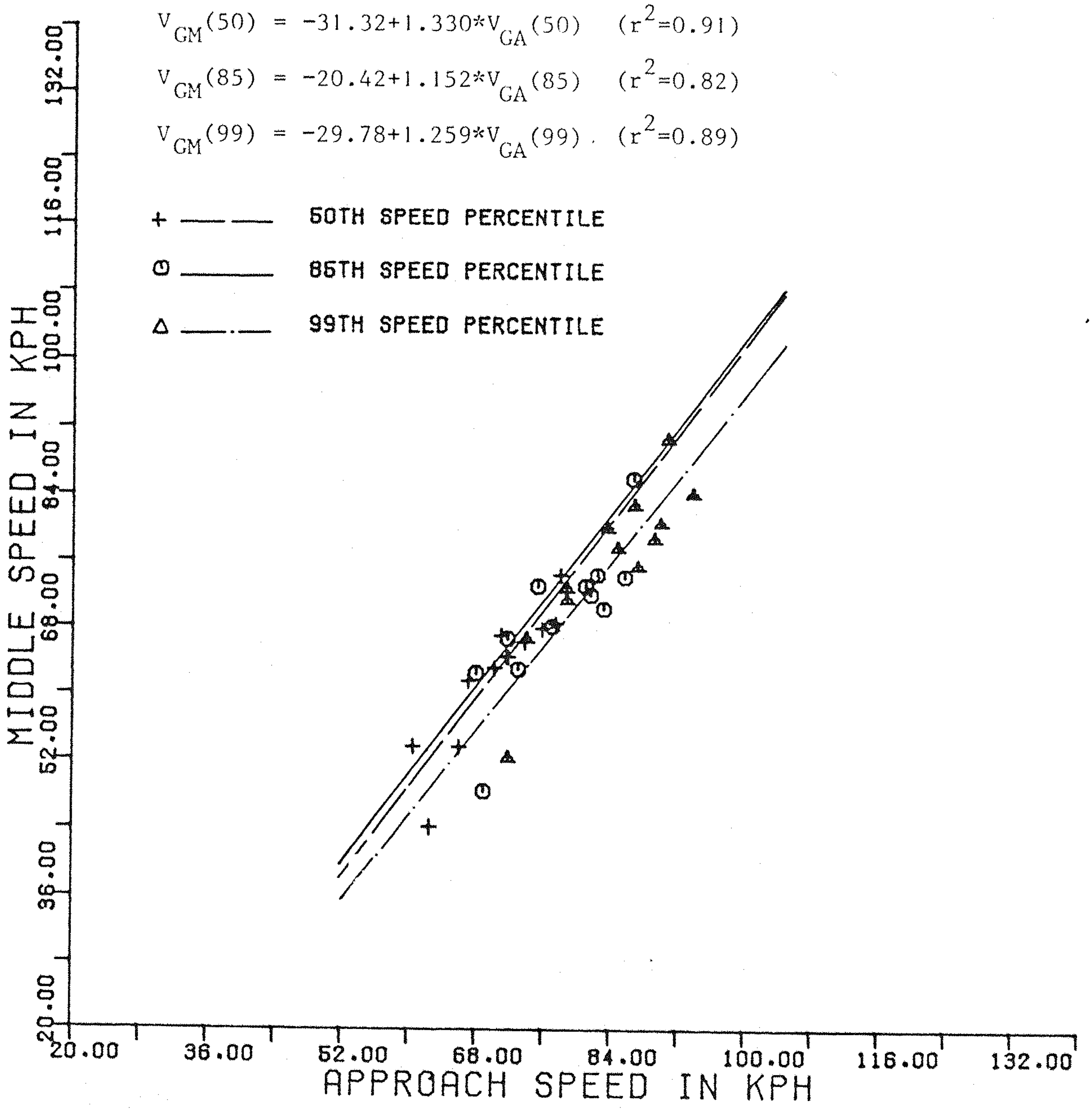


Figure D4(b) : Relationship between Middle Speed and Approach Speed
(Dual Carriageways - Goods Vehicles)

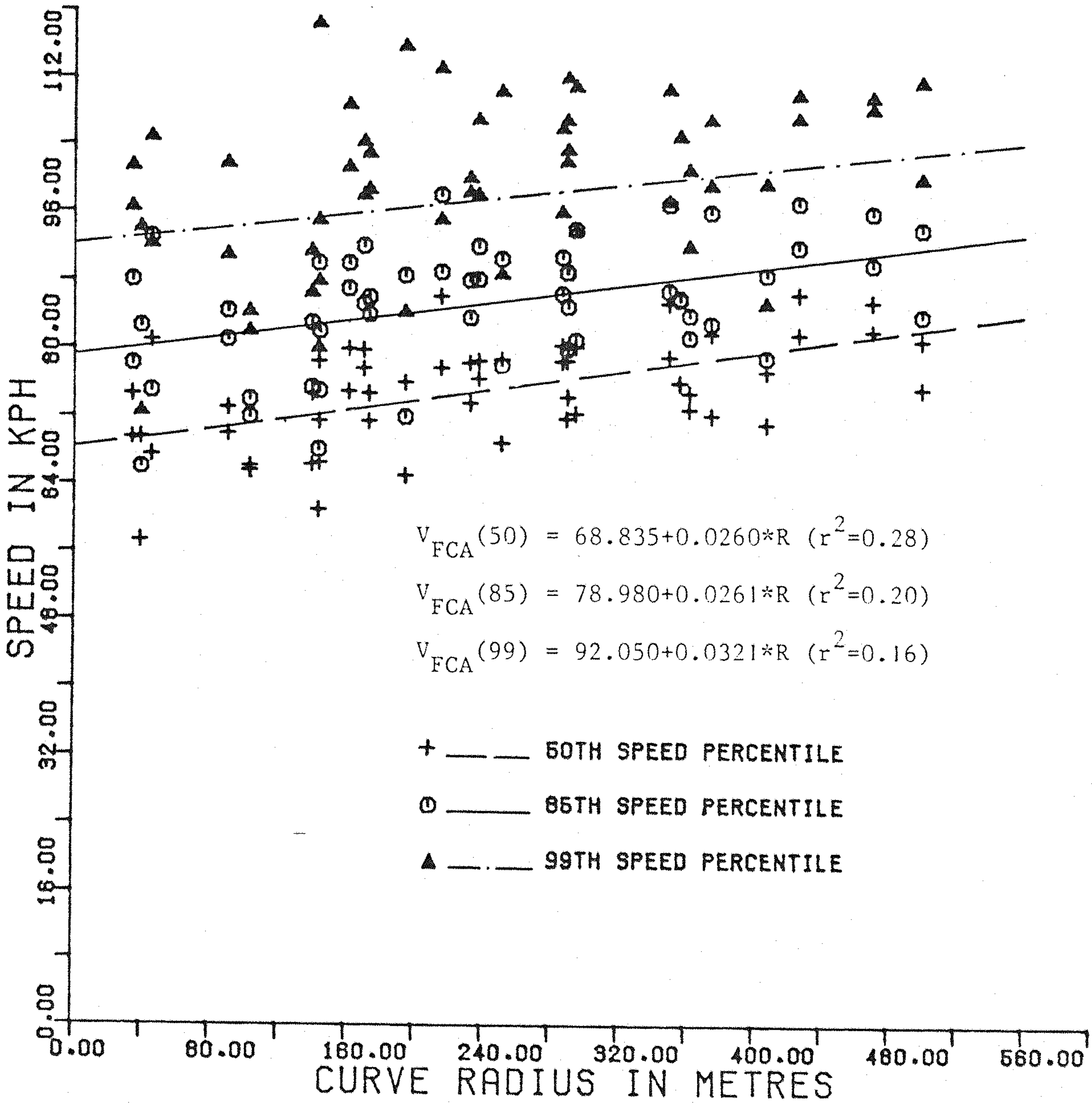


Figure D5 : Relationship between Approach Speed and Curve Radius (Single Carriageways - Free Cars)

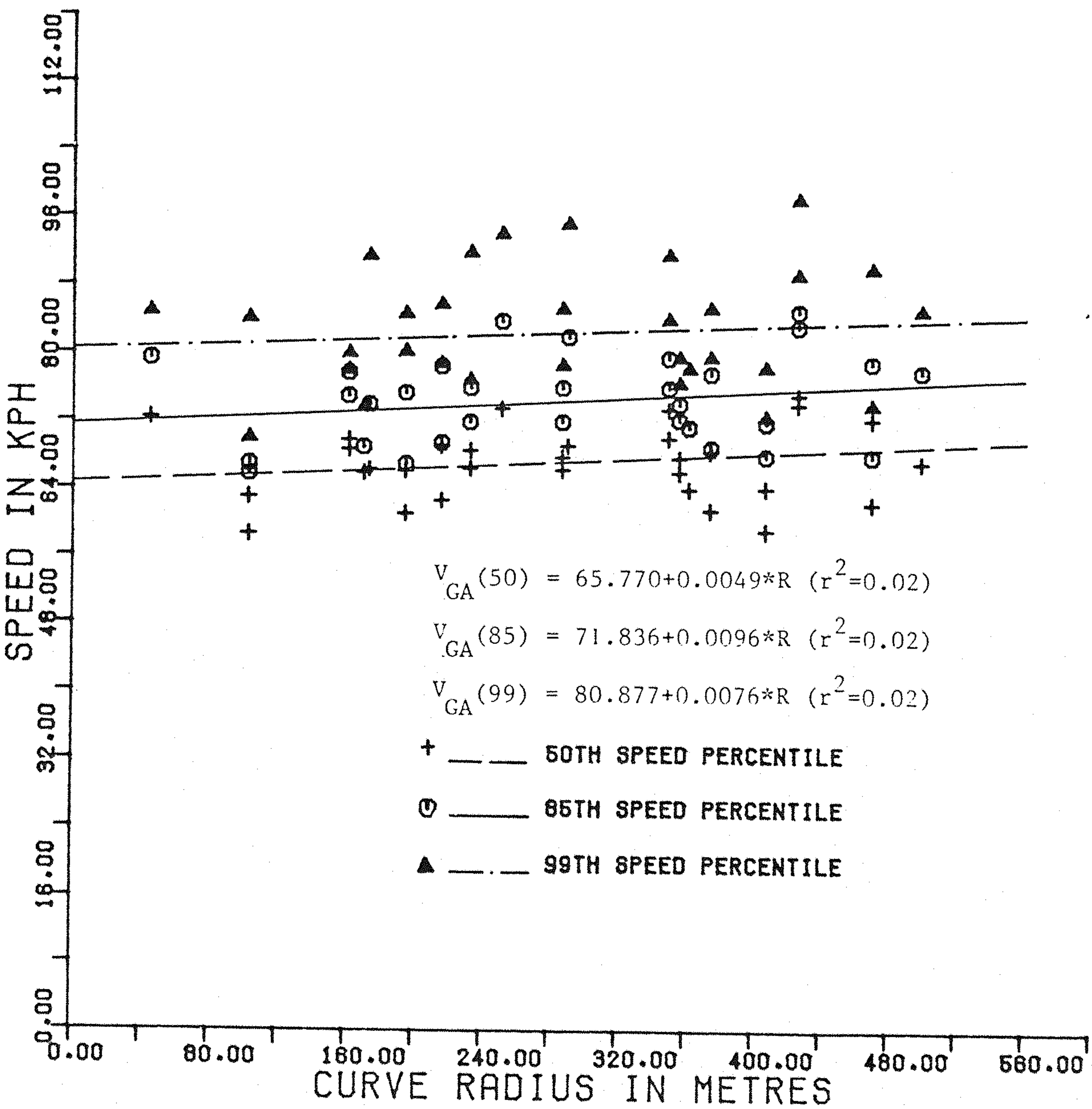


Figure D6 : Relationship between Approach Speed and Curve Radius (Single Carriageways - Goods Vehicles)

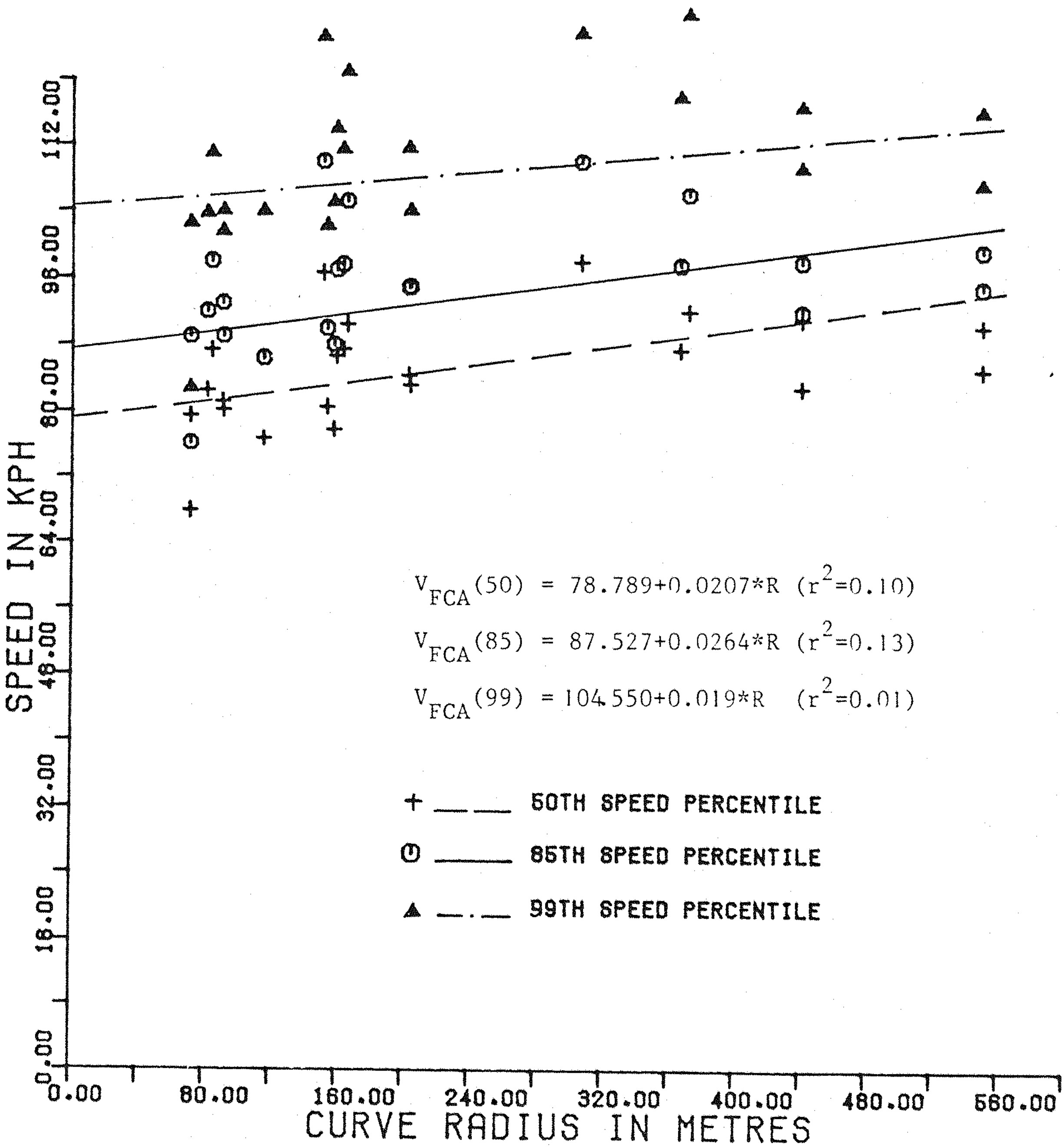


Figure D7 : Relationship between Approach Speed and Curve Radius (Dual Carriageways - Free Cars)

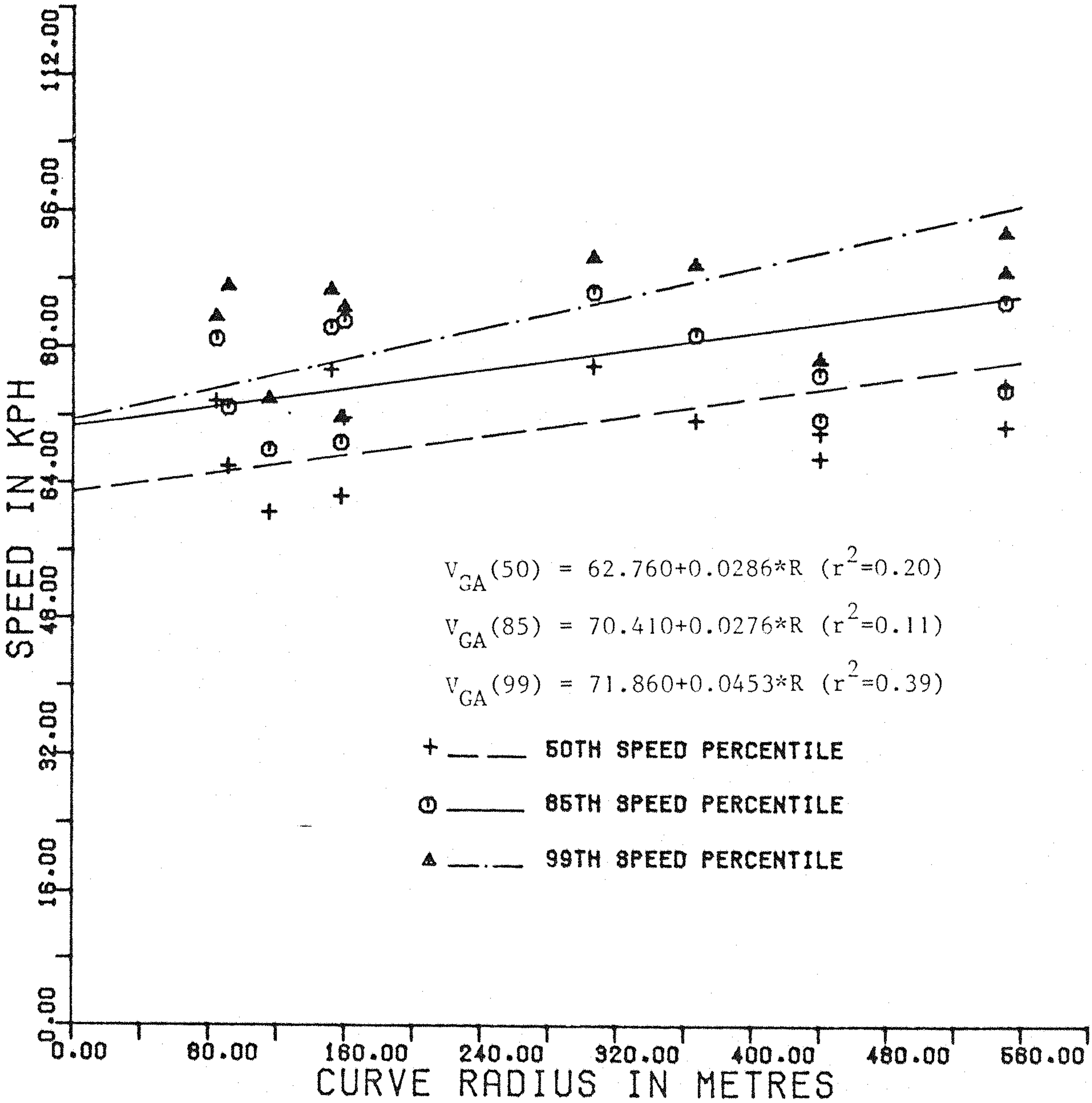


Figure D8 : Relationship between Approach Speed and Curve Radius (Dual Carriageways - Goods Vehicles)

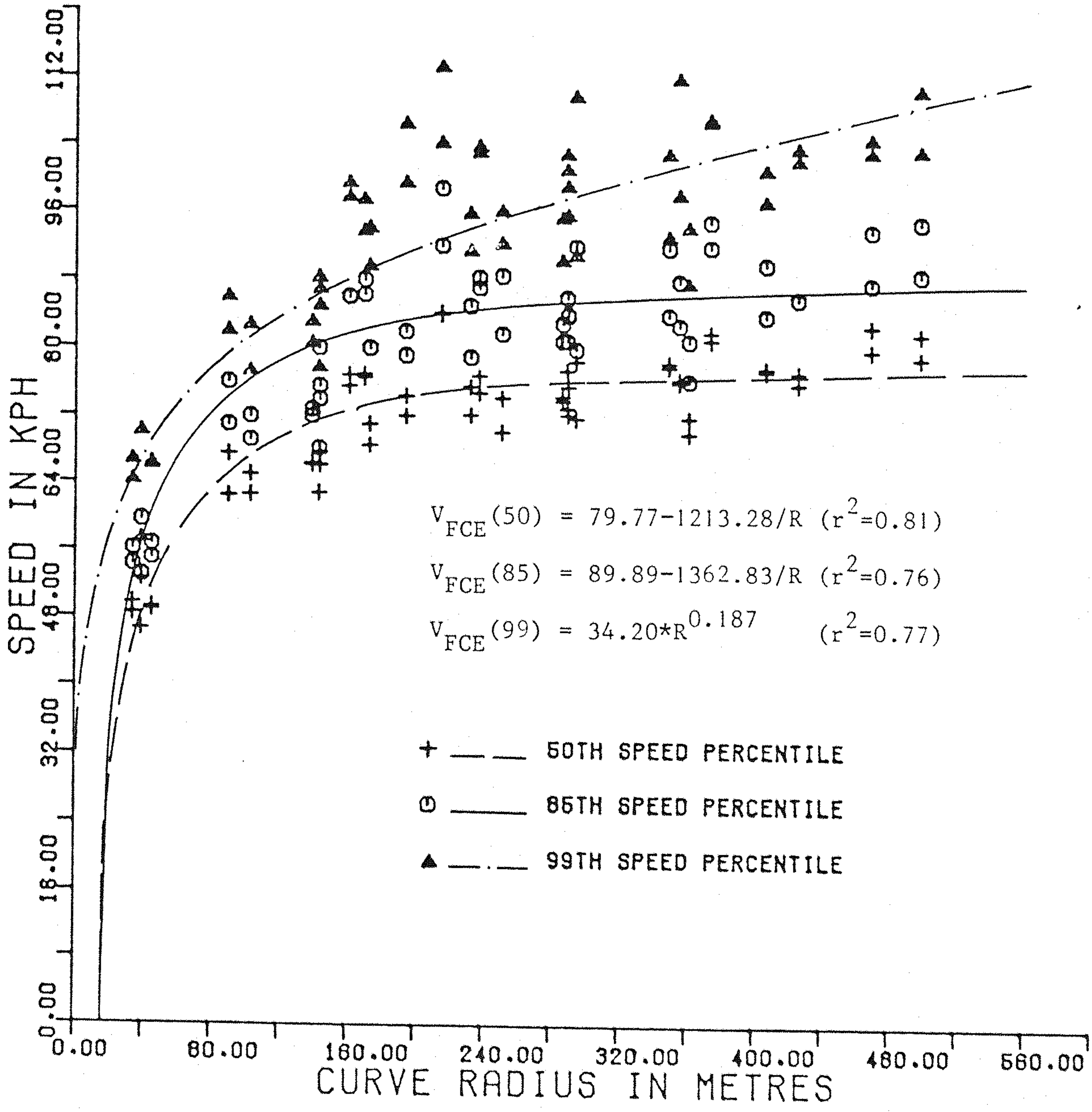


Figure D9 : Relationship between Entry Speed and Curve Radius (Single Carriageways - Free Cars)

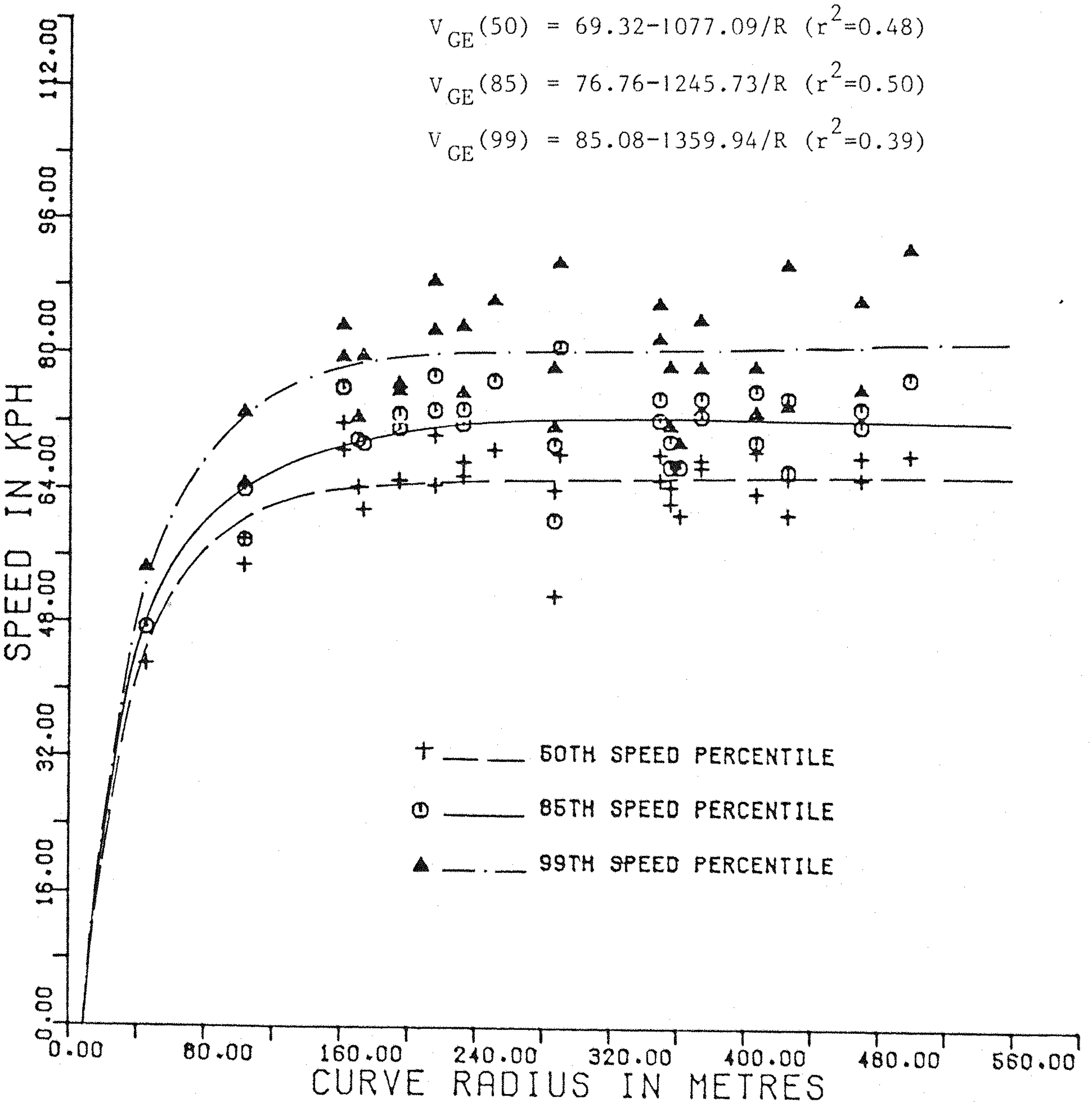


Figure D10 : Relationship between Entry Speed and Curve Radius
(Single Carriageways - Goods Vehicles)

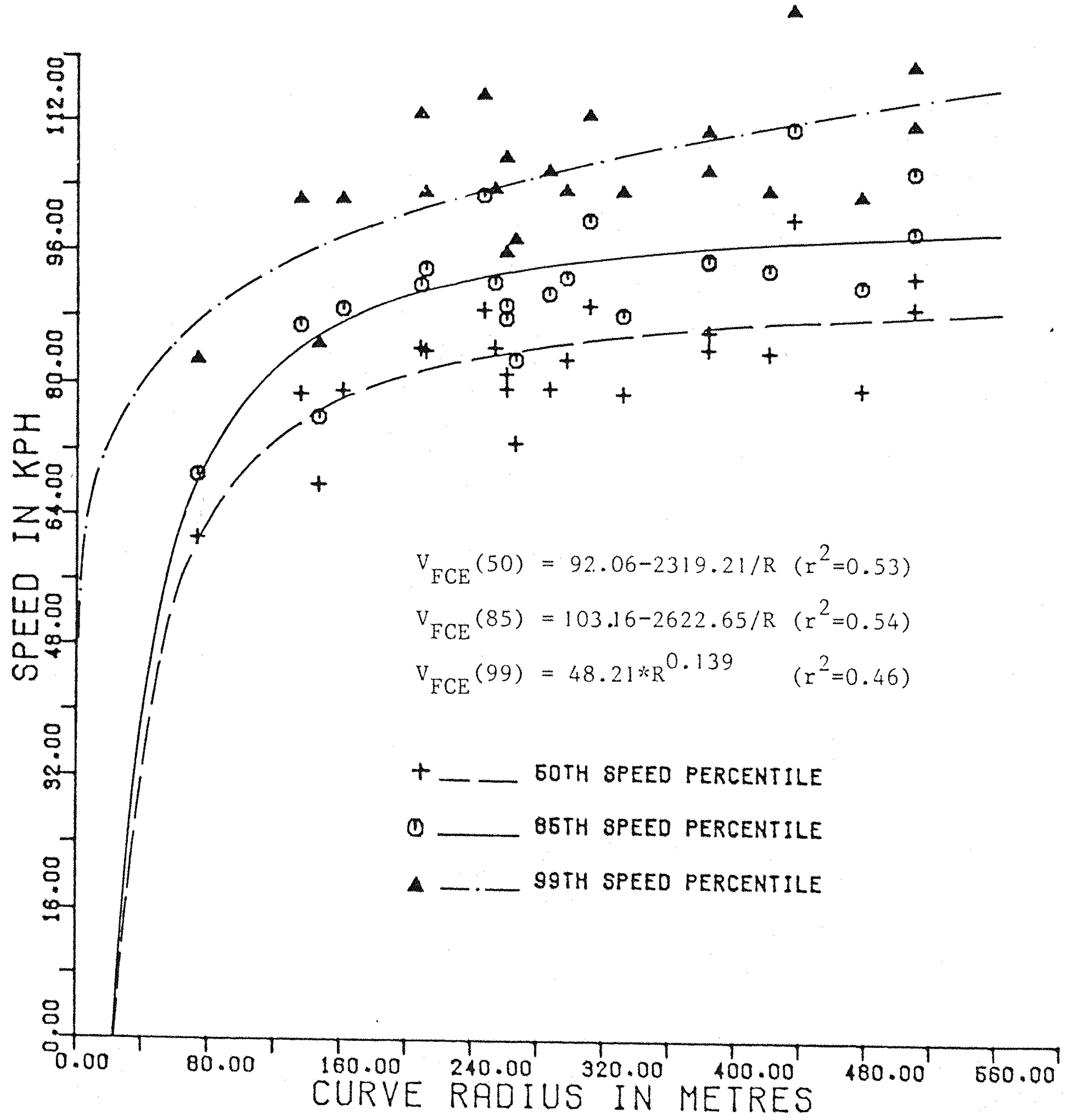


Figure D11 : Relationship between Entry Speed and Curve Radius (Dual Carriageways - Free Cars)

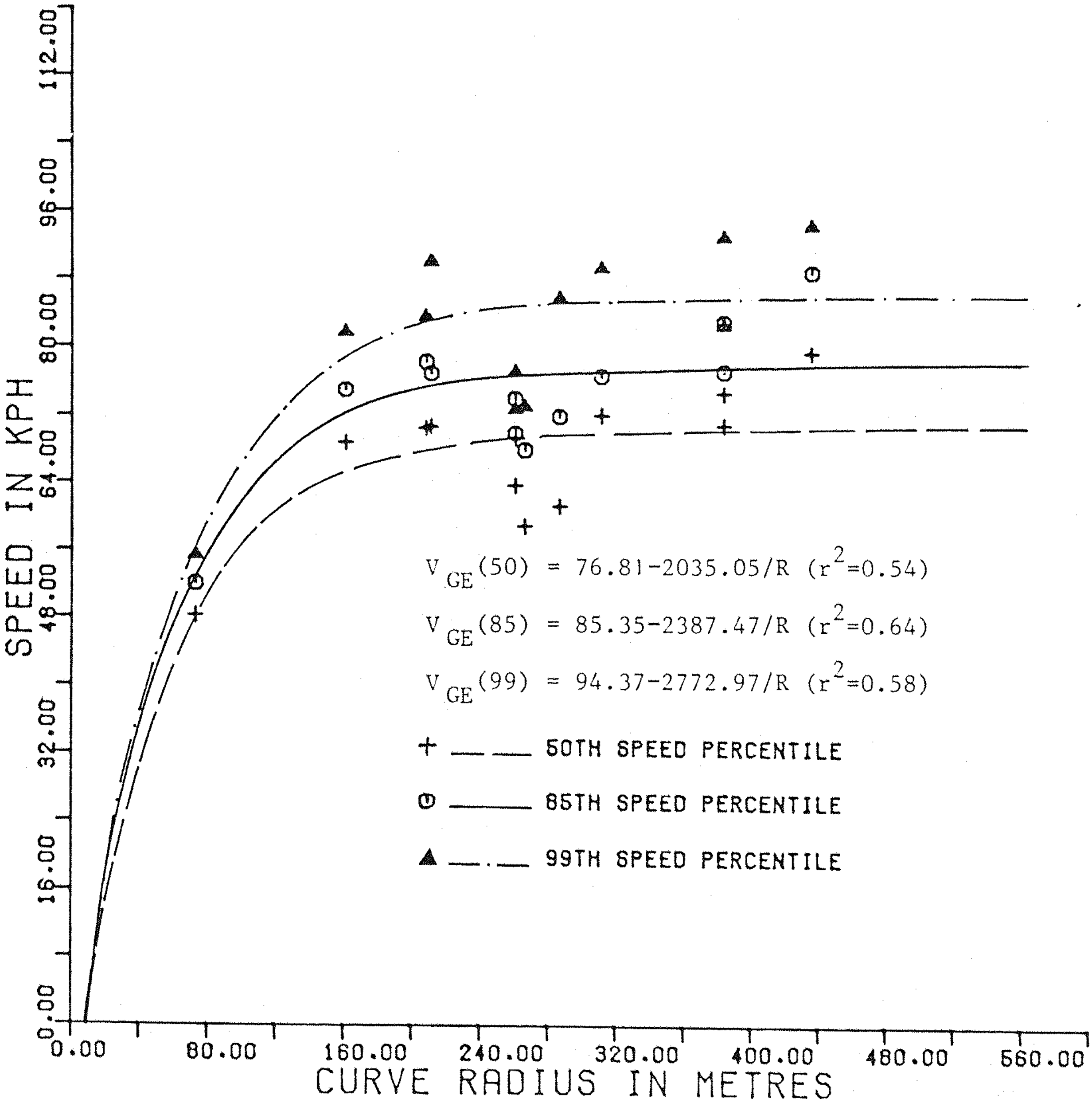


Figure D12 : Relationship between Entry Speed and Curve Radius
(Dual Carriageways - Goods Vehicles)

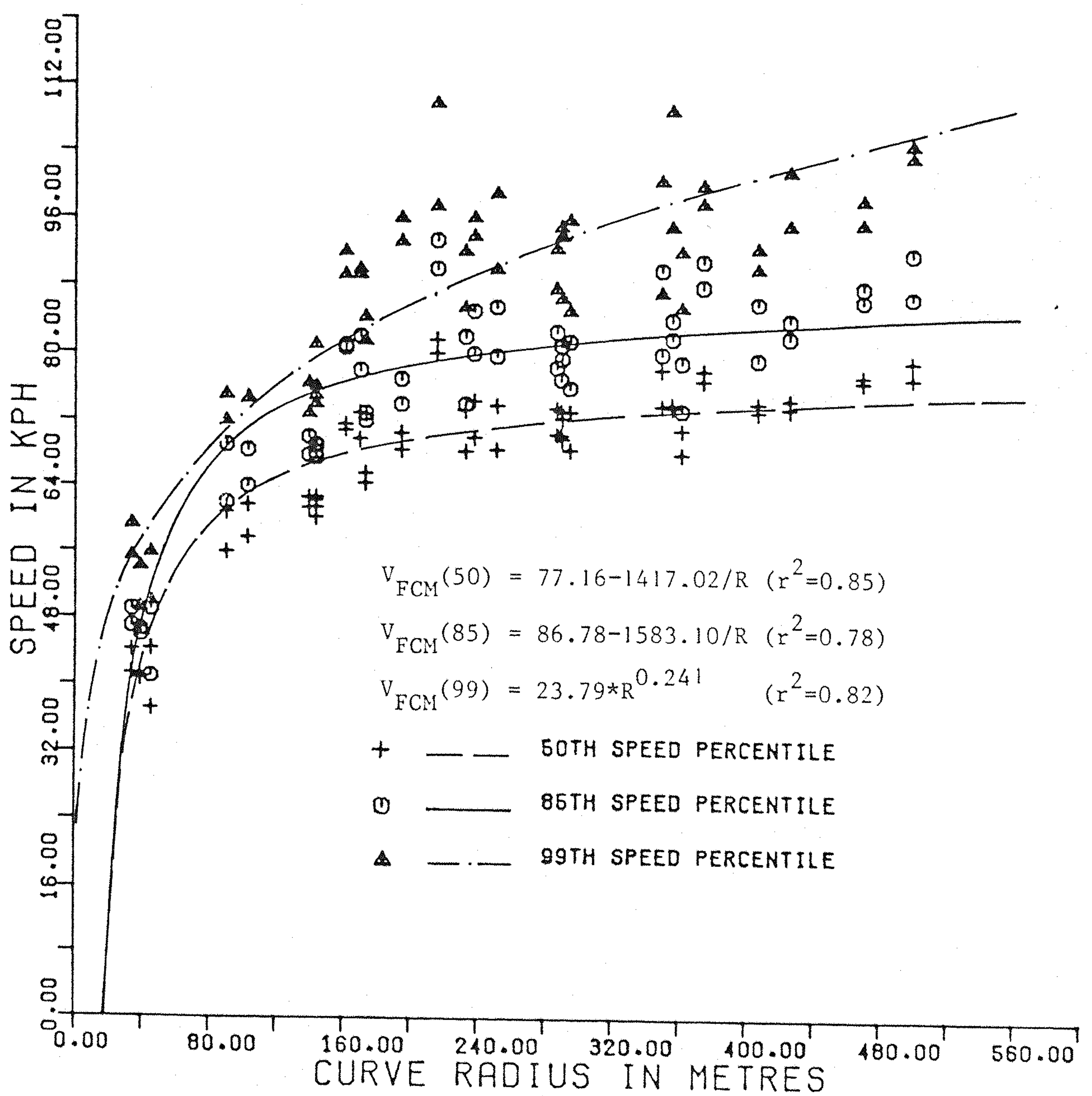


Figure D13 : Relationship between Middle Speed and Curve Radius (Single Carriageways - Free Cars)

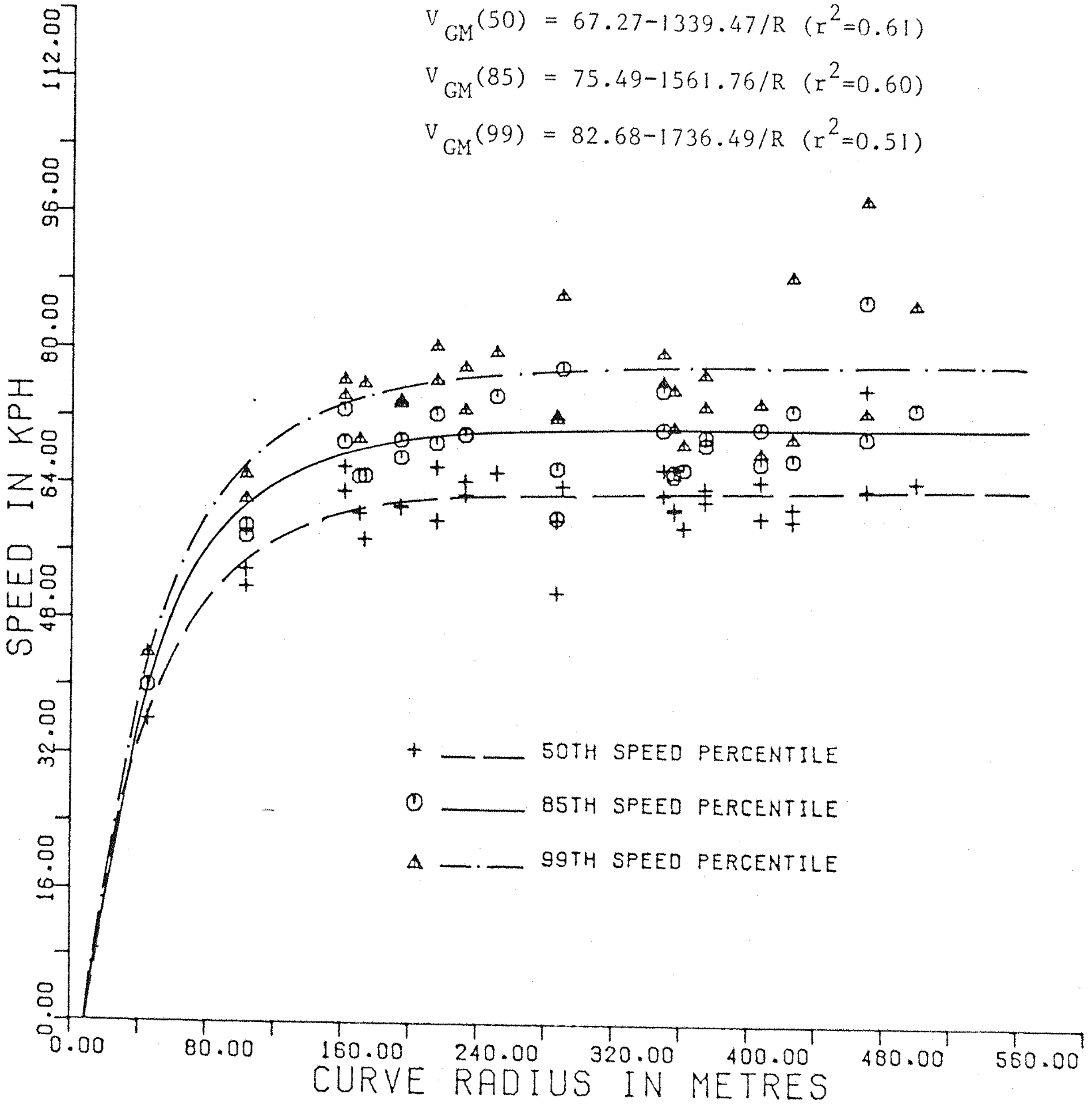


Figure D14 : Relationship between Middle Speed and Curve Radius (Single Carriageways - Goods Vehicles)

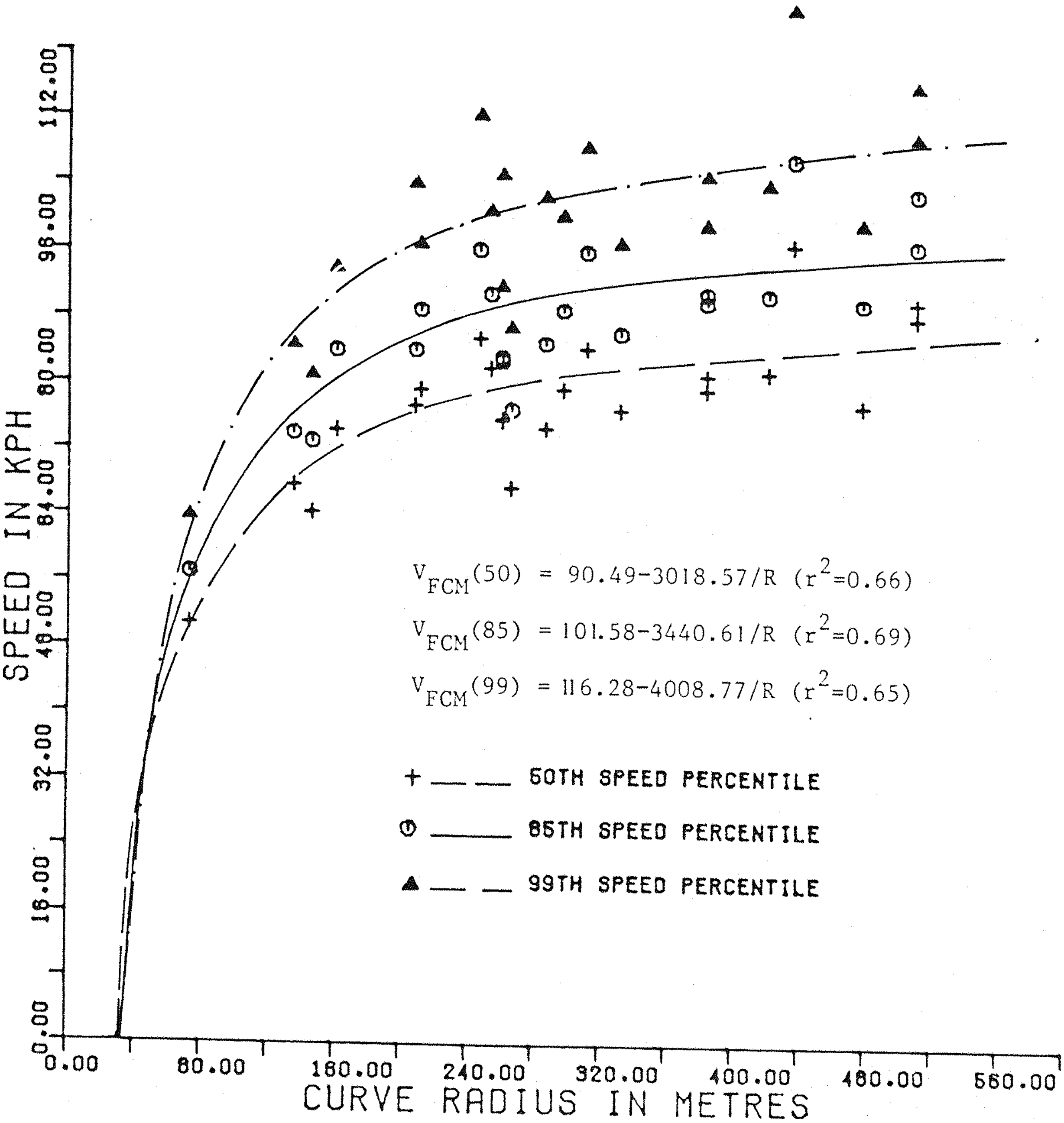


Figure D15 : Relationship between Middle Speeds and Curve Radius (Dual Carriageways - Free Cars)

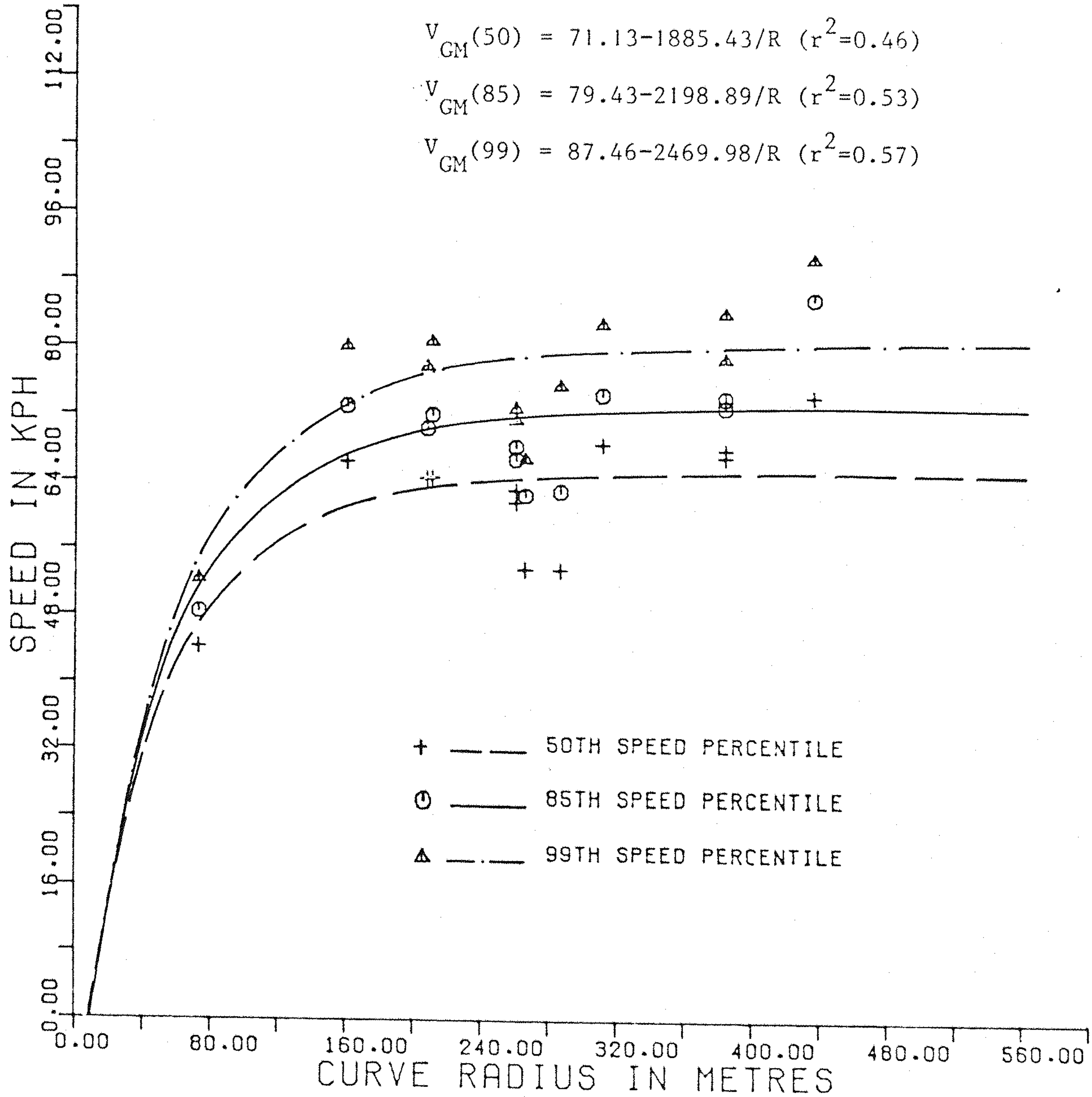


Figure D16 : Relationship between Middle Speed and Curve Radius
(Dual Carriageways - Goods Vehicles)

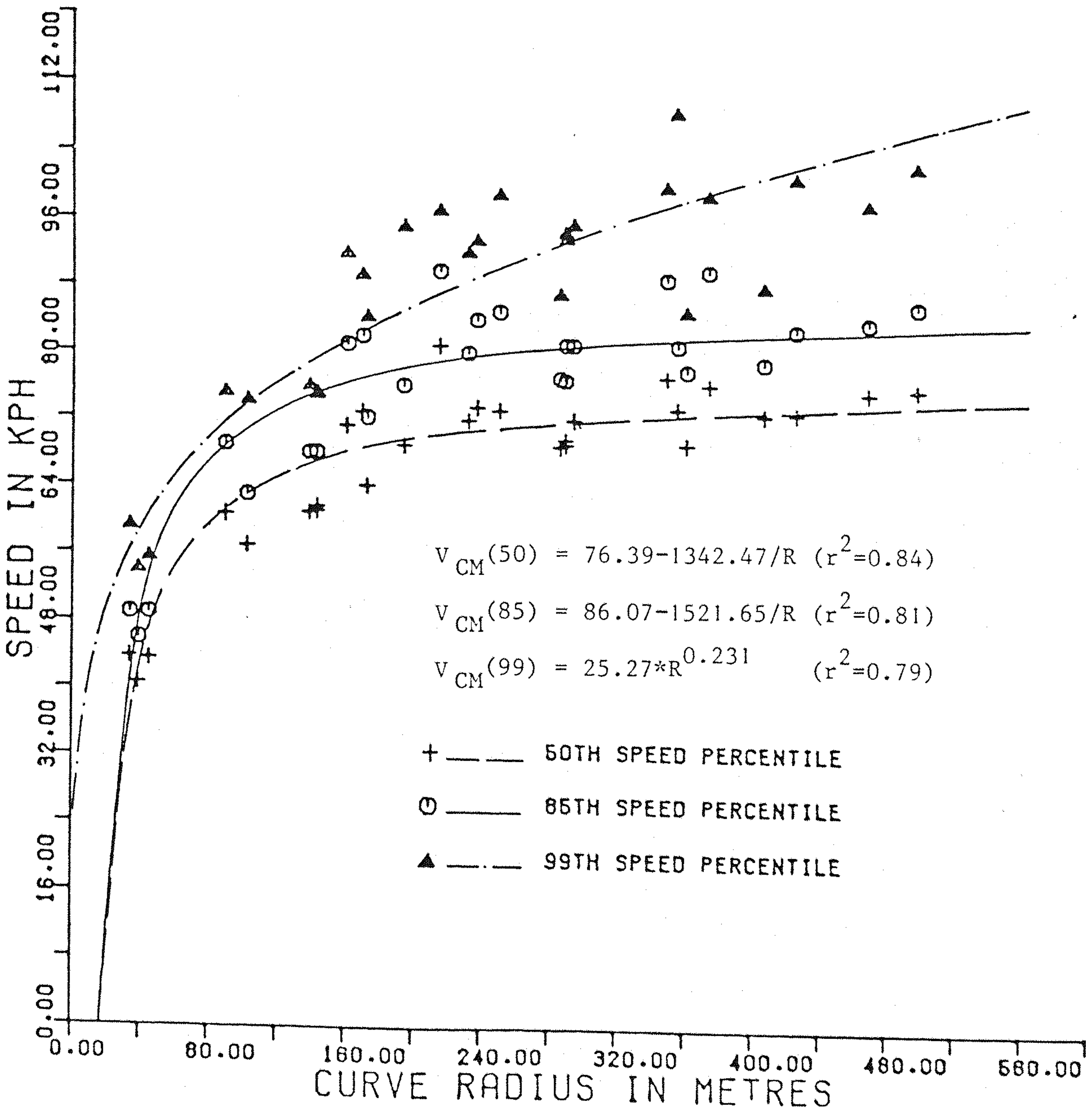


Figure D17 : Relationship between Middle Speed and Curve Radius
(Single Carriageways - All Cars - Right-Hand Curves)

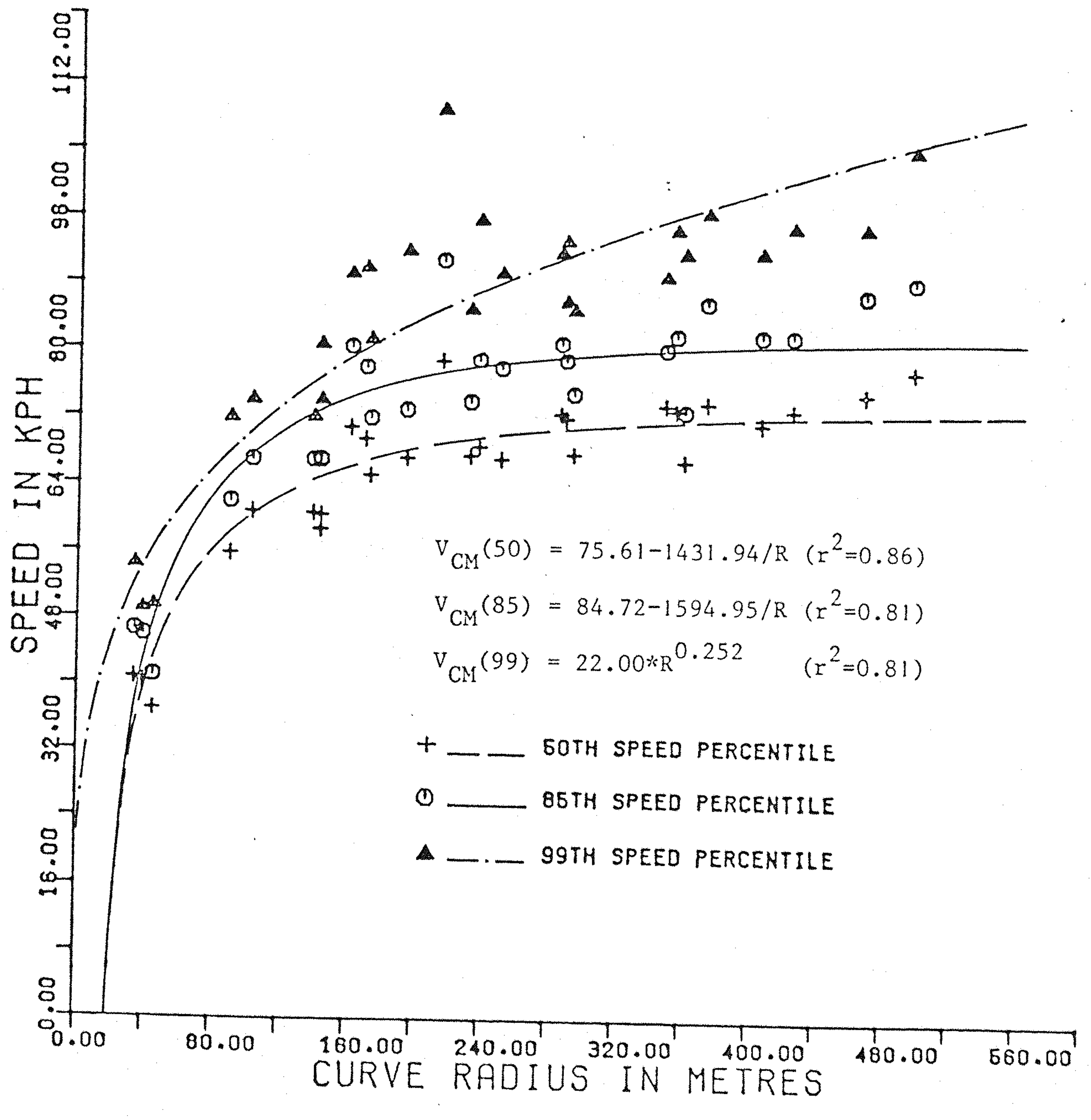


Figure D18 : Relationship between Middle Speed and Curve Radius
(Single Carriageways - All Cars - Left-Hand Curves)

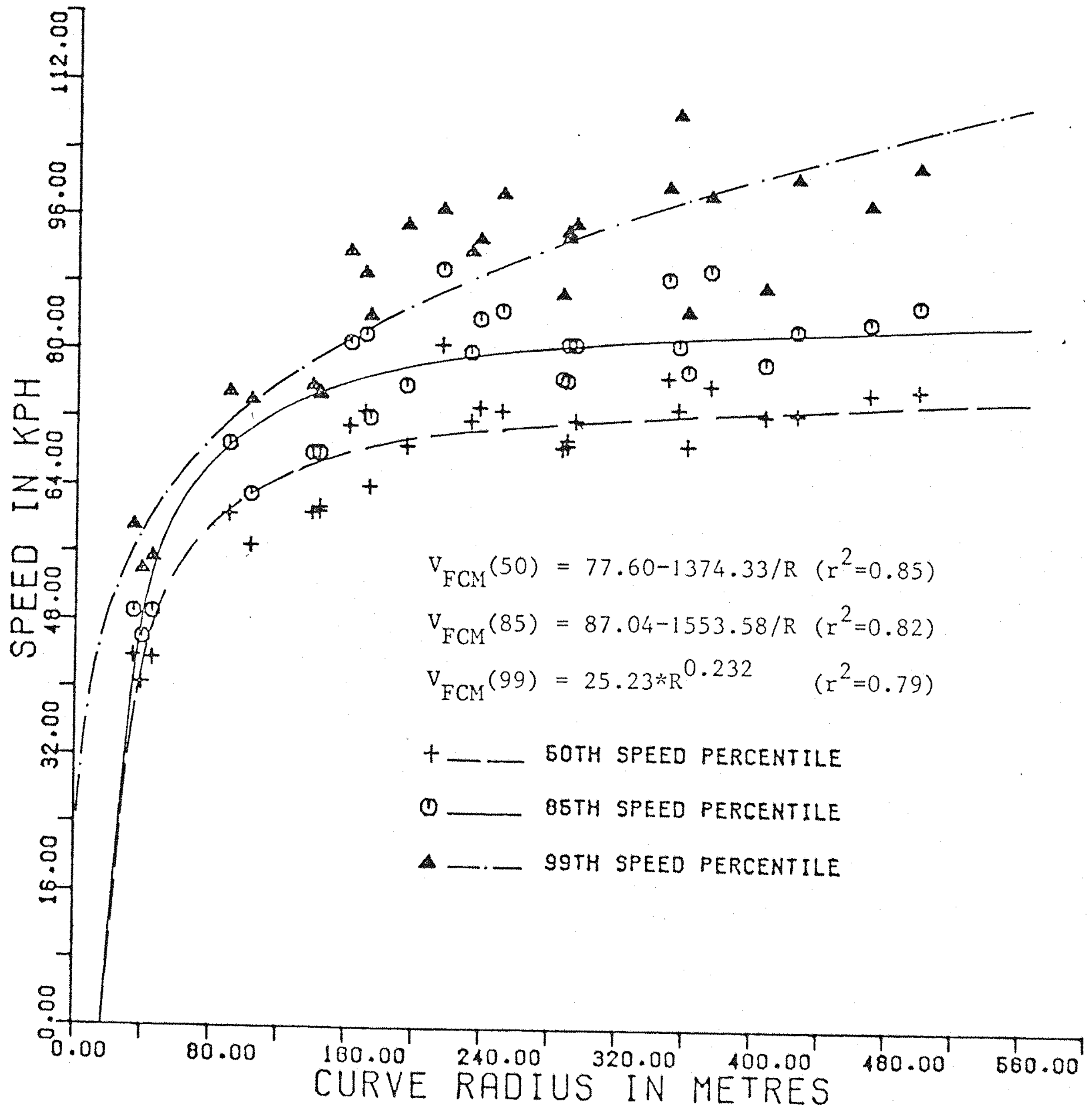


Figure D19 : Relationship between Middle Speed and Curve Radius
(Single Carriageways - Free Cars - Right-Hand Curves)

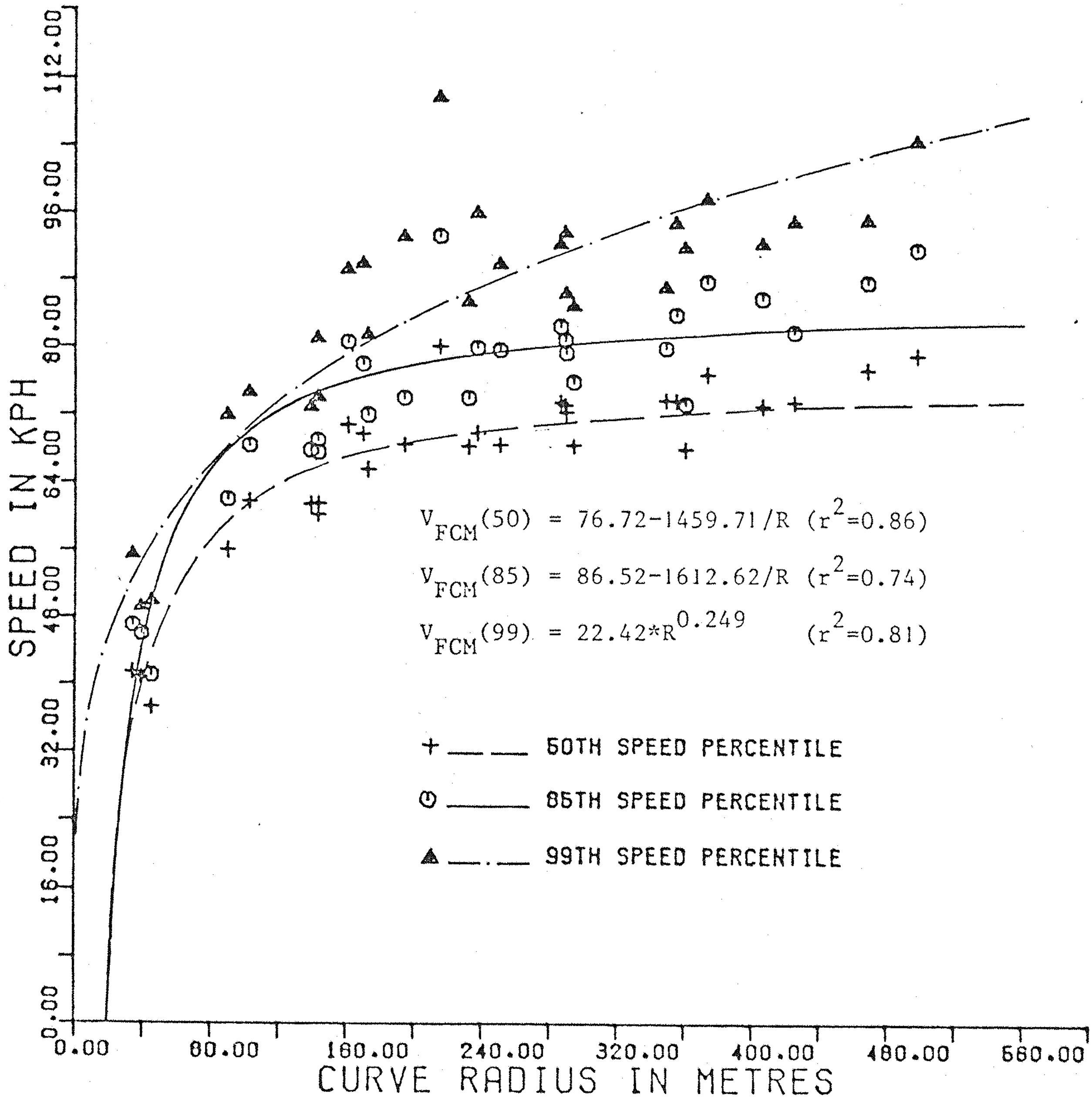


Figure D20 : Relationship between Middle Speed and Curve Radius

(Single Carriageways - Free Cars - Left-Hand Curves)

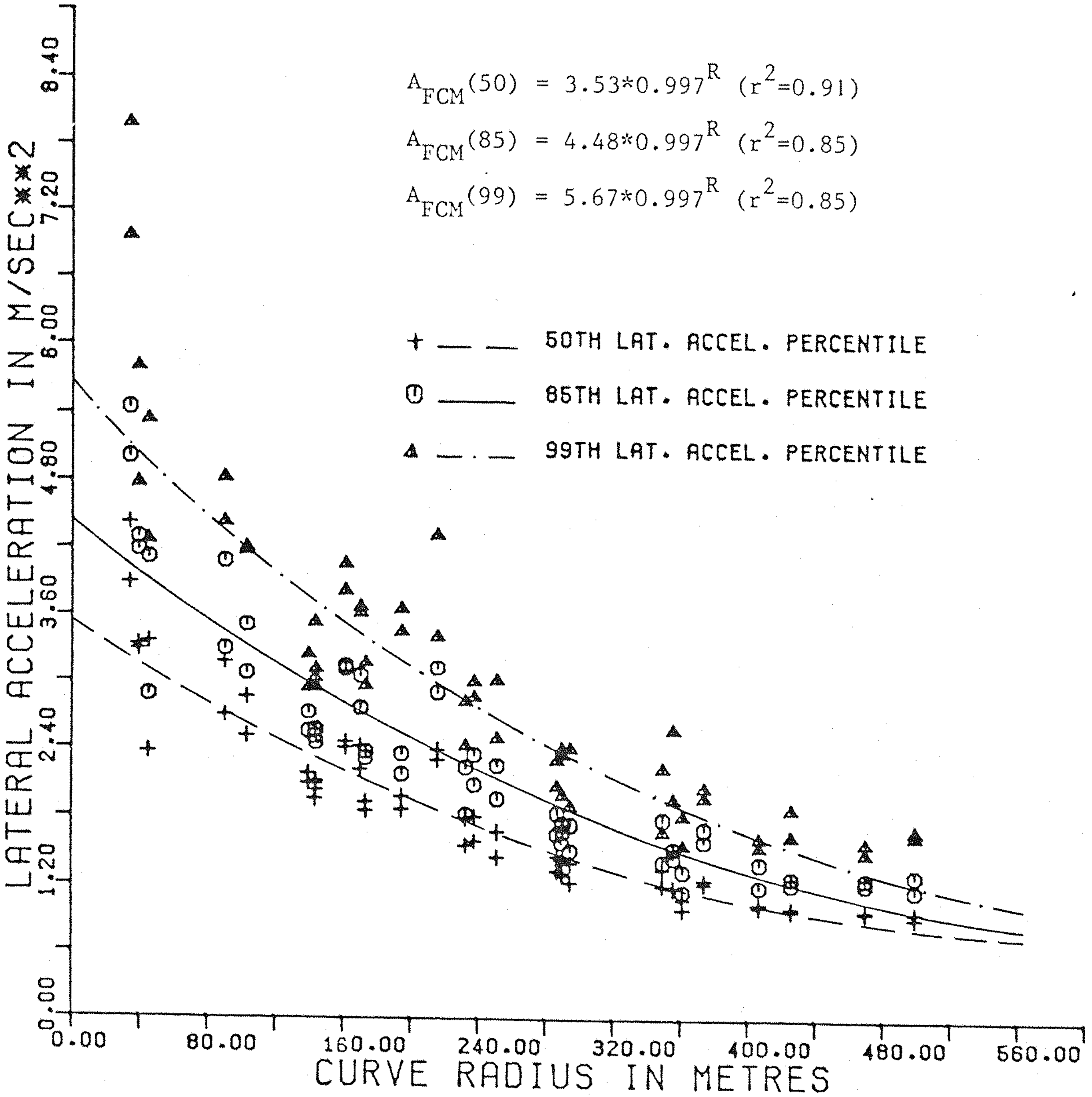


Figure D21 : Relationship between Middle Lateral Acceleration and Curve Radius
(Single Carriageways - Free Cars)

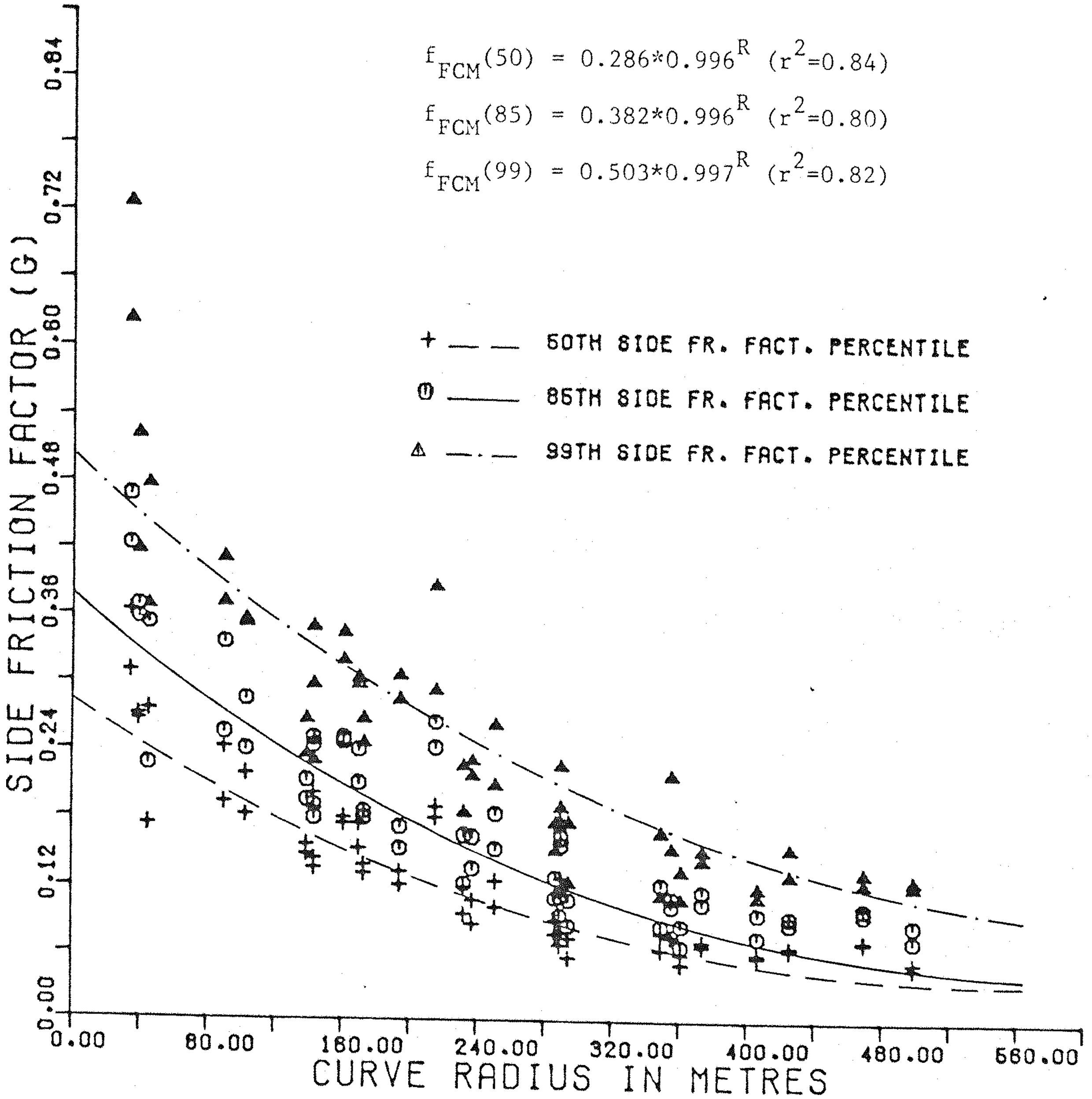


Figure D22 : Relationship between Middle Side - Friction Factor and Curve Radius
(Single Carriageways - Free Cars)

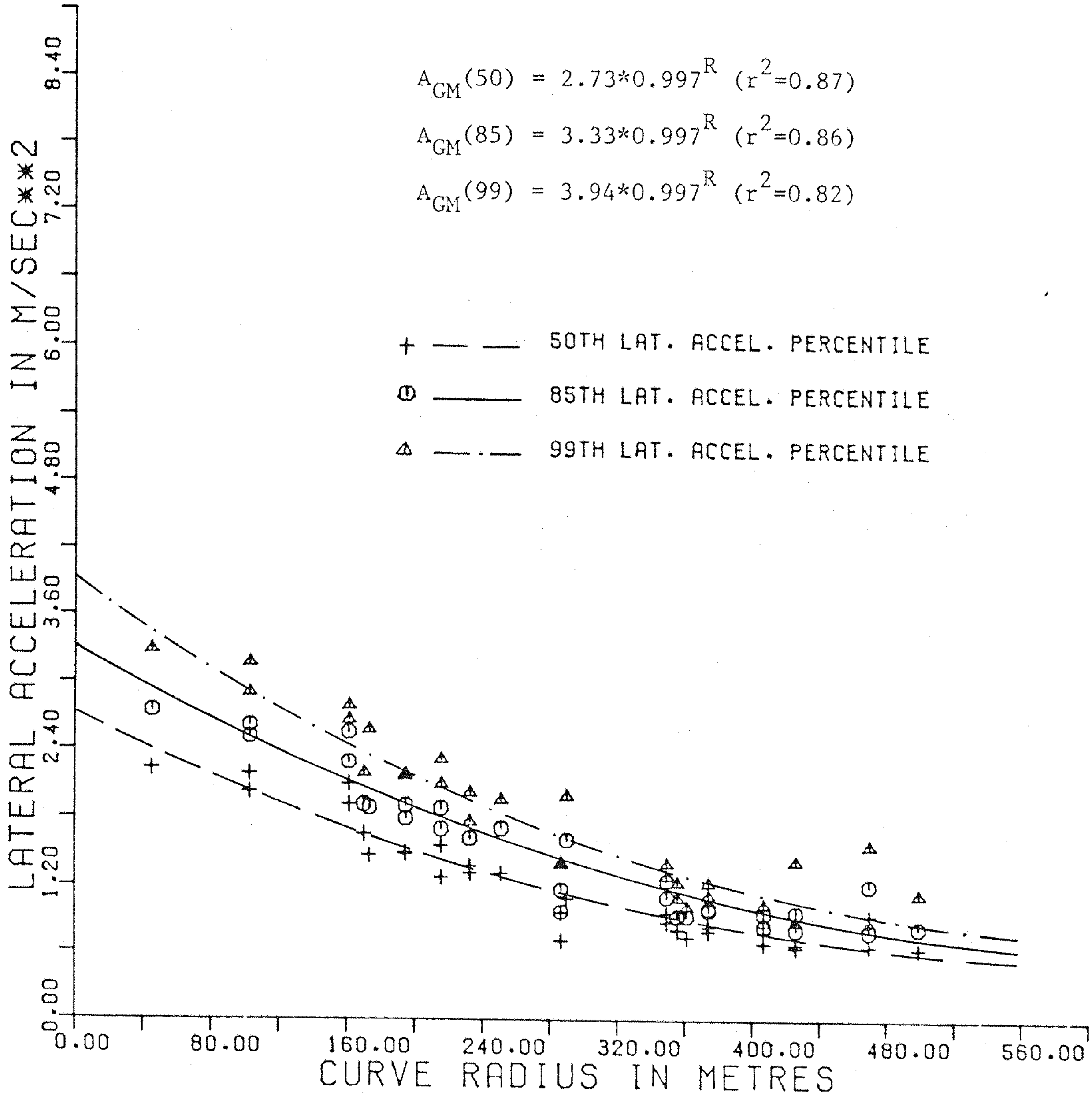


Figure D23 . Relationship between Middle Lateral Acceleration and Curve Radius
(Single Carriageways - Goods Vehicles)

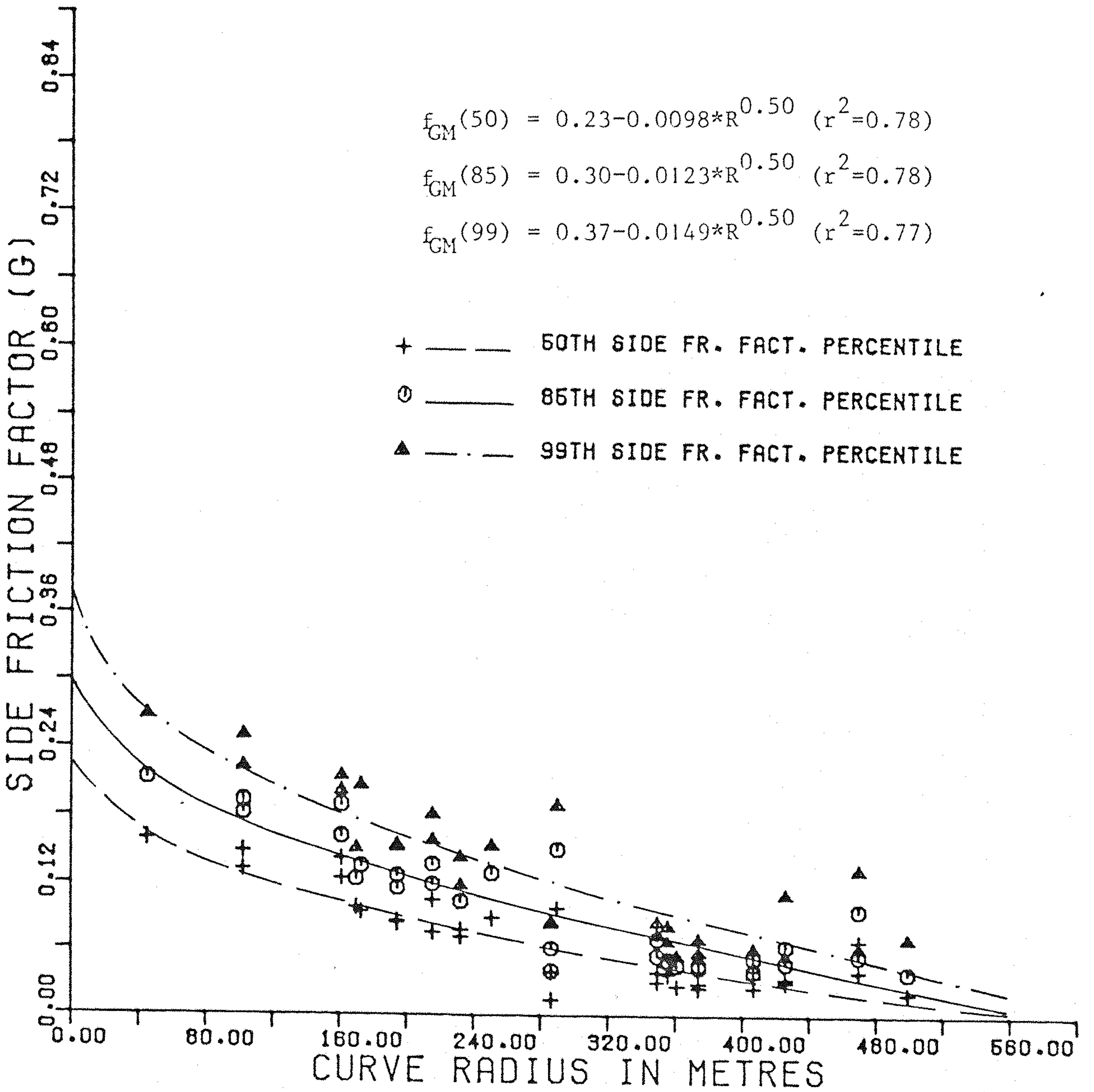


Figure D24 : Relationship between Middle Side-Friction Factor and Curve Radius
(Single Carriageways - Goods Vehicles)

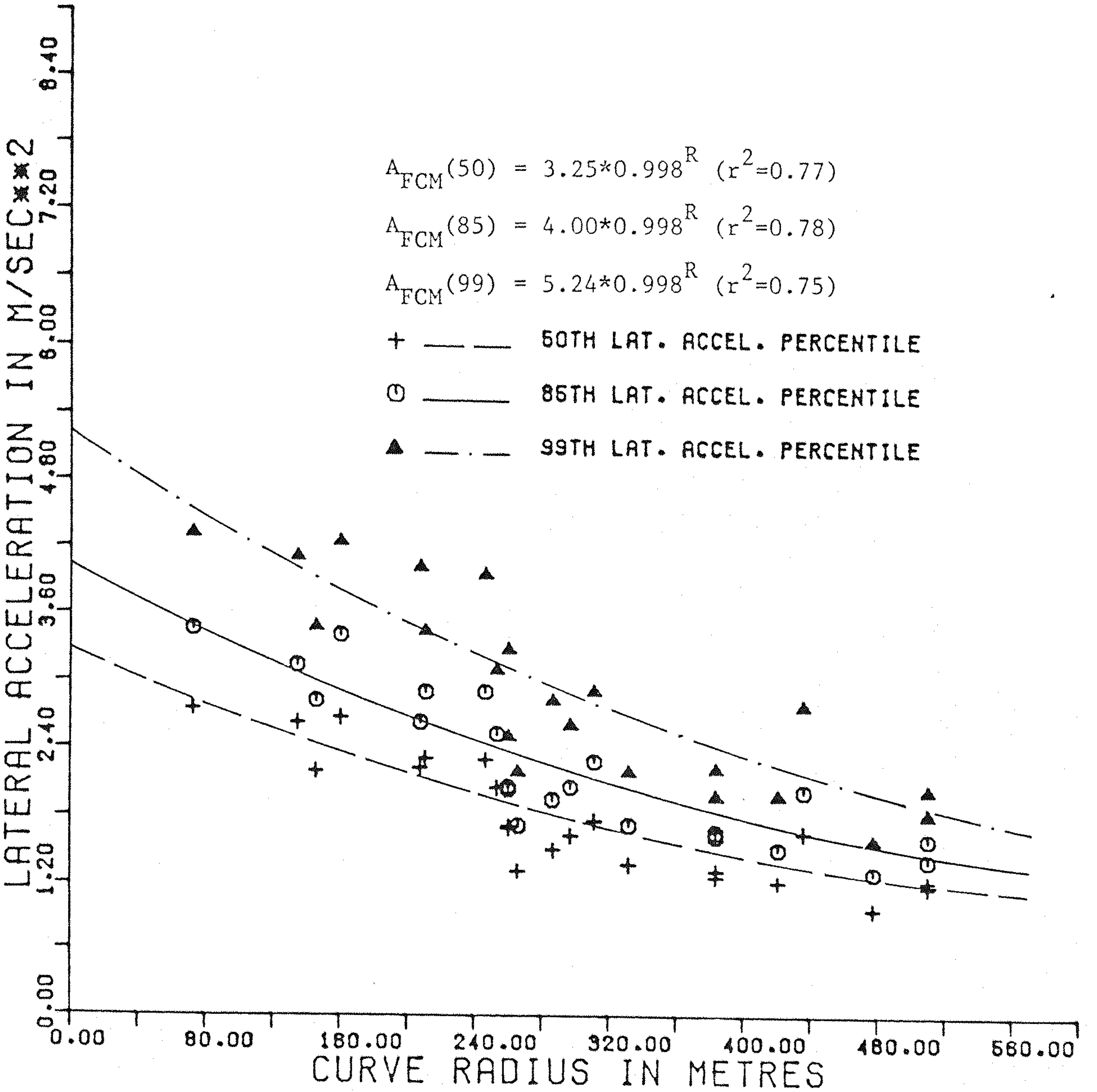


Figure D25 : Relationship between Middle Lateral Acceleration and Curve Radius
(Dual Carriageways - Free Cars)

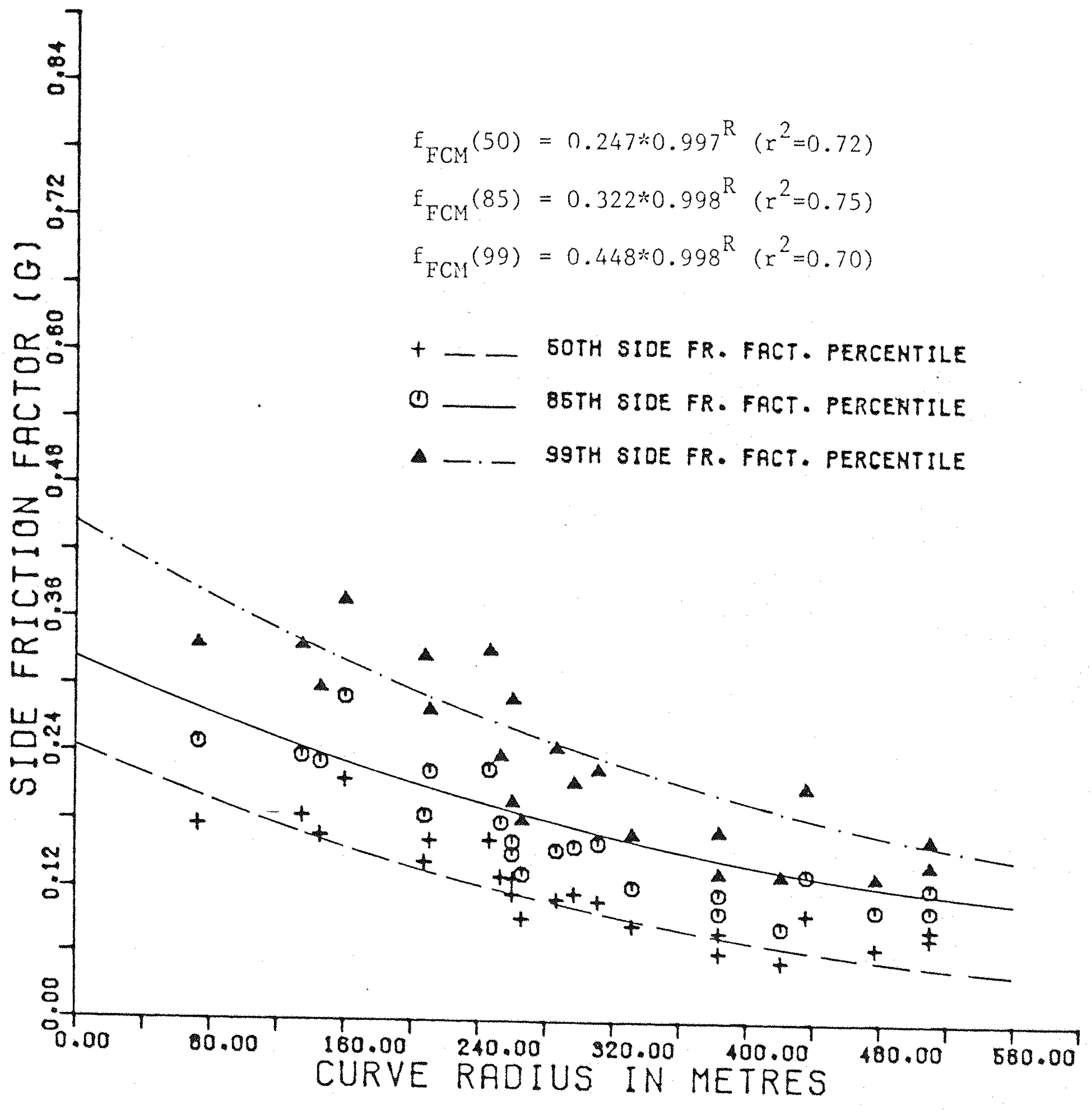


Figure D26 : Relationship between Middle Side-Friction Factor and Curve Radius
(Dual Carriageways - Free Cars)

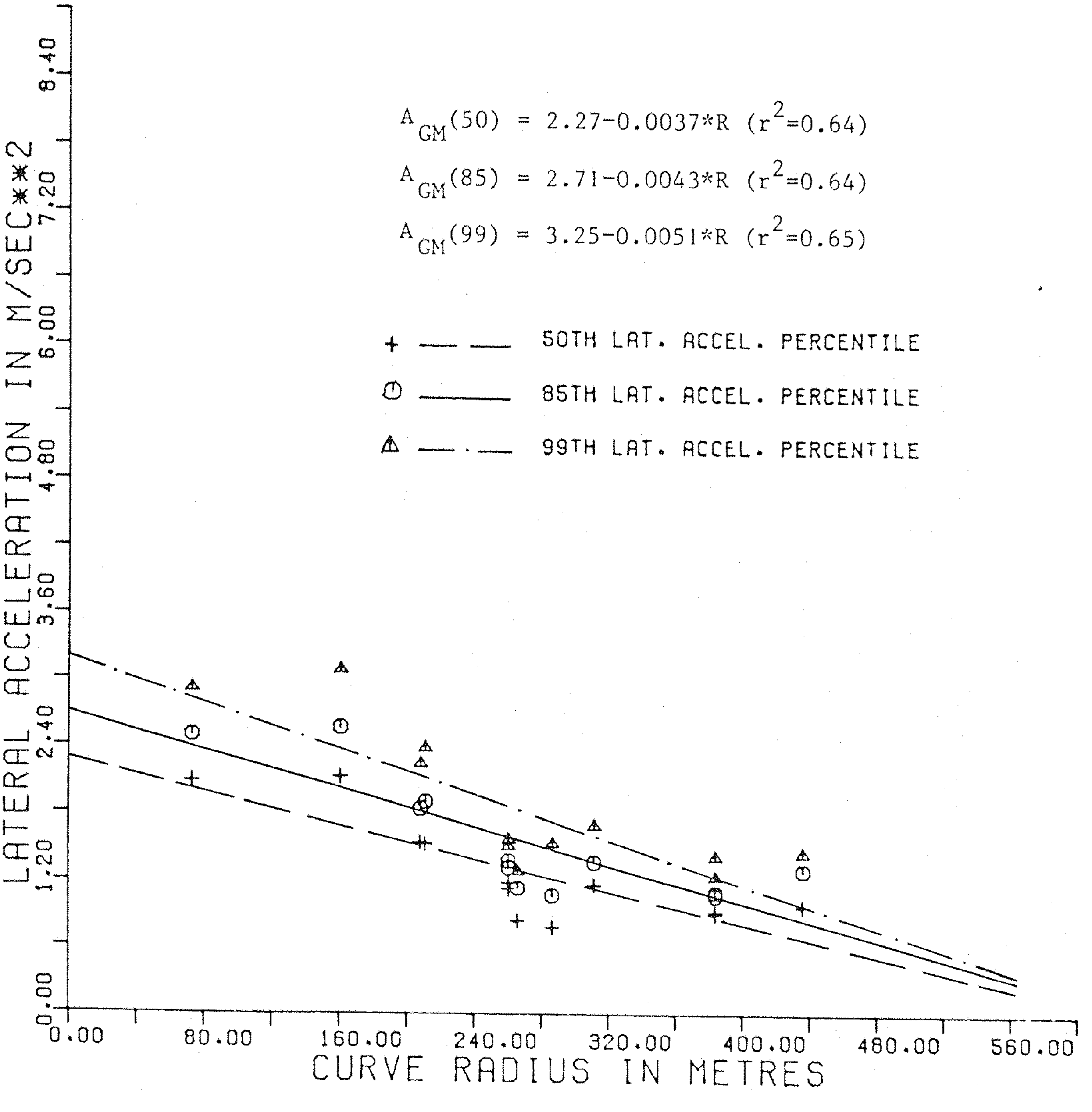


Figure D27 : Relationship between Middle Lateral Acceleration and Curve Radius
(Dual Carriageways - Goods Vehicles)

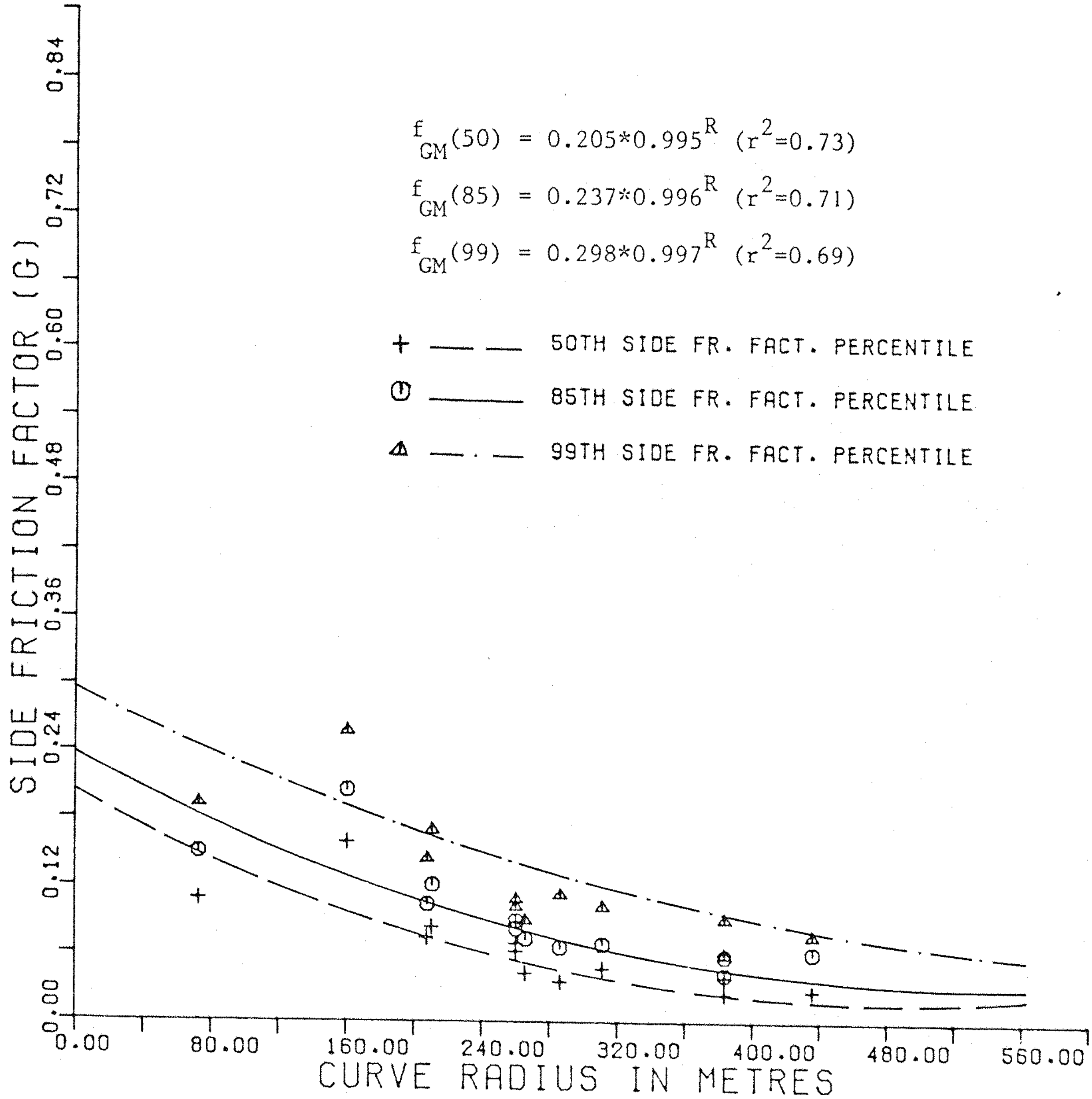


Figure D28 : Relationship between Middle Side-Friction Factor and Curve Radius
(Dual Carriageways - Goods Vehicles)

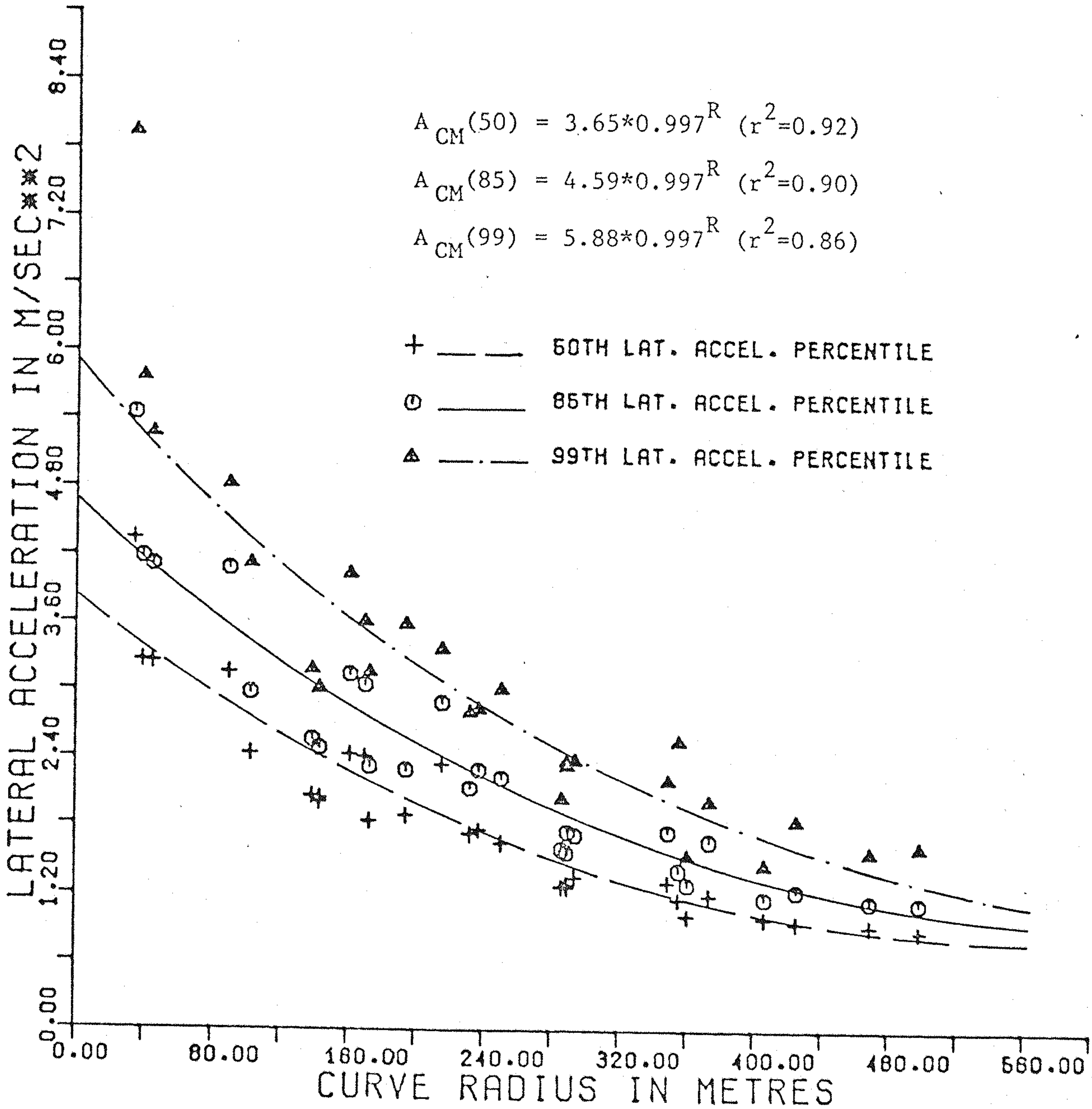


Figure D29 : Relationship between Middle Lateral Acceleration and Curve Radius
(Single Carriageways - All Cars - Right-Hand Curves)

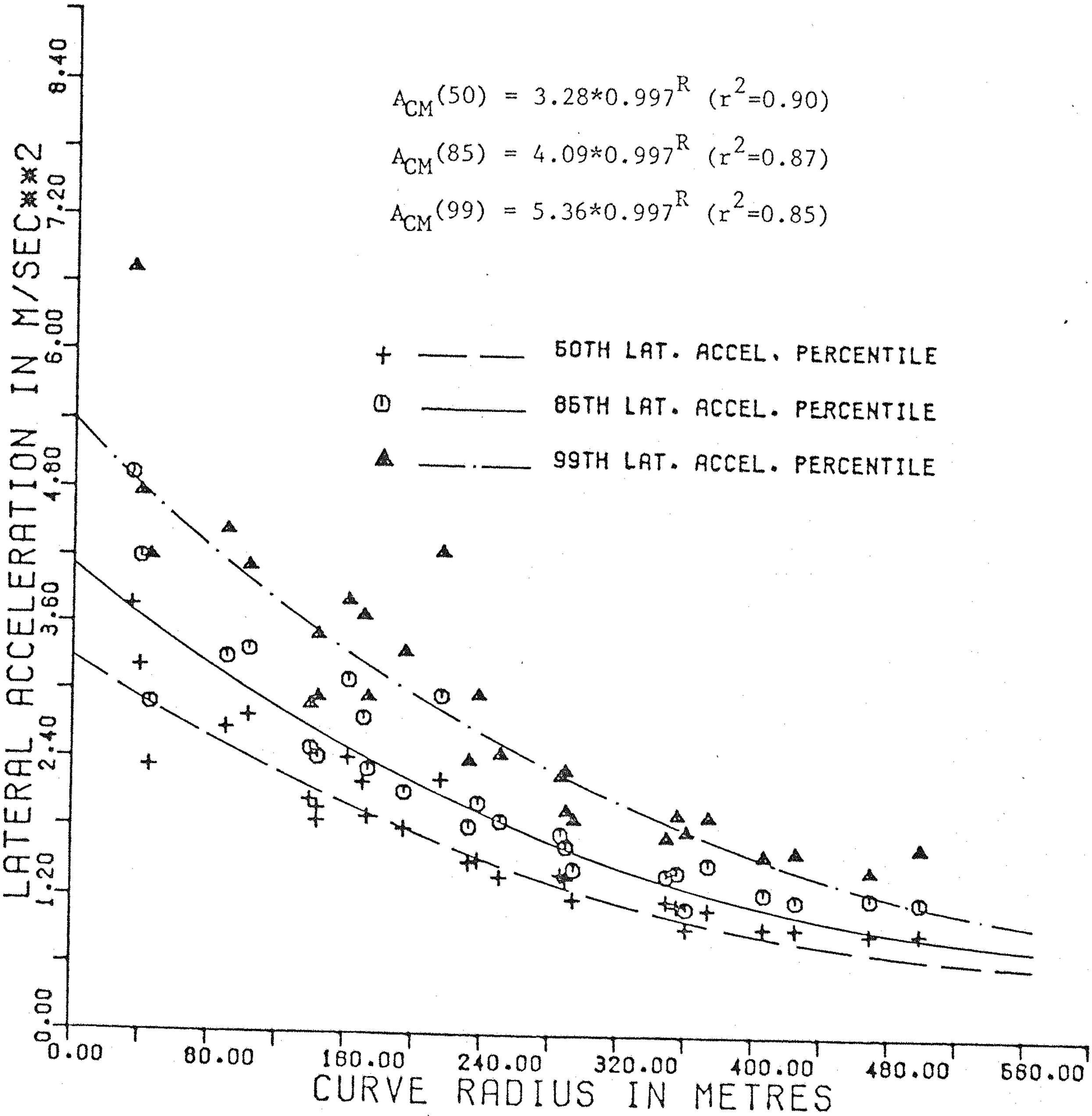


Figure D30 : Relationship between Middle Lateral Acceleration and Curve Radius
(Single Carriageways - All Cars - Left-Hand Curves)

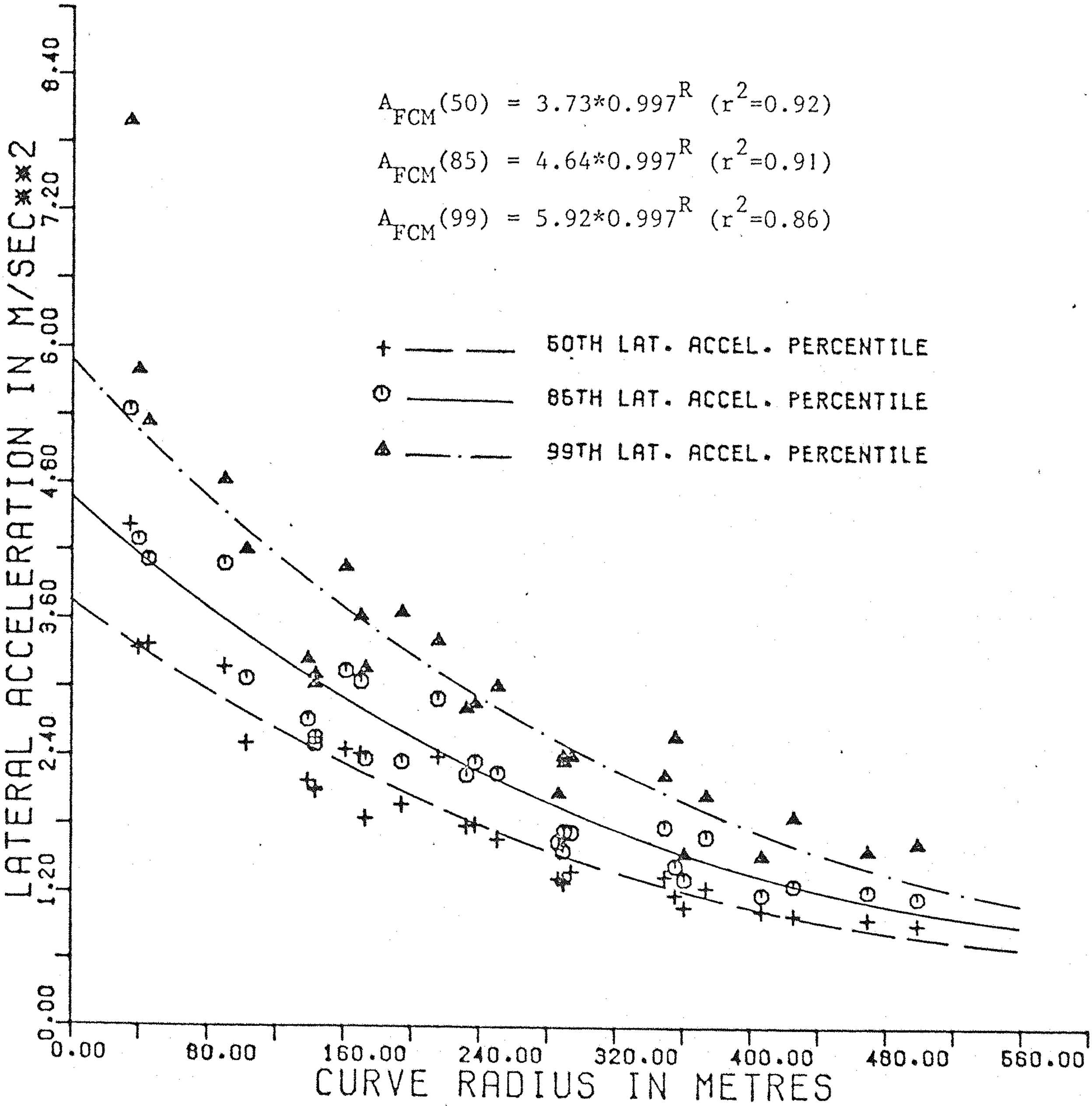


Figure D31 : Relationship between Middle Lateral Acceleration and Curve Radius
(Single Carriageways - Free Cars - Right-Hand Curves)

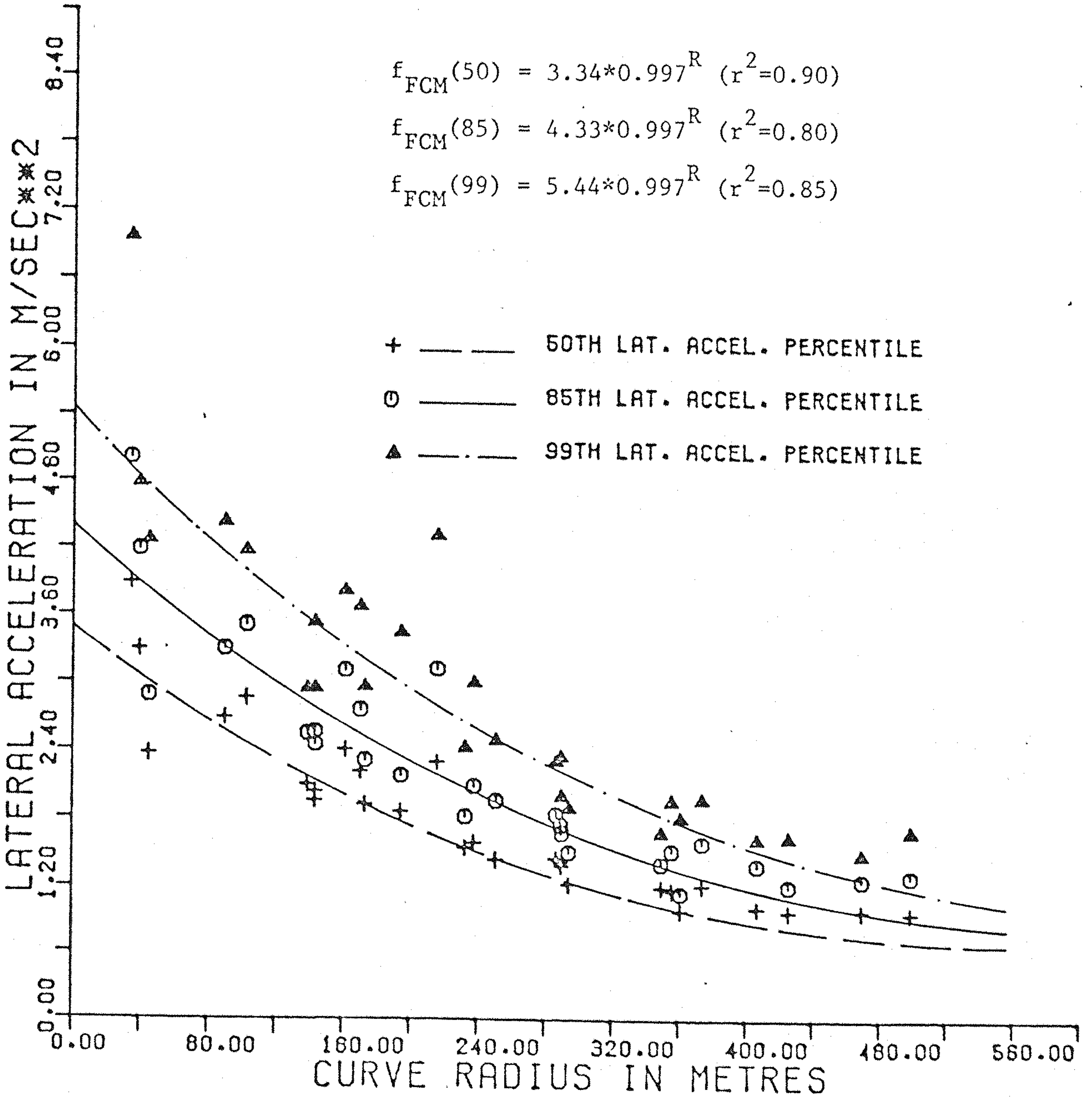


Figure D32 : Relationship between Middle Lateral Acceleration and Curve Radius
(Single Carriageways - Free Cars - Left-Hand Curves)

$A_{FCM}(50) = 5.74-0.058*V$ (r^2=0.59)

$A_{FCM}(85) = 6.40-0.053*V$ (r^2=0.36)

$A_{FCM}(99) = 8.68-0.065*V$ (r^2=0.47)

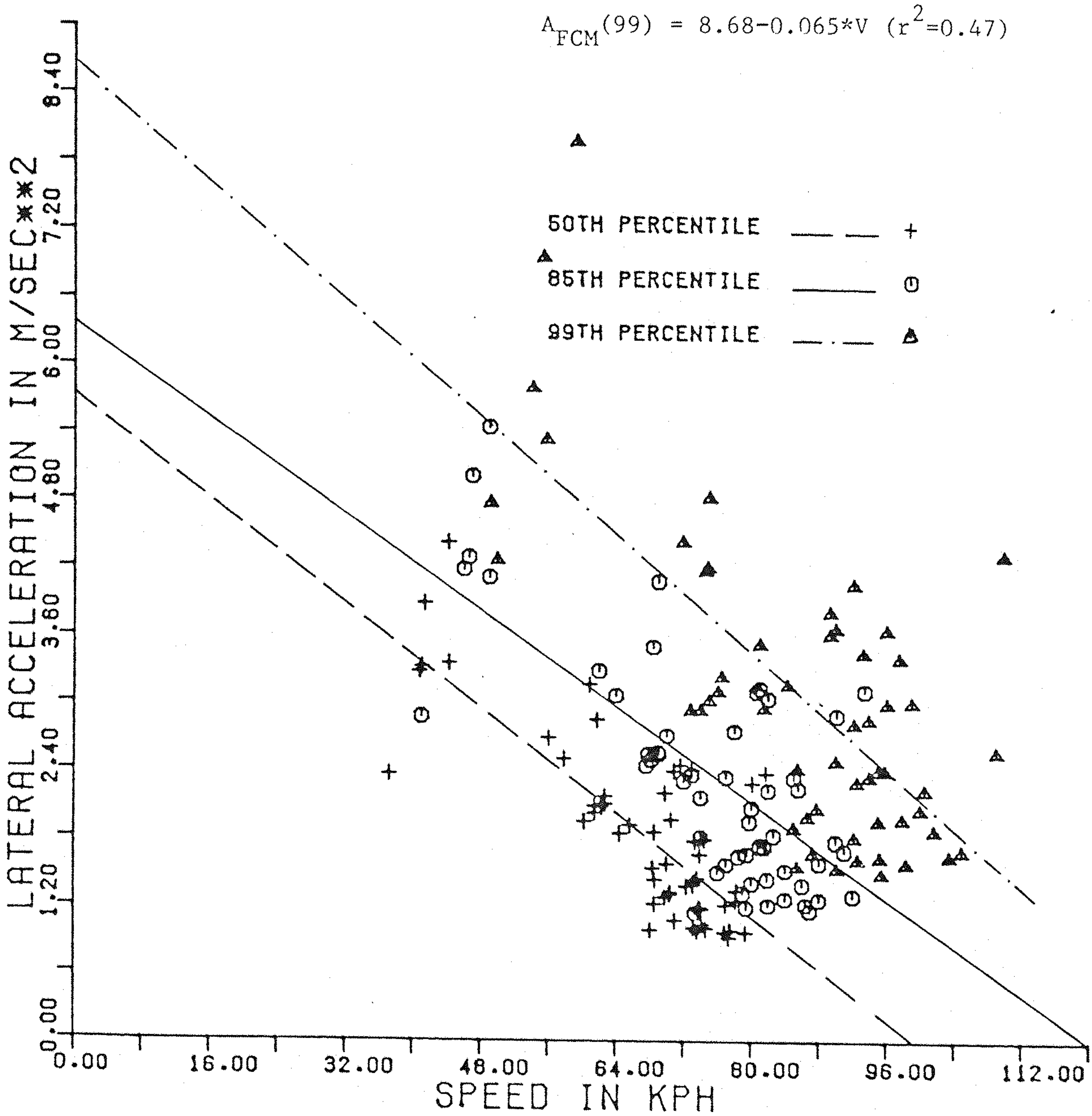


Figure D33 : Relationship between Middle Lateral Acceleration and Middle Speed
(Single Carriageways - Free Cars)

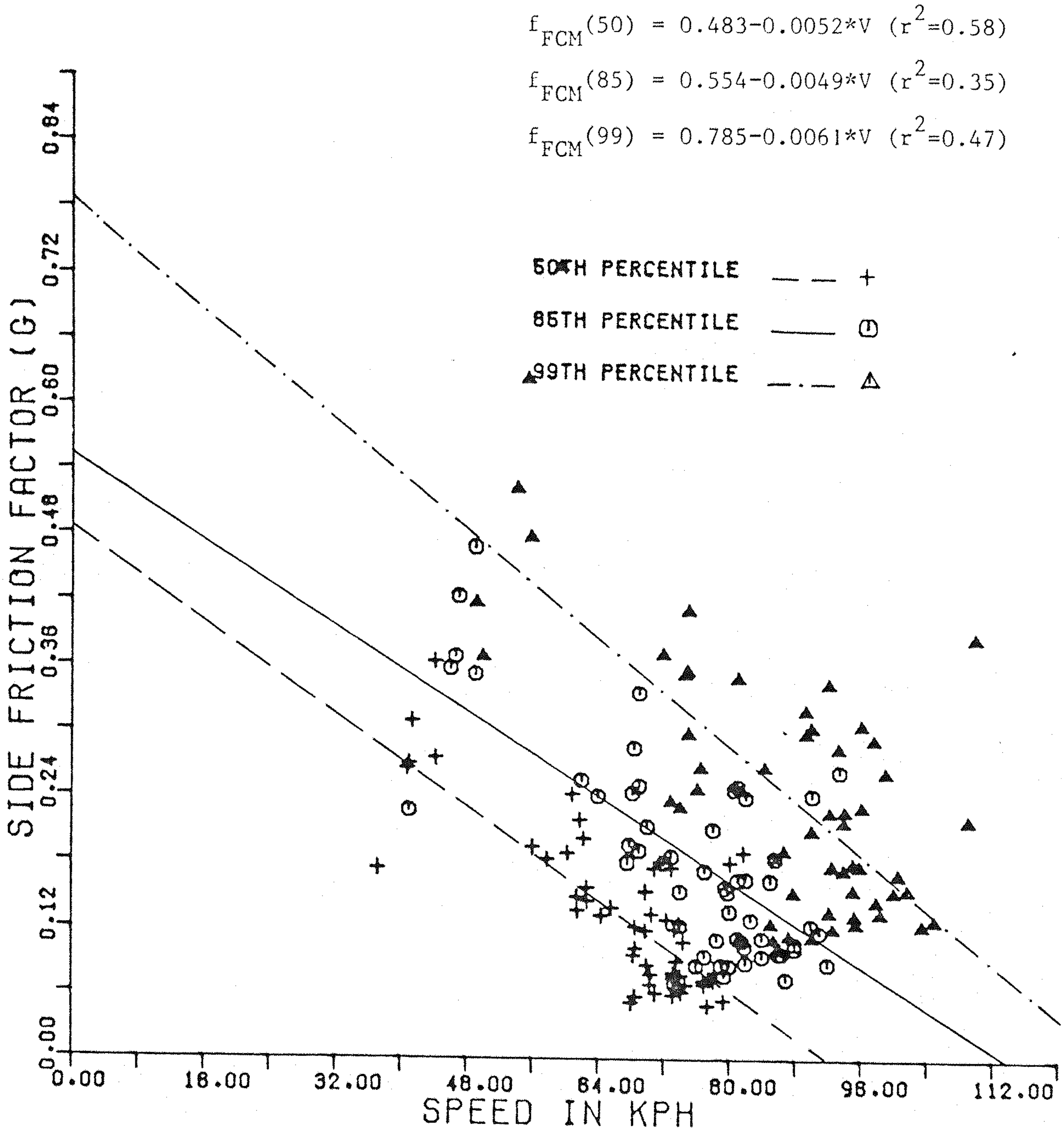


Figure D34 : Relationship between Middle Side-Friction Factor and Middle Speed
(Single Carriageways - Free Cars)

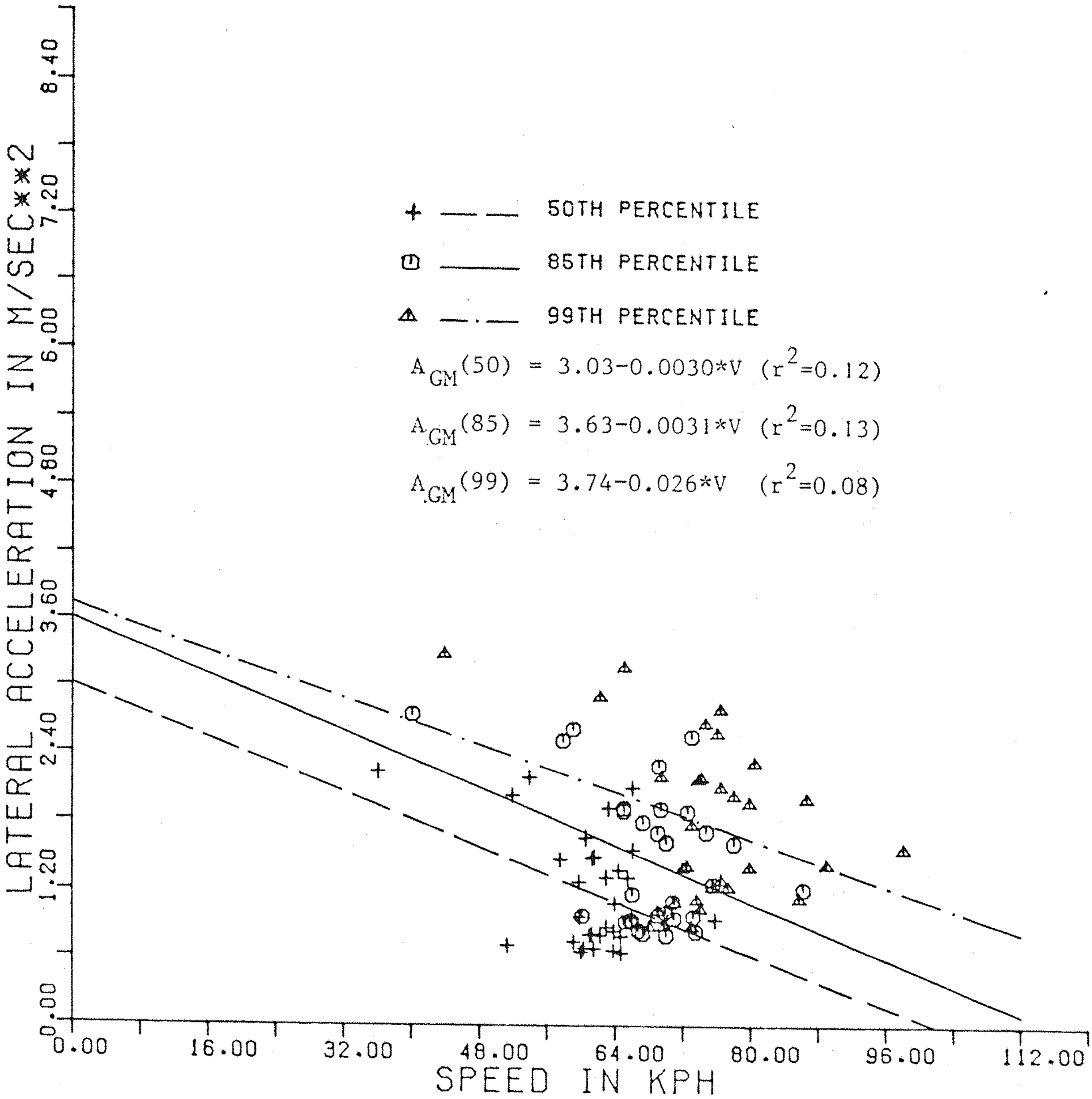


Figure D35 : Relationship between Middle Lateral Acceleration and Middle Speed
(Single Carriageways - Goods Vehicles)

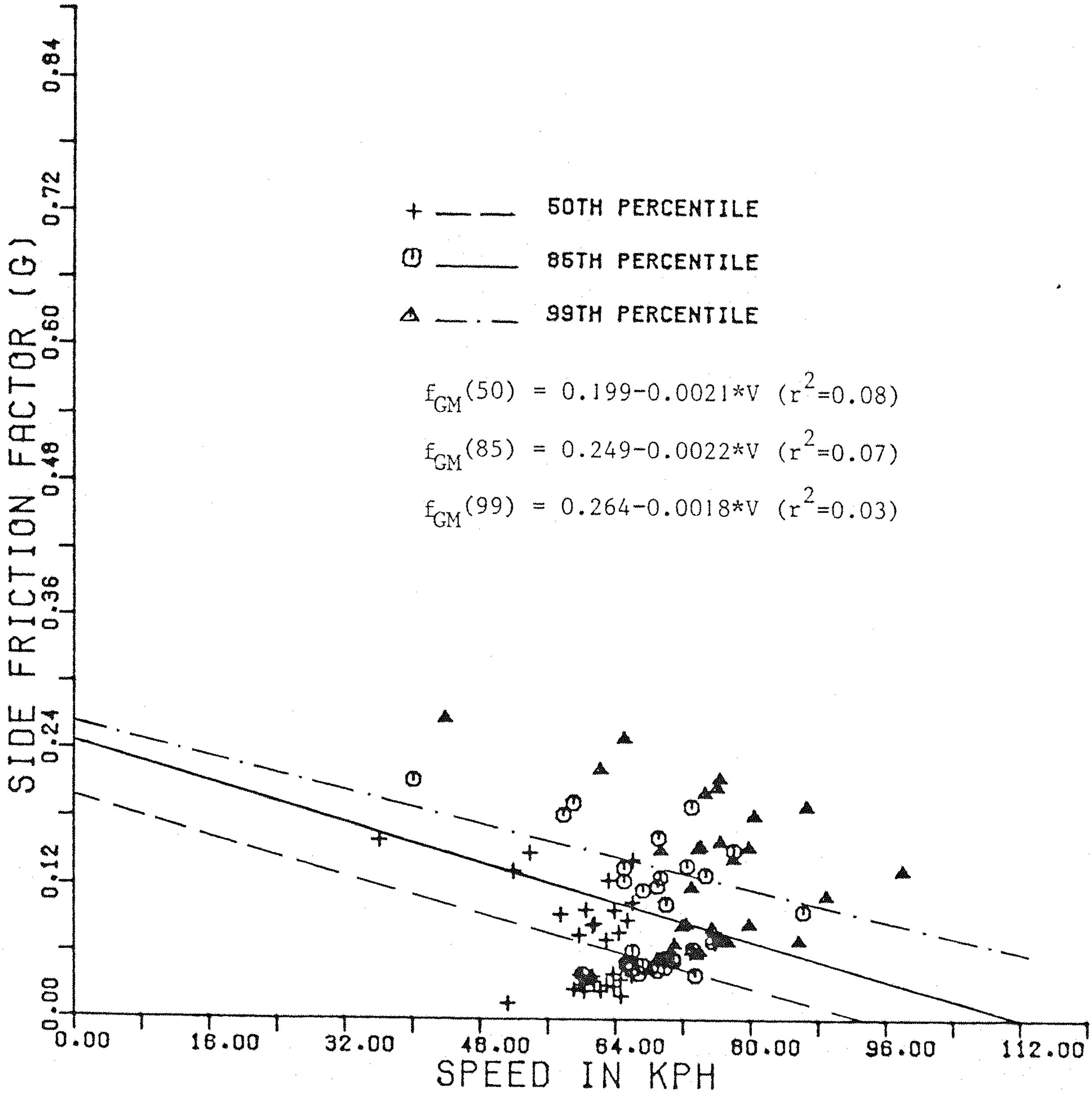


Figure D36 : Relationship between Middle Side-Friction Factor and Middle Speed
(Single Carriageways - Goods Vehicles)

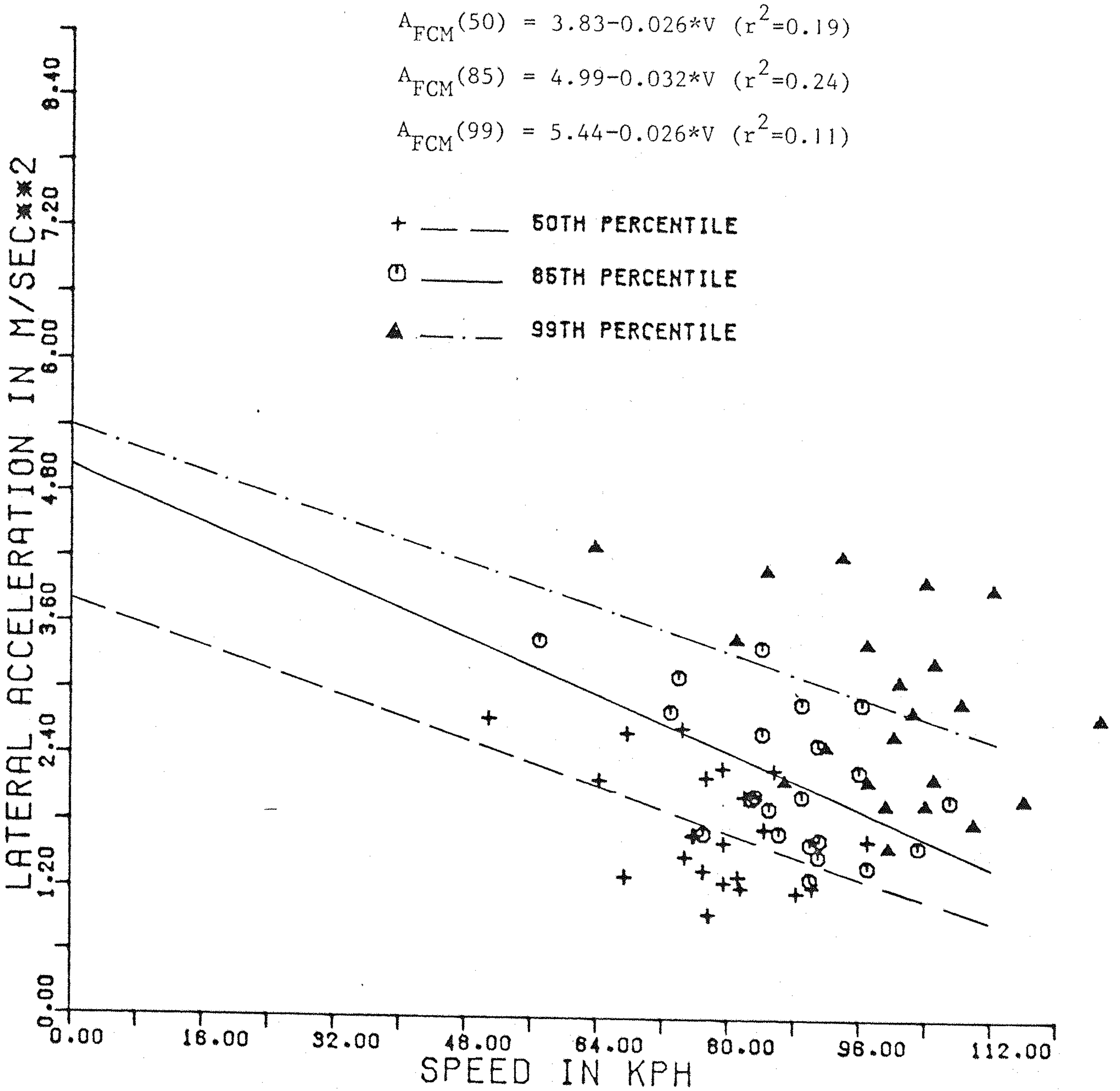


Figure D37 : Relationship between Middle Lateral Acceleration and Middle Speed
(Dual Carriageways - Free Cars)

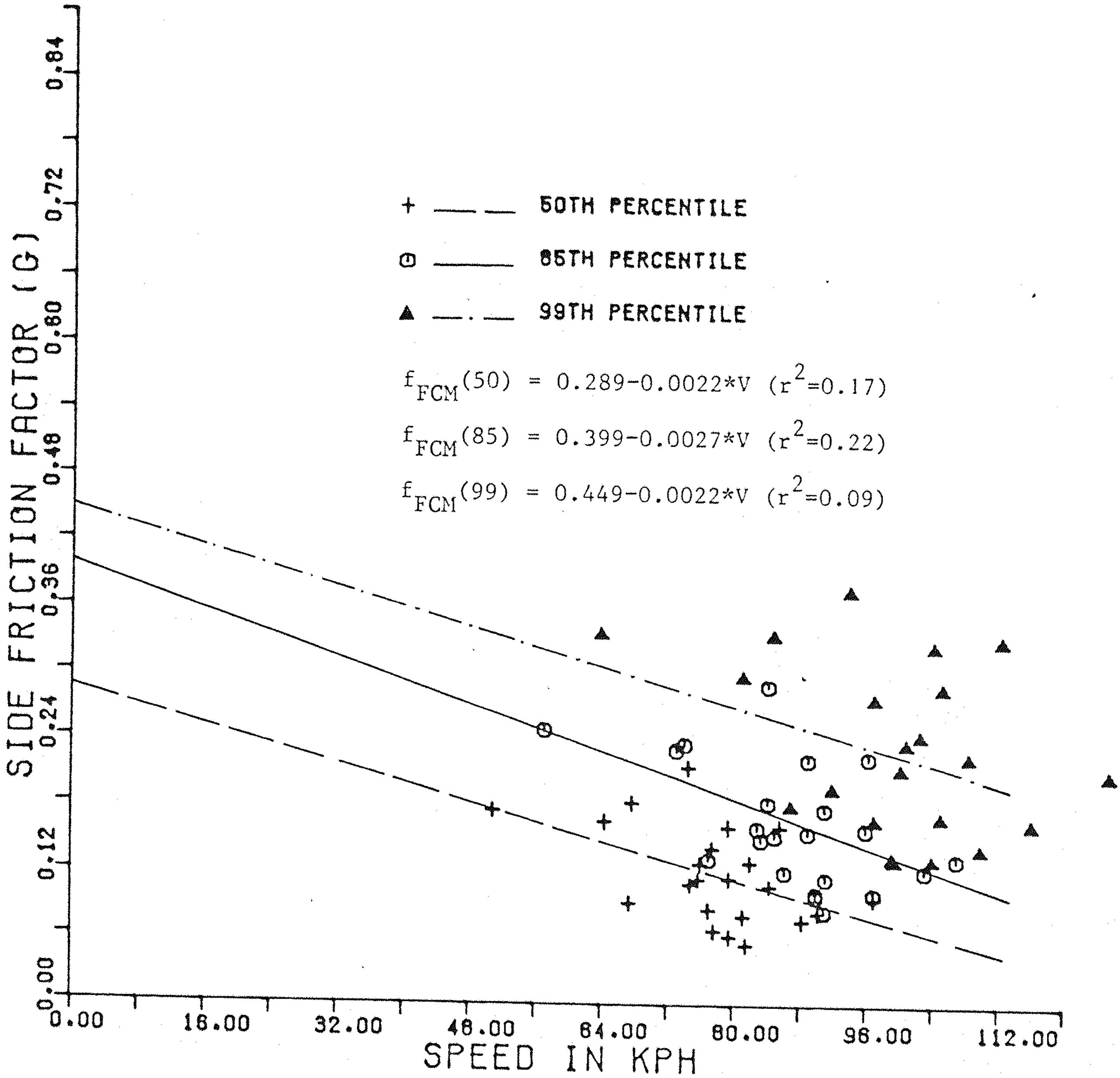


Figure D38 : Relationship between Middle Side-Friction Factor and Middle Speed
(Dual Carriageways - Free Cars)

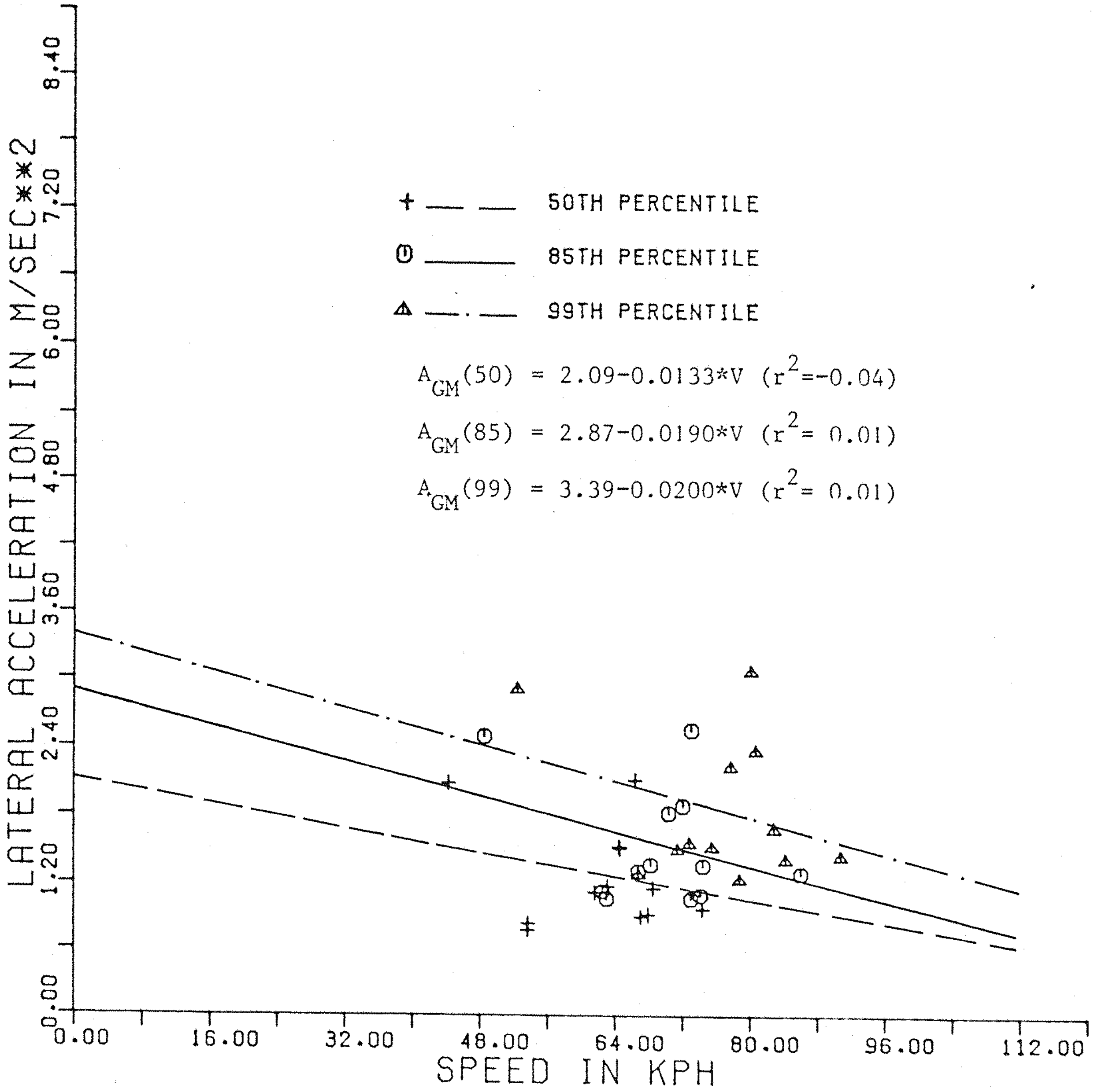


Figure D39 : Relationship between Middle Lateral Acceleration and Middle Speed
(Dual Carriageways - Goods Vehicles)

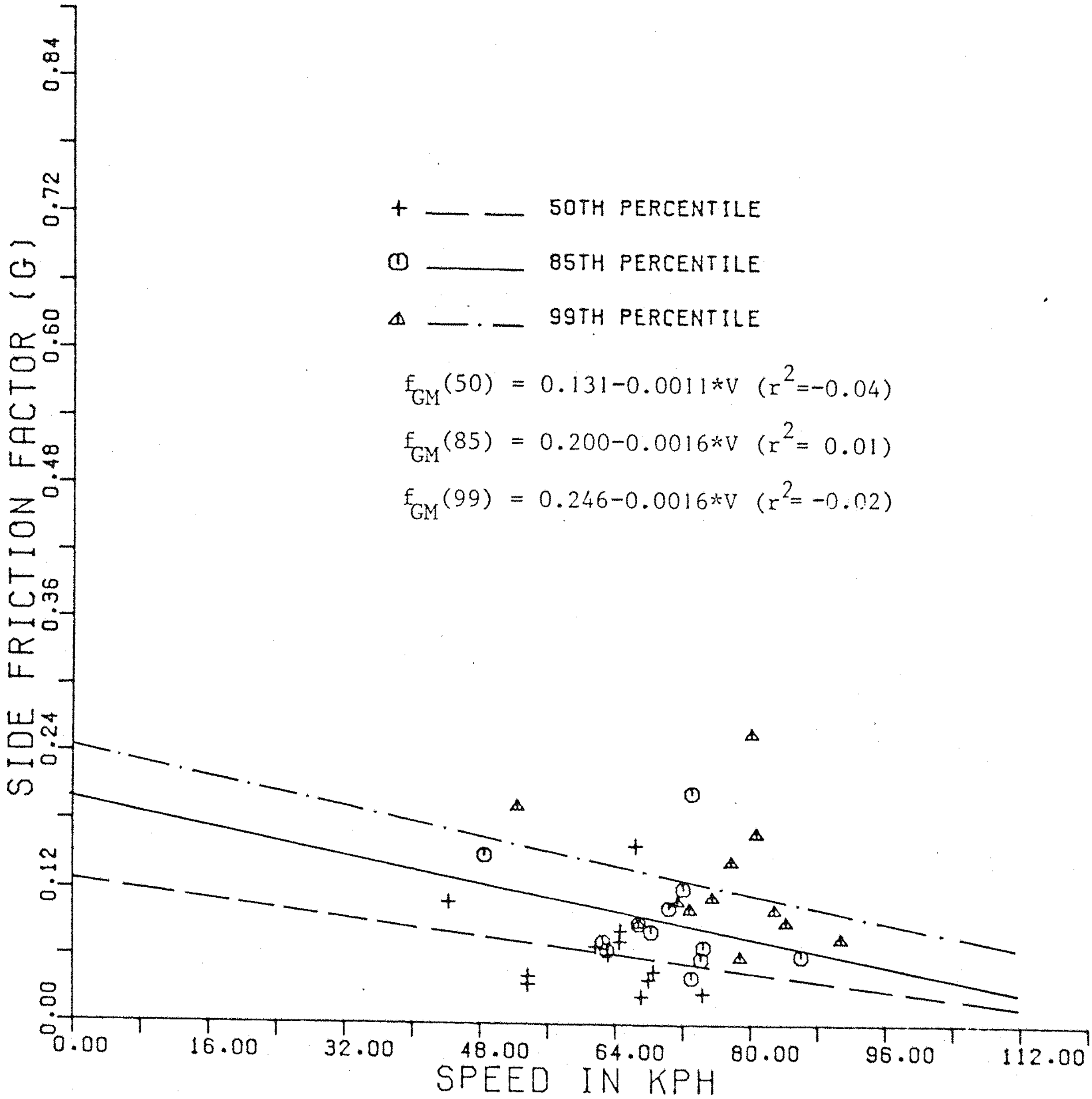


Figure D40 : Relationship between Middle Side-Friction Factor and Middle Speed
(Dual Carriageways - Goods Vehicles)

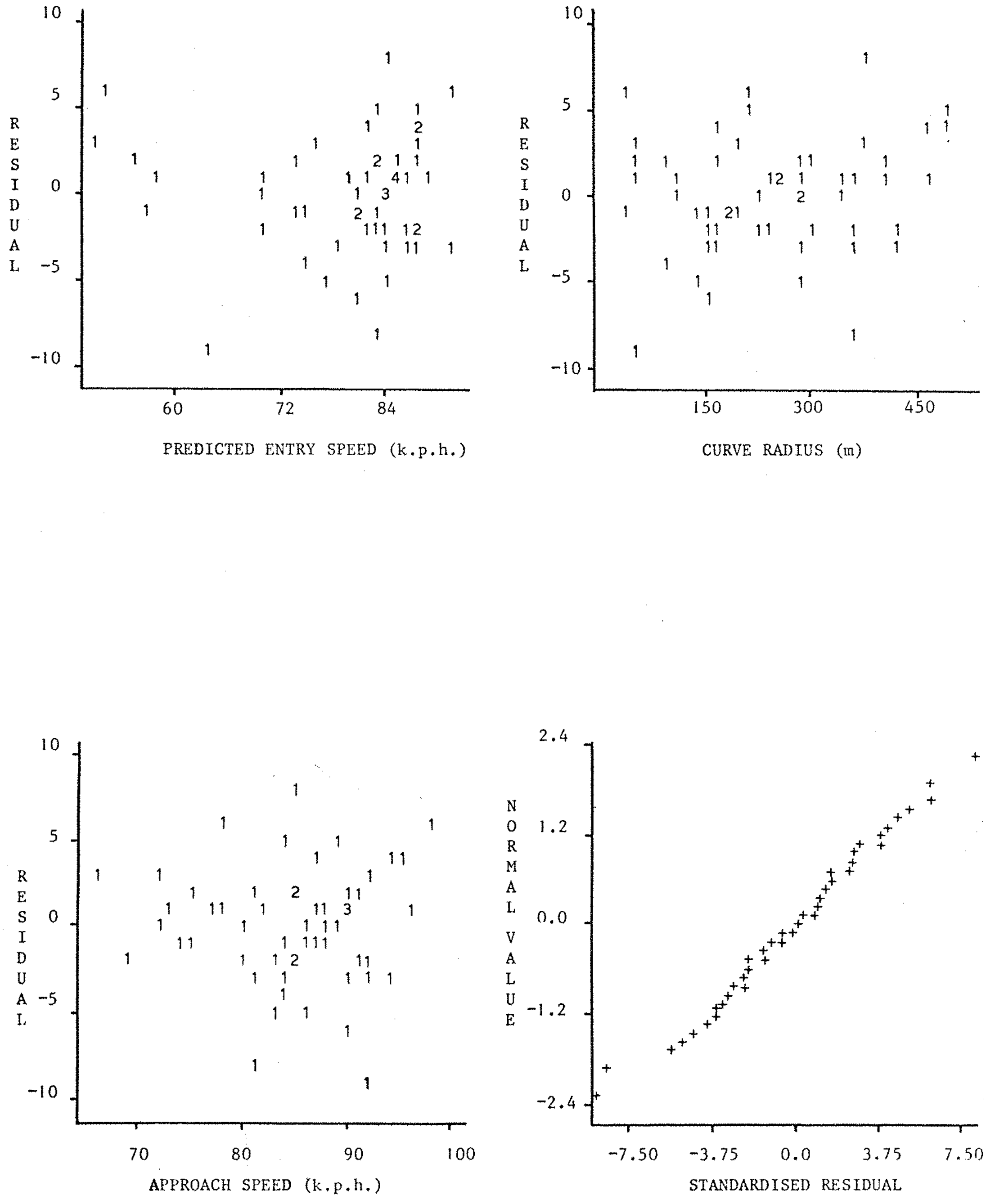


Figure D41 : Plots of Residuals for Relationship $V_{CE}(85)=43.28-0.65C+0.49AS-0.824VW$
(Single Carriageways - All Cars)

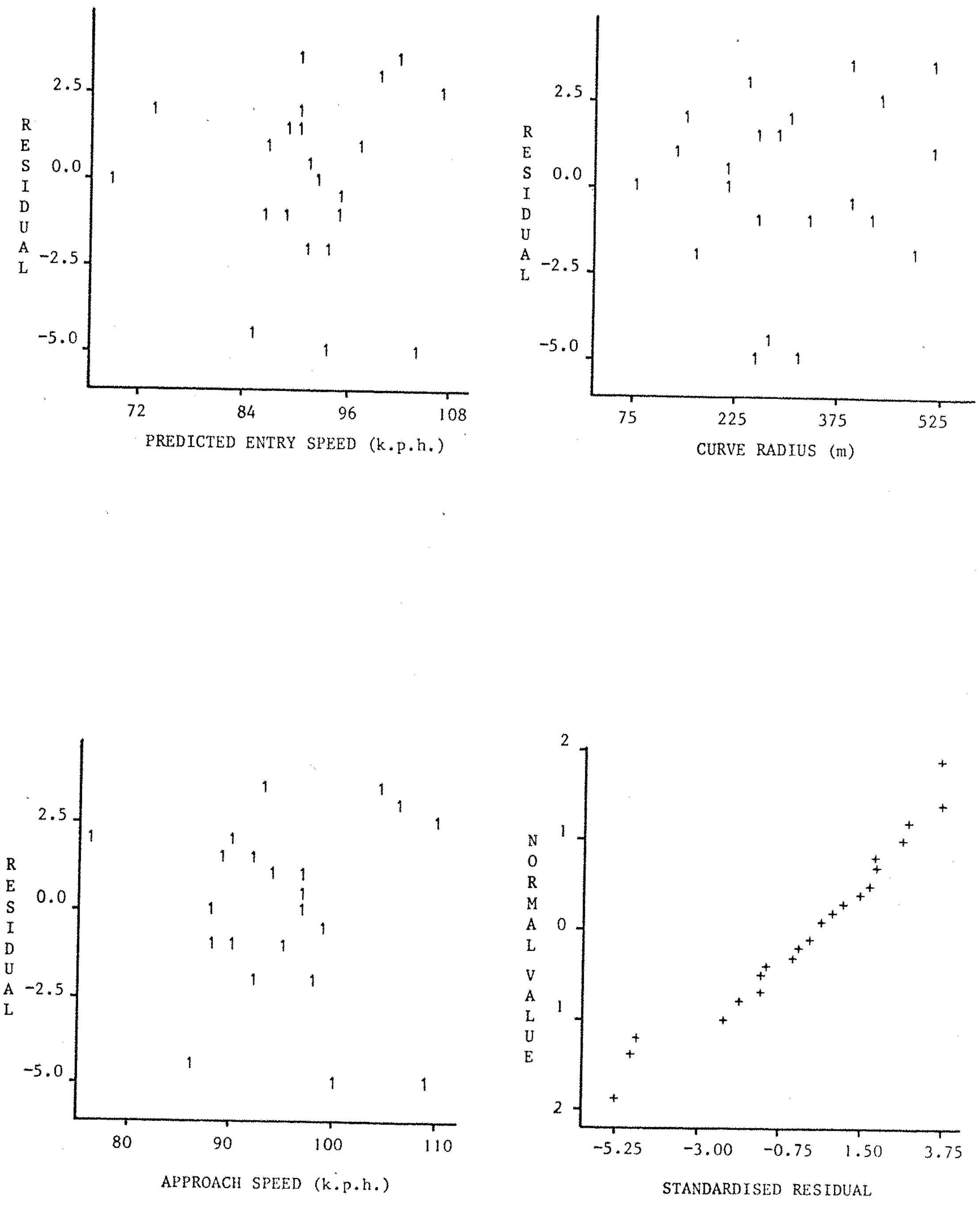


Figure D42 : Plots of Residuals for Relationship V_{CE} (85)=32.34+0.744AS-1.096C-0.005FL
(Dual Carriageways - All Cars)

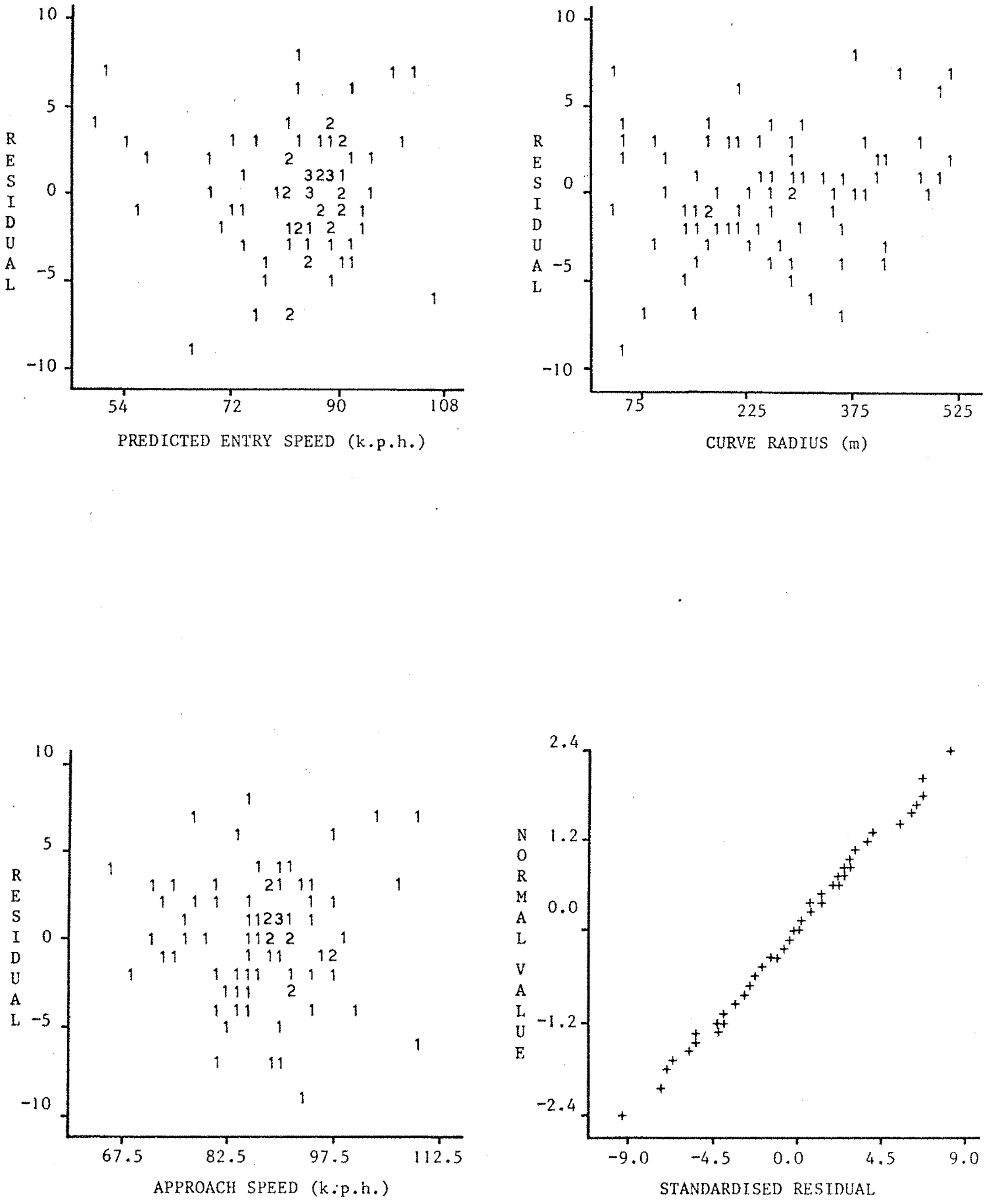


Figure D43 : Plots of Residuals for Relationships $V_{CE}(85)=34.86-0.64C+0.56AS+0.735VW+0.69RW$
(Single and Dual Carriageways - All Cars)

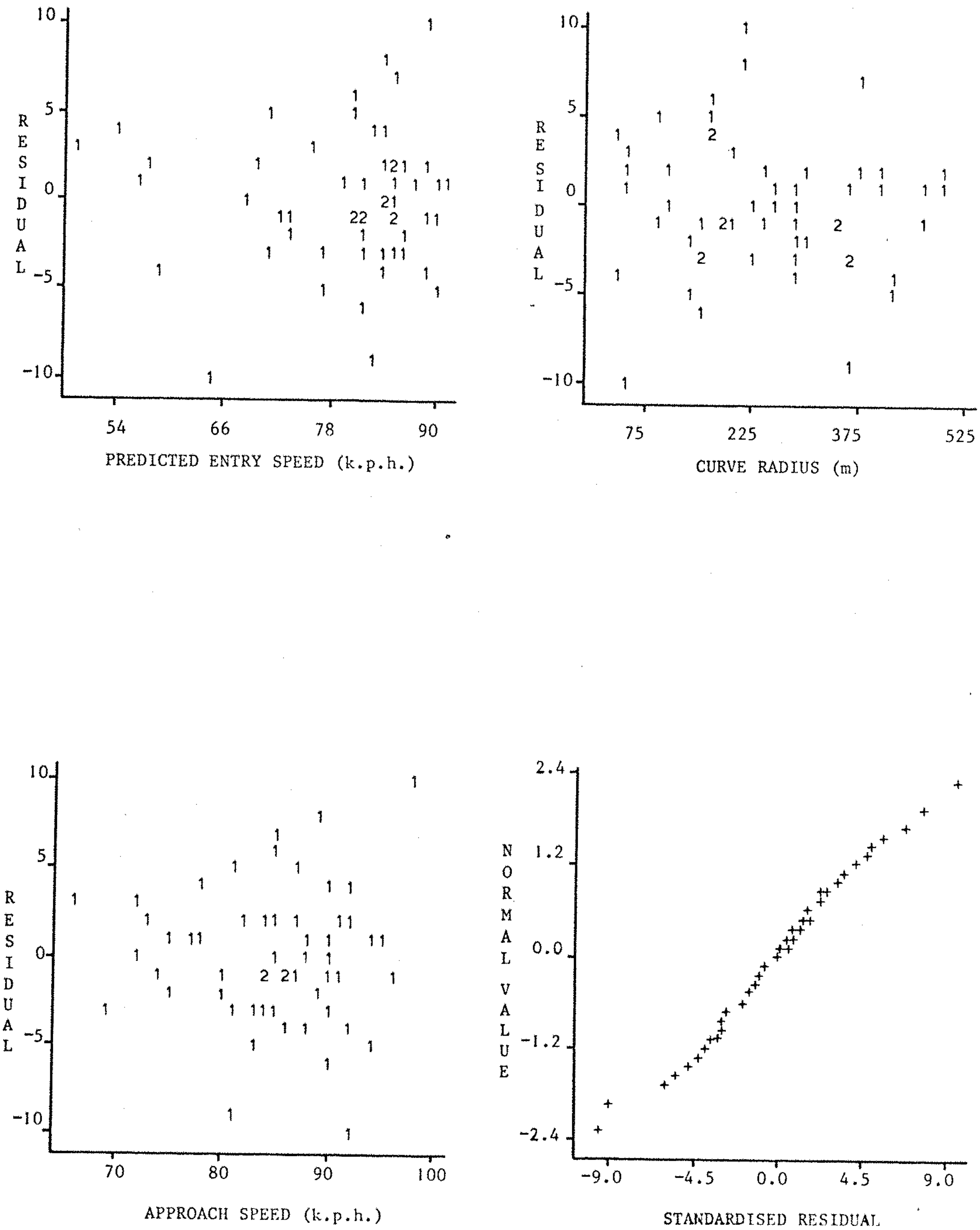


Figure D44 : Plots of Residuals for Relationship V_{CE} (85)=48.69-0.86C+0.475AS+0.0004C^3 (Single Carriageways - All Cars)

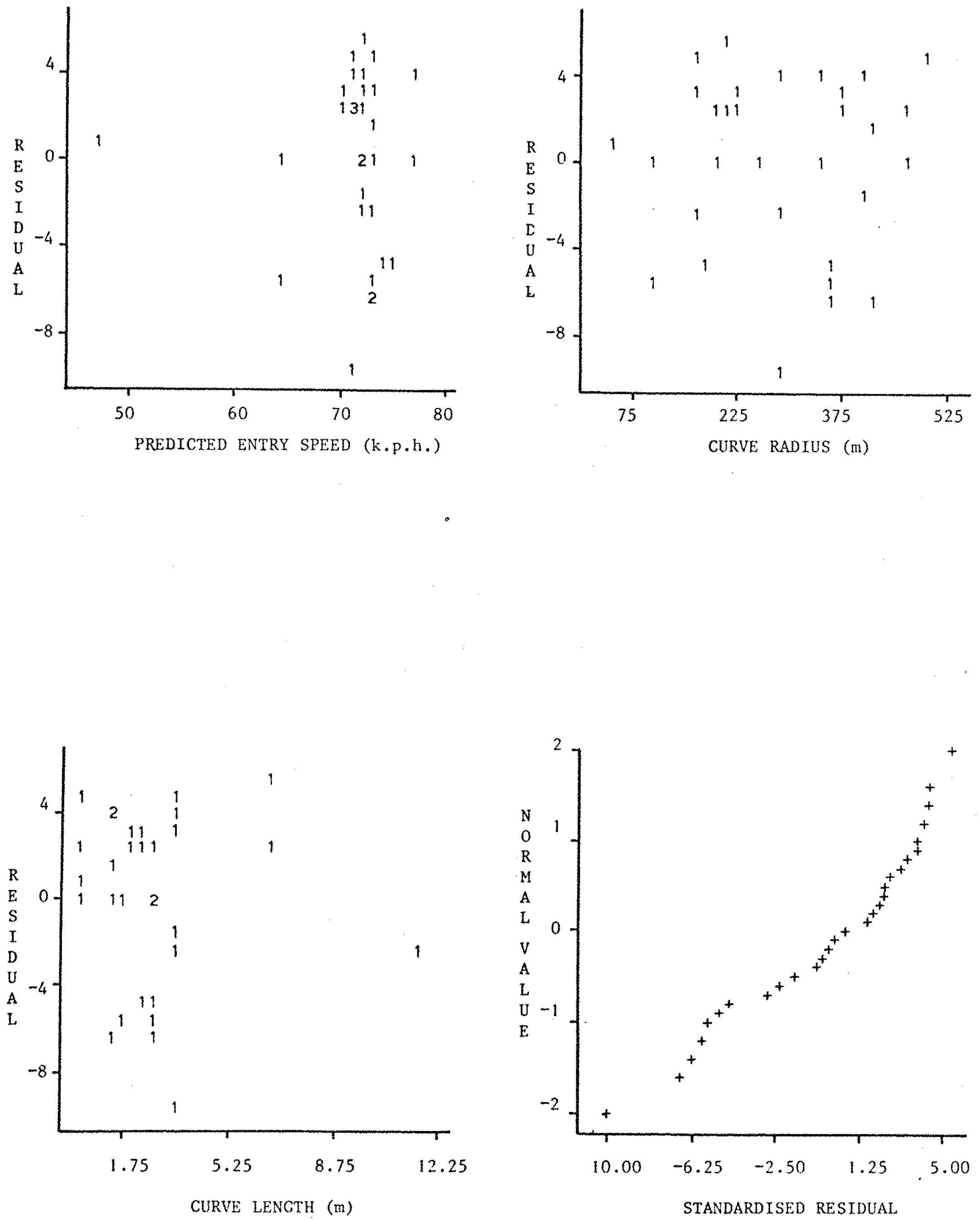


Figure D45 : Plots of Residual for Relationship V_{GE} (85)=85.53-0.894C-0.014FL
(Single Carriageways - Goods Vehicles)

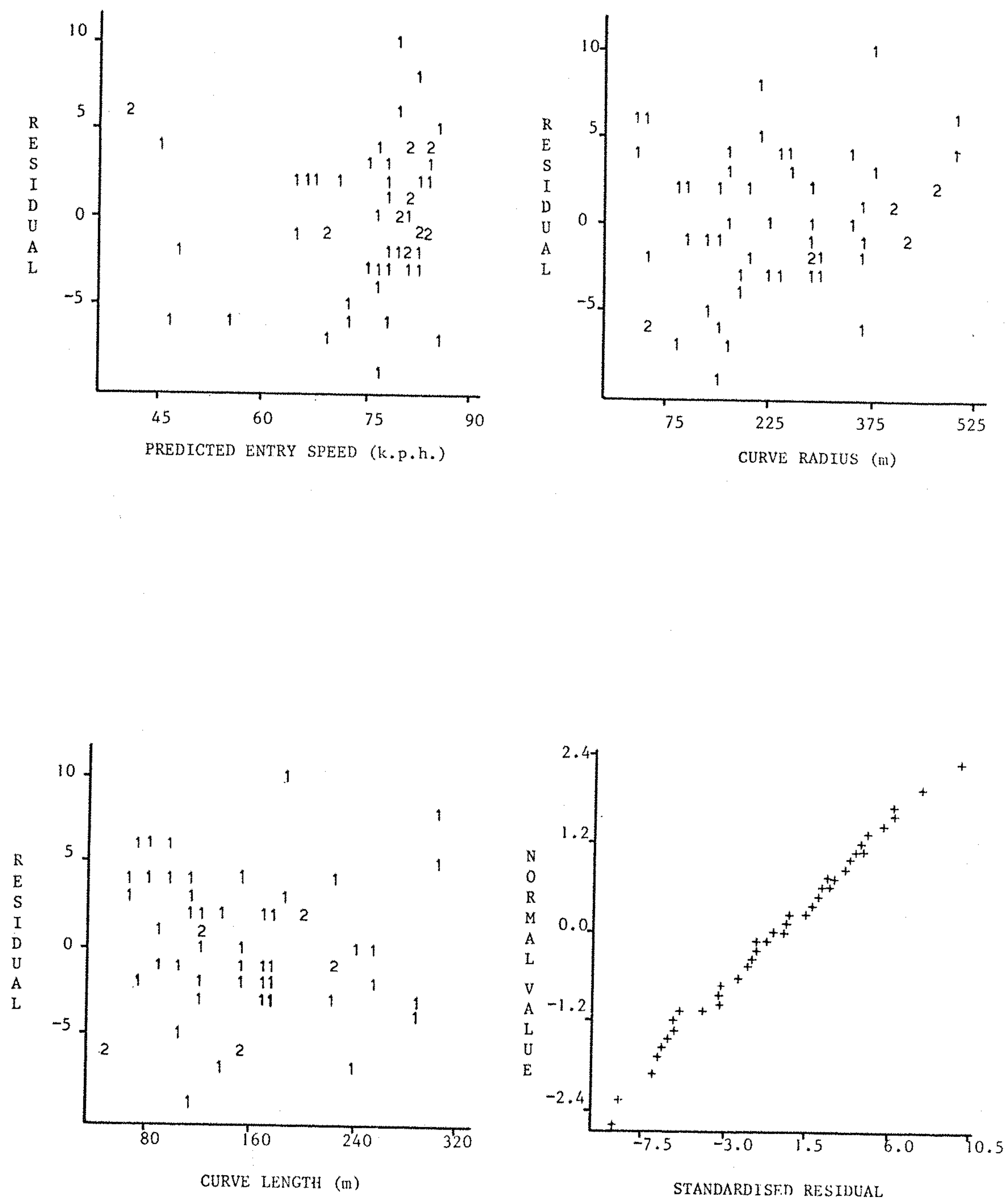


Figure D46 : Plots of Residuals for Relationship $V_{CM}(85)=43.63-0.804C+0.46AS+0.627VW$
(Single Carriageways - All Cars)

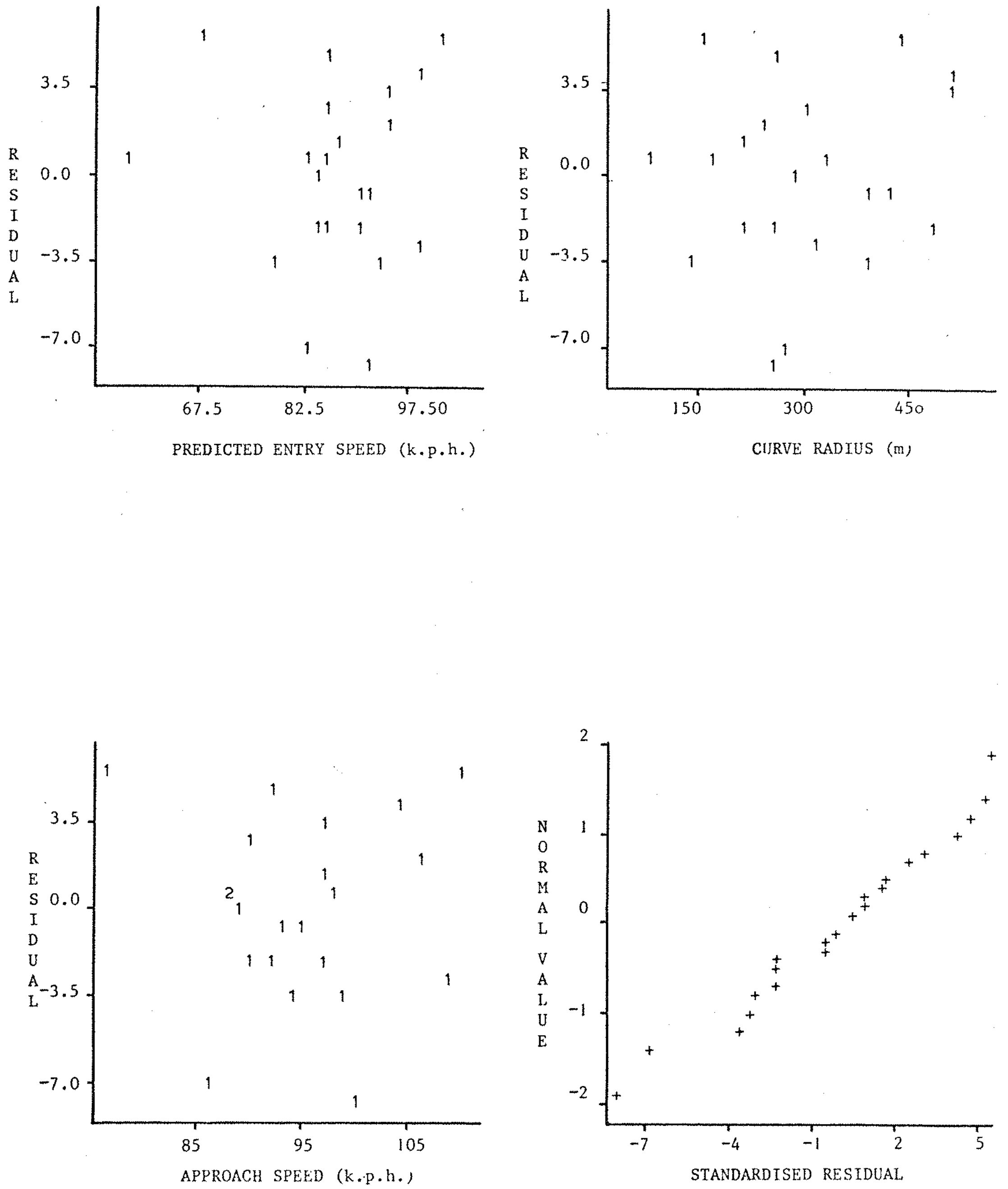


Figure D47 : Plots of Residuals for Relationship $V_{CM}(85)=35.30-1.526C+0.657AS$
(Dual Carriageways - All Cars)

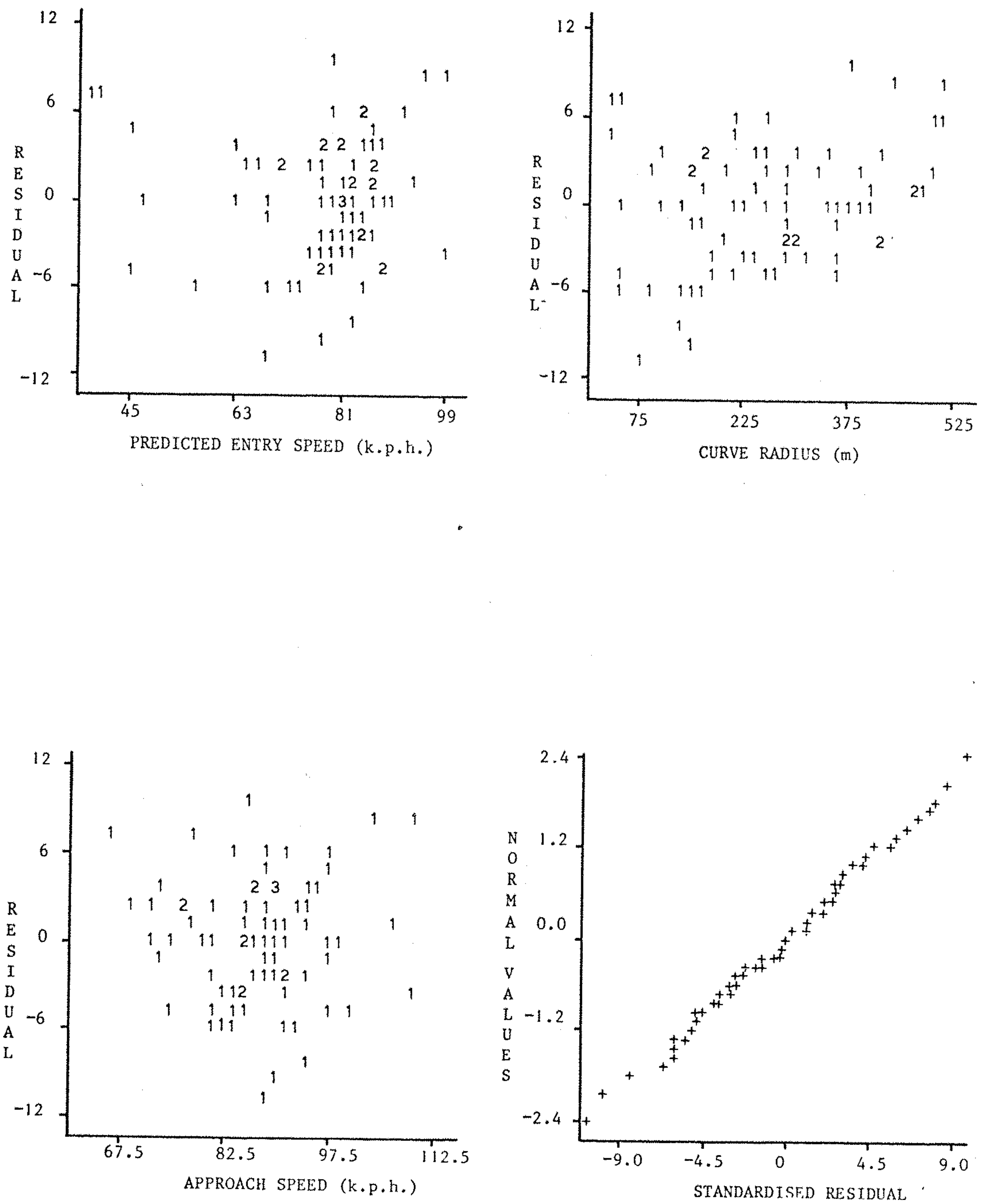


Figure D48 : Plots of Residuals for Relationship $V_{CM}(85)=35.06-0.815C+0.533AS+0.546VW+0.65RW$
(Single and Dual Carriageways - All Cars)

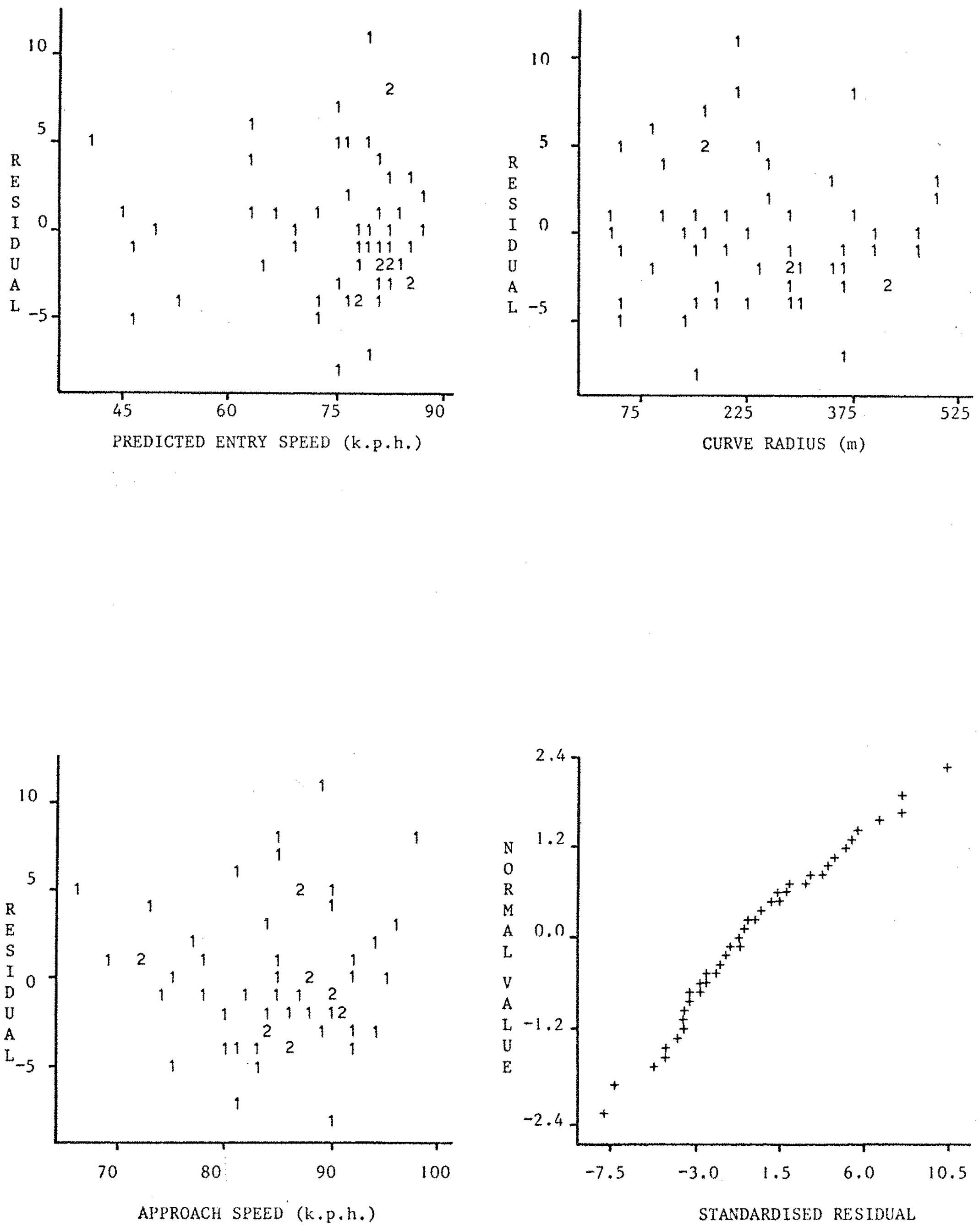


Figure D49 : Plots of Residuals for Relationship $V_{CM}(85)=54.58-1.24C+0.39AS+0.0004C^3$
(Single Carriageways - All Cars)

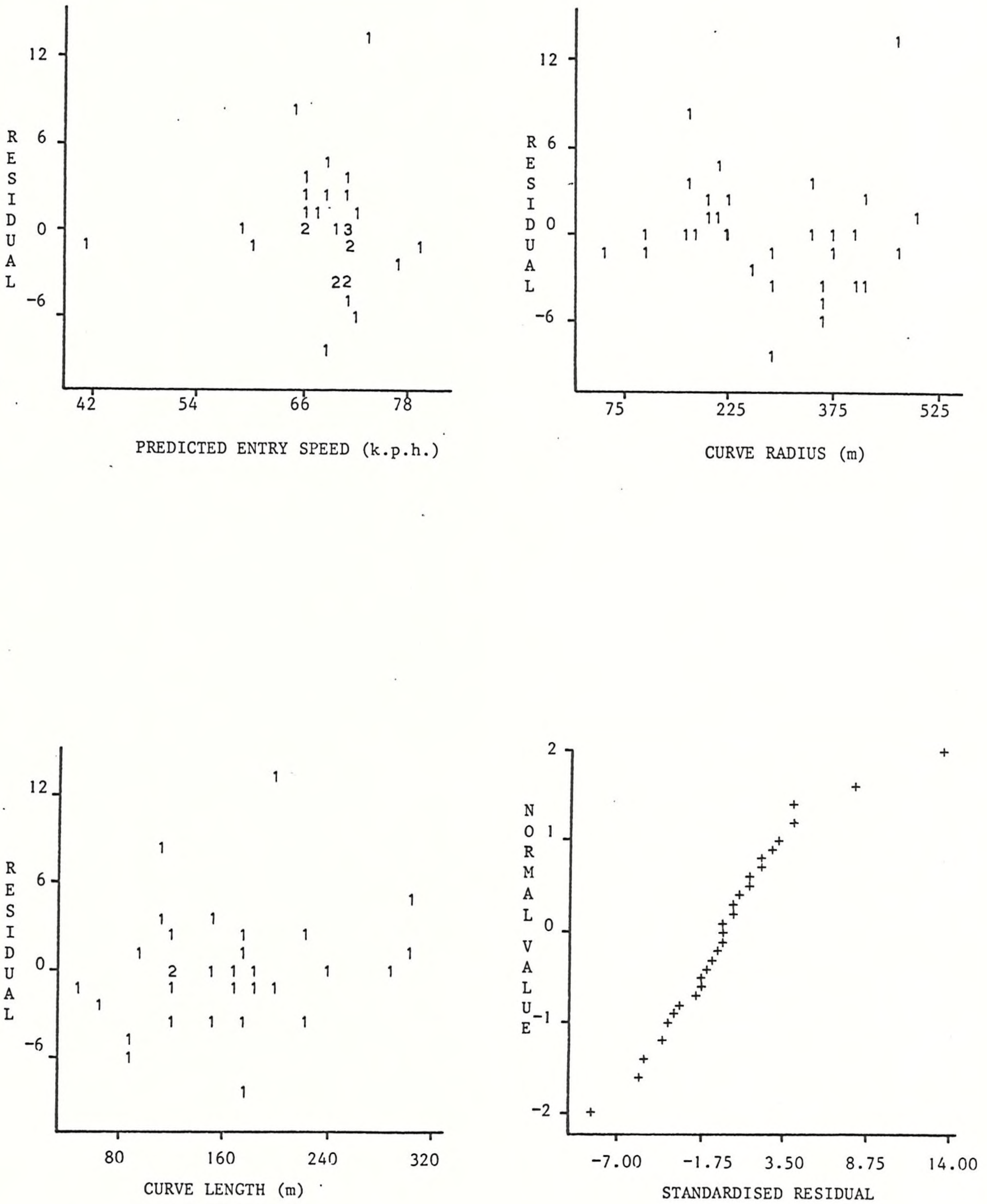


Figure D50 : Plots of Residuals for Relationship $V_{GM}(85)=73.55-0.856C+0.005SD$
(Single Carriageways - Goods Vehicles)

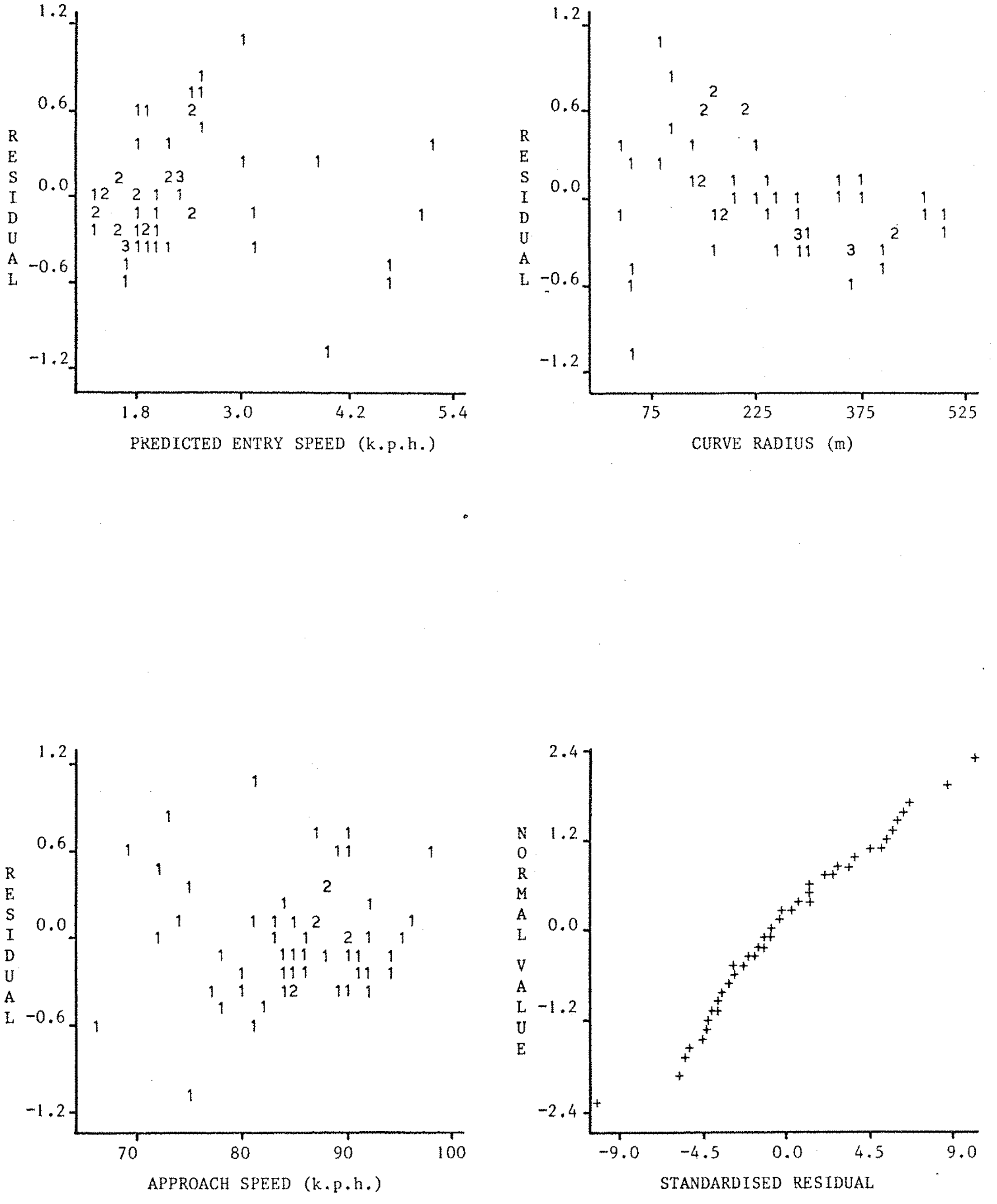


Figure D51 : Plots of Residuals for Relationship $A_{CM}=2.12-0.007R+0.023AS$
(Single Carriageways - All Cars)

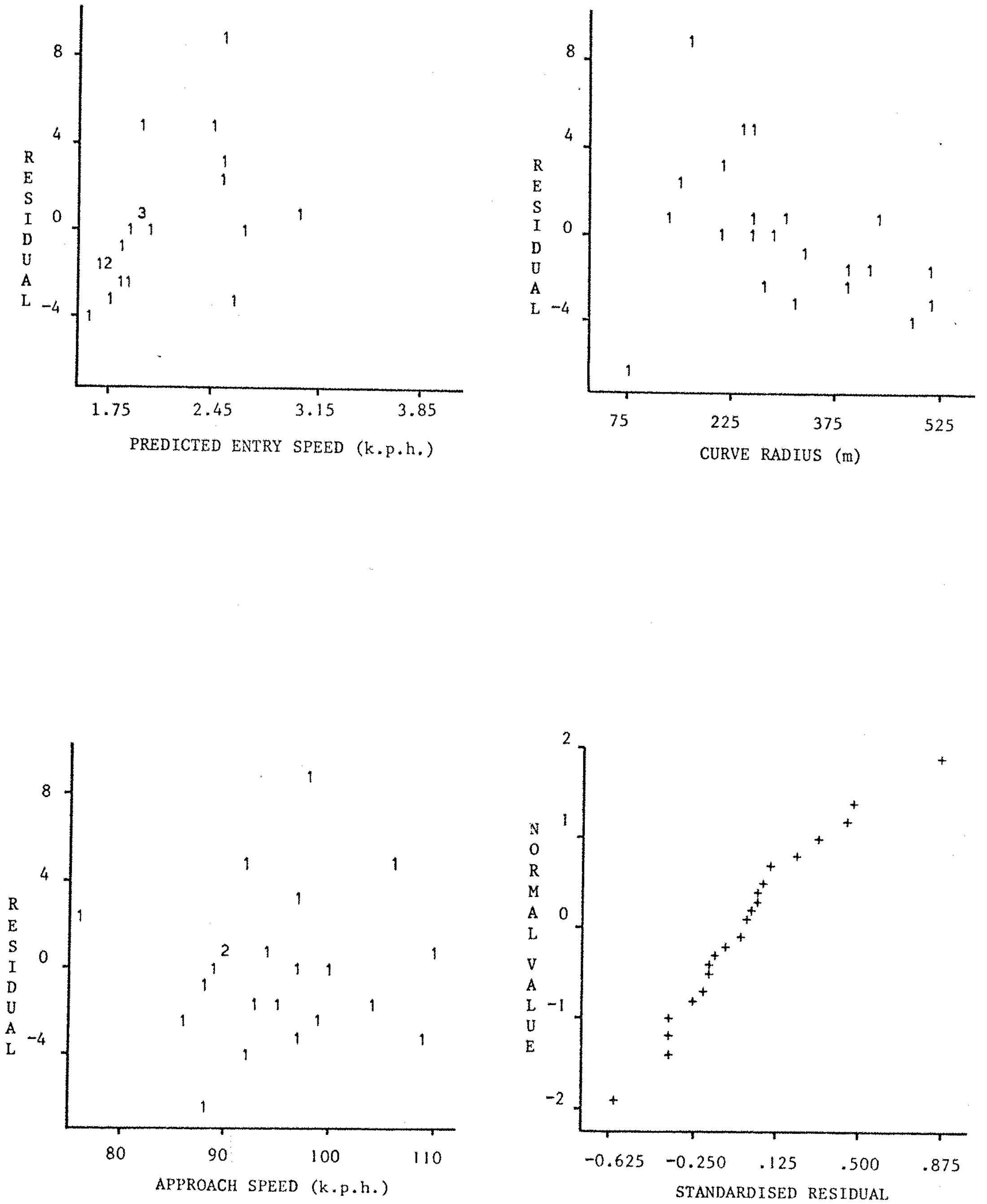


Figure D52 : Plots of Residuals for Relationship $A_{CM}(85)=0.219-0.005R+0.022AS+0.209RW$
(Dual Carriageways - All Cars)