

OVERSEAS ROAD NOTE 40



***A guide to axle load surveys
and traffic counts for determining
traffic loading on pavements***





TRL Limited
Old Wokingham Road
Crowthorne, Berkshire, RG45 6AU



Department for International Development
1 Palace Street
London, SW1E 5HE

Overseas Road Note 40

A guide to axle load surveys and traffic counts for determining traffic loading on pavements

This document is an output from a project funded by the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of the DFID.

TRL is committed to optimising energy efficiency, reducing waste and promoting recycling and re-use. In support of these environmental goals, this report has been printed on recycled paper, comprising 100% post-consumer waste, manufactured using a TCF (totally chlorine free) process.

The Department for International Development: a brief mission statement

The Department for International Development (DFID) is the UK Government department responsible for promoting sustainable development and reducing poverty. The central focus of the Government's policy, based on the 1997 and 2000 White Papers on International Development, is a commitment to the internationally agreed Millennium Development Goals, to be achieved by 2015. These seek to:

- Eradicate extreme poverty and hunger
- Achieve universal primary education
- Promote gender equality and empower women
- Reduce child mortality
- Improve maternal health
- Combat HIV/AIDS, malaria and other diseases
- Ensure environmental sustainability
- Develop a global partnership for development

DFID's assistance is concentrated in the poorest countries of sub-Saharan Africa and Asia, but also contributes to poverty reduction and sustainable development in middle-income countries, including those in Latin America and Eastern Europe.

DFID works in partnership with governments committed to the Millennium Development Goals, with civil society, the private sector and the research community. It also works with multilateral institutions, including the World Bank, United Nations agencies, and the European Commission.

DFID has headquarters in London and East Kilbride, offices in many developing countries, and staff based in British embassies and high commissions around the world.

DFID, 1 Palace Street, London SW1E 5HE

DFID, Abercrombie House, Eaglesham Road, East Kilbride, Glasgow G75 8EA

Tel: +44 (0) 20 7023 0000

Fax: +44 (0) 20 7023 0019

Public Enquiry Point: 0845 300 4100 (from outside the UK: +44 1355 84 3132)

DFID website: www.dfid.gov.uk

Email: enquiry@dfid.gov.uk

ACKNOWLEDGEMENTS

This edition was based on an earlier document, Road Note 40, on axle load measurement using a portable weighbridge. The new Overseas Road Note has been expanded to include traffic counting in addition to axle load survey procedures and was produced by the TRL team of Dr John Rolt, Nigel Hewitt, Linda Parsley and Nick Elsworth.

OVERSEAS ROAD NOTES

Overseas Road Notes are prepared principally for road and transport organisations in developing countries. A limited number of copies are available to other organisations and to individuals with an interest in road management, and may be obtained from:

Centre for International Development

TRL Limited

Crowthorne

Berkshire, RG45 6AU

United Kingdom

www.trl.co.uk

Limited extracts from the text may be reproduced provided the source is acknowledged. For more extensive reproduction, please contact TRL using the postal or website address above.

FOREWORD

In many countries road traffic is growing rapidly in volume and in the size and weight of the vehicles using the roads. As a consequence, highway engineers concerned with designing new roads or the strengthening of existing roads require reliable information about the distribution of axle loads for existing traffic as well as information on national or regional axle load trends. This information is required so that accurate forecasts can be made of the axle loads that a road will have to carry over its design life.

The importance of reliable traffic information for pavement design purposes is emphasised by the widely accepted engineering law that the degree of pavement damage caused by an axle load is proportional to approximately the fourth power of the axle load. This implies that the heaviest ten percent of axle loads can often cause more pavement damage than the rest of the traffic combined.

To provide adequate information on axle load distributions, road-side surveys of axle loads are required. Such surveys can conveniently be made using portable wheel or axle weighing devices that are widely available.

This note describes the methodology and procedures required to carry out both a traffic count and an axle load survey and includes methods of data analysis for pavement design purposes. The procedures are based on tried and tested methods used by experienced staff who have undertaken numerous axle load surveys world-wide.

GLOSSARY

<i>ADT/AADT</i>	(Annual) Average Daily Traffic. This is the total annual traffic in both directions divided by 365. Hence it is an average 24-hour daily traffic volume. This statistic usually includes all motorised traffic, including motorbikes, but in some countries it may also include non-motorised traffic, e.g. bicycles or bullock carts. It is important to note that this is TWO WAY traffic flow. For pavement design purposes ONE WAY traffic flow is normally used. Pavement design is normally based on the lane with the highest traffic loading.
<i>CV</i>	Commercial vehicles. This category comprises the main types of vehicle that damage the pavement. This usually includes medium trucks (2 axles with twin rear tyres), heavy trucks (greater than 2 axles) and large buses (with greater than about 40 seats).
<i>Design life</i>	This is the number of years that the pavement should remain in good condition and be able to carry the design traffic loading. During this period the pavement layers should not deteriorate to any serious extent and pavement distress (in the form of roughness, rutting and cracking) should be restricted to predetermined values. For most roads, a design life of between 10 and 40 years from the date of opening is appropriate. It is assumed that during this time, routine and periodic maintenance activities are carried out. At the end of the design life the pavement should NOT be completely worn out and in need of reconstruction; although it will usually need to be strengthened so that it can continue to carry traffic satisfactorily for a further period.
<i>EF</i>	Equivalence Factor (per axle). This is the pavement damaging effect of an axle in relation to the damage created by a <i>standard axle</i> which has a load of 8.16 tonnes. It can be calculated using the formula: $EF = (\text{axle load in tonnes}/8.16)^{4.5}$. For example, an axle load of 16.32 tonnes (twice the standard axle load of 8.16 tonnes), will cause an amount of damage equal to 22.6 passages of a standard axle. The EF values for each axle are usually summed for each vehicle, then the average vehicle equivalence factor (VEF) is calculated for each vehicle group. This is then used with traffic count data to calculate ESAs for pavement design purposes.
<i>ESA / ESAL</i>	Equivalent Standard Axle (Load). May also be known as E80. A standard axle load is 8.16 metric tonnes (or 80kN). All axle loads are converted to an equivalent number of standard axle loads (ESAs) and pavement design is usually based upon the total cumulative ESAs that the pavement will have to carry over its design life.
<i>E80</i>	See ESA.
<i>GVW</i>	Gross Vehicle Weight (i.e. total vehicle weight after loading with goods). The total weight of the unloaded vehicle is the unladen or Tare weight.
<i>HGV</i>	Heavy Goods Vehicle. Vehicle with more than two axles or an unladen weight of 3.0 tonnes or more.
<i>MESA</i>	See msa.
<i>msa</i>	Millions of equivalent standard axles (ESAs). Sometimes also abbreviated to mesa or 10^6 esa. These are the units of traffic loading over the pavement design life, used for design and rehabilitation purposes.
<i>vpd</i>	Vehicles per day. This is usually the total daily number of vehicles (usually only motorised) in both directions (i.e. two-way flow) unless stated otherwise.
<i>vpld</i>	Vehicles per lane per day. This is usually the total daily number of motorised vehicles in one direction or lane.
<i>WIM</i>	Weigh-in-motion. Vehicles can be weighed at normal traffic speeds using this type of equipment technology. Various types of equipment are available, some types can be permanently installed whilst others are temporarily attached to the road surface.

CONTENTS

	Page
Preface	1
Part 1: Traffic counts	3
1 Introduction	5
2 Vehicle classification	6
3 Types of traffic count	7
3.1 Manual counts	7
3.2 Automatic counts	7
3.2.1 <i>Pneumatic tube systems</i>	8
3.2.2 <i>Buried loop systems</i>	8
3.2.3 <i>Piezo systems</i>	9
3.2.4 <i>Reliability and sensitivity</i>	9
4 Variation in traffic flows and accuracy of counts	10
4.1 Hourly variation	10
4.2 Daily and weekly variation	10
4.3 Monthly and seasonal variation	11
4.4 Summary and recommendations	12
5 Planning a classified traffic count survey	14
5.1 When to carry out the survey and its duration	14
5.2 Traffic counts in conjunction with an axle load survey	14
5.3 Location of survey	14
5.4 Staffing and equipment	14
5.5 Recording traffic count data	15
6 Analysis of results	16
6.1 Converting a partial day's count into a full day's traffic count	16
6.2 Correction for seasonal variation	16
6.3 Automatic count data	17
6.4 Traffic forecasting	18
7 Common errors in traffic count surveys and data analysis	19

	Page
Part 2: Axle load surveys	21
8 Introduction	23
9 Equipment	25
9.1 Permanent weighbridges	25
9.2 Portable weighpads	26
9.2.1 Use of a recessed pit for the weighpads	28
9.2.2 Weighing without constructing a pit	28
9.2.3 Width of weighpads	29
9.3 Weigh-in-motion	29
9.3.1 Recording weighbridge	30
9.3.2 Piezoelectric cables	30
9.3.3 Calibration	30
10 Planning a survey	31
10.1 Duration and timing of a survey	31
10.2 Survey location and site layout	31
10.2.1 Medium to high traffic flows, using two sets of weighpads	32
10.2.2 Medium to high traffic flows, using one set of weighpads	33
10.2.3 Low traffic flows using one set of weighpads	33
10.2.4 Position of weighpads or pit	34
10.3 Safety and road signs	35
10.4 Police presence	36
10.5 Staffing and equipment	36
11 Survey procedure	37
11.1 The number of vehicles to weigh	37
11.2 Reducing the number of vehicles to weigh and increasing survey accuracy by selective sampling	38
11.3 Survey data forms	39
11.3.1 Axle load survey form	39
11.3.2 Vehicle survey form	39
11.4 Axle classification	39
11.5 Driver questionnaire	39
12 Analysis of results	41
12.1 Calculating the EF/vehicle (for each vehicle class)	41
12.1.1 Data input	41
12.1.2 Data check	41
12.1.3 Converting to axle loads (if necessary)	42
12.1.4 Data sorting	42
12.1.5 Calculating the EF for each axle	43

	Page
12.1.6 <i>Calculating the EF for each vehicle</i>	43
12.1.7 <i>Calculating the average EF per vehicle for each vehicle type</i>	43
12.2 Example of data analysis	44
13 Some common errors made during axle load survey and data analysis	45
14 Total traffic loading during the pavement design life	46
14.1 Pavement design life	46
14.2 Total traffic loading	46
14.3 Data accuracy and pavement design	47
15 References	48
Appendix A: Form for manual classified traffic count	49
Appendix B: Forms for axle load survey	50
Appendix C: Equipment list for traffic count and/or axle load survey	52
Appendix D: Example of analysing traffic count data	53
Appendix E: Manufacturers of portable axle weighing equipment	56
Appendix F: Manufacturers of traffic counting equipment	58
Appendix G: Suggested specification for portable weighbridges	59

PREFACE

The deterioration of paved roads caused by traffic is due to both the magnitude of the individual wheel loads and the number of times these loads are applied. For pavement design purposes it is therefore necessary to consider not only the total number of vehicles that will use the road but also the vehicle wheel or axle loads. Hence both traffic count and axle load information are essential for pavement design purposes.

The aim of this guide is to help in the planning and execution of both classified traffic counts and axle load surveys. The guide shows how to analyse the data to give current traffic loadings and provides guidance on forecasting future traffic levels to predict the total traffic loading that a pavement will carry during its design life.

Traffic loading is normally expressed in terms of millions of 'standard axles' (msa) over the design life of the pavement. The standard axle concept was consolidated during the AASHO Road Test carried out in the USA (Highway Research Board, 1962). In this large and comprehensive pavement performance study, an axle carrying 8.16 tonnes (18,000 lbs) was arbitrarily defined as a 'standard axle'. Equivalence factors (EFs) were then derived for other axle loads in such a way that the damaging effects of heavier and lighter axles could be expressed in terms of the number of passes of the standard axle that produce the same damage (Liddle, 1962).

The relationship between axle load and equivalent standard axles (or pavement damage) is a power function such that a small increase in load causes a large increase in pavement damage. As a consequence, some of the greatest errors in pavement design have been made because of inadequate information about axle loading. For example, the erroneous assumptions that vehicle operators do not overload their vehicles or that the legal maximum axle load limits are rarely exceeded have led to under-design and many premature pavement failures.

Vehicle overloading is a serious problem that is endemic throughout the world. For example, a comprehensive study in Asia of a sample of 13,000 loaded trucks showed that overloading was apparent in 31% of 2-axled trucks, 85% of 3-axled trucks, 74% of 4-axled trucks and 75% of 5-axled trucks. In another Asian study, Hartanto and Sastrowiyoto (1990) showed that, excluding trucks running empty, overloading was apparent in 77% of heavy 2-axled trucks, 70% of 3-axled trucks, and 60% of 4-axled trucks. Earlier studies in Africa (e.g. Jones, 1977 and Jones and Gulilat, 1977) have found that up to 70% of commercial vehicles were overloaded. These figures are confirmed by studies throughout the world.

But it is not just the fact that so many vehicles are overloaded that is important; it is also the magnitude or degree of overloading which is often very surprising. In one example on a trunk road in Africa, it was found that overloading was such that the *average* equivalence factor for commercial vehicles was more than five times the value that would have been obtained if the vehicles were loaded to legal limits (Rolt, 1981).

Thus if pavements are to be designed adequately, the importance of accurate knowledge about the magnitude and frequency of the axle loads being carried on the roads is self-evident. When any road project is being designed, or appraised at the feasibility stage, it is recommended that a classified traffic count and an axle load survey of commercial vehicles is undertaken. Ideally such surveys should be carried out several times during the year to reflect seasonal changes in the numbers of vehicles and the magnitude of the loads.

Part 1 of this Road Note deals with classified traffic counting and includes guidance on forecasting future traffic levels and estimating total traffic over the design life of a road. Part 2 is concerned with axle load surveys and includes information about weighing equipment, the planning of surveys, site layout, practical advice on actually carrying out surveys and analysing the results. It also specifically highlights some of the errors that are frequently made in this process. Finally, the traffic count and axle load information is brought together in a summary of the information required for pavement design.

The Appendices provide examples of suitable pro-forma designs for the surveys, equipment lists to ensure that surveys are successful, details of suppliers, and examples of data analysis.

Part 1: Traffic counts

1 Introduction

There are many reasons for collecting traffic data and many different types of information that can be collected. Types of survey include surveys to determine vehicle speeds, peak hourly traffic flow, total traffic flow, and traffic flow separated into different vehicle types (called a classified traffic count). This Road Note is concerned primarily with traffic count data for the purpose of designing a new pavement or for designing the strengthening or rehabilitation of an existing pavement but the principles and methods are also applicable for other types of traffic survey.

In order to estimate the total traffic over the design life of the road, the first step is to determine the current volume and type of traffic travelling on the road. If no reliable current data are available, a classified traffic count will be necessary. Classified traffic counts are often carried out manually by teams of observers recording vehicle numbers and types on data sheets. Simple automatic traffic counters usually record only total traffic flow data and for this purpose they are invaluable. Automatic counters that can classify vehicles are becoming increasingly available, although generally considered less accurate than manual classification. This guide deals mainly with manual counts.

Although most of the traffic loading used for structural design purposes arises from buses, medium goods and heavy goods vehicles, the additional traffic count information for the other types of vehicles is useful for many other purposes such as for calculating road user costs, for road classification, for environmental appraisal, and for cost-benefit analysis.

The Annual Average Daily Traffic (AADT or ADT) is the most widely used statistic to indicate the level of traffic on a road. The ADT can be determined from a classified traffic count and is defined as the total annual traffic summed for *both* directions and divided by 365.

For structural design purposes the highest traffic loading in *one direction* is required and so care is always required when interpreting ADT figures.

The required accuracy of a traffic count is a critical issue that needs to be decided at the outset because this influences both the duration of the traffic count and the possible number of repetitions during the year. For example, for pavement design purposes, light vehicles cause no significant *structural* damage and so, in principle, they do not need to be counted accurately, indeed, they hardly need to be counted at all. On the other hand, for economic evaluation, the numbers of vehicles in each category are of almost equal importance and so a similar level of accuracy is needed. In practice it is rare for a traffic count to be conducted for only one purpose and so the same level of accuracy is adopted for all vehicle types. Nevertheless it is always important that the user of the data understands its likely accuracy and hence this is dealt with in some detail in Chapter 4.

For projects on long roads, large differences in traffic flows can occur along the road and it may be necessary to determine the traffic flow at several locations.

If a classified traffic count is to be carried out prior to an axle load survey, it should be carried out on the same stretch of road, with no junctions or other causes of major variations in traffic flow between the count location and the intended site of the axle load survey.

The information from a classified traffic count also helps in planning the axle load survey. The information on commercial vehicle flows per hour throughout the day will indicate whether it is possible to weigh all of the commercial vehicles or whether a sampling of vehicles will be necessary for different times of the day. The survey can also indicate whether it is necessary to weigh commercial vehicles for all hours throughout the night.

2 Vehicle classification

The classification of vehicles into different types can vary according to the local conditions and the exact reason for the survey. For example, an urban traffic flow study in China may include a separate classification for bicycles, or a road upgrading appraisal study in a rural area may include a separate classification for animal-drawn carts or other slow traffic.

For general purposes a standard vehicle classification system is given in Table 1. For the pavement design of main roads, more detail is usually needed for the heavy vehicle categories and hence additional categories are usually defined as illustrated in part 3 of the table.

For some purposes, classifications are defined in such a way that vehicles can be assigned to them from a quick and purely visual inspection; in other words, irrespective of knowledge of a vehicle's unladen weight or payload capacity. The important point is that classifications can be flexible and those responsible for carrying out a survey should be aware of national practices. In the UK, for example, for pavement design purposes commercial vehicles are split into just three categories: Public Service Vehicles (PSV), Other Goods Vehicles 1 (OGV1) (two and three axles) and OGV2 (four or more axles) (The Highways Agency, 1996).

Table 1 Standard vehicle classification chart

<i>Category</i>	<i>Type of vehicle</i>	<i>Description</i>
1 Light vehicles		
1a	Motorcycles, etc	Motorcycles (with or without side-cars, e.g. motor tricycles).
1b	Passenger cars	Includes passenger cars seating not more than nine persons, estate cars, hire cars and taxis.
1c	Small buses	Includes minibuses, jeepneys, matatus, etc. Usually less than 40 seats.
1d	Light goods	
2 Medium and heavy vehicles		
2a	Large buses	All regular large passenger vehicles and coaches. This category does not include minibuses, jeepneys, matatus, etc. Usually more than 40 seats.
2b	Medium goods	2-axled vehicles with twin tyres on rear axle, more than 1.5 tonnes unladen weight but not exceeding 8.5 tonnes gross vehicle weight.
2c	Heavy goods (3 axles)	Larger trucks with three axles.
2d	Heavy goods (4 or more axles)	Vehicles with four or more axles (trailers being included as part of the vehicle) or exceeding 8.5 tonnes gross vehicle weight. Heavy vehicles may also be defined as those with an unladen weight of 3.0 tonnes or more.
3 Others		
		Includes miscellaneous vehicles such as tractors, road rollers, etc.. Many different types of vehicle could be recorded here. The type will depend upon factors including the purpose of the survey, the transport modes widely used in a particular country and the survey location. For example: i) for roads with high flows of multi-axled commercial vehicles, trucks with five or more axles and trucks with trailers could all be identified separately; ii) rickshaws, bicycles or tricycles could be recorded since large flows can be important when designing road width and geometry.

3 Types of traffic count

Traffic counts for pavement design purposes are often obtained by manual counts. These are satisfactory under many circumstances but for low volume roads in rural areas there is likely to be a very high variation in daily traffic flow (Parsley and Ellis, 2003). To obtain a sufficiently accurate estimate of average traffic flow, a manual count would need to be carried out for a relatively long period of time and this might be impractical. A better solution could be to use an automatic counter. Automatic counters can record continuous information for 24 hours per day, 365 days per year. This can improve accuracy and also provide valuable information about seasonal variations.

3.1 Manual counts

Manual counts are carried out by observers situated at an observation point at the side of the road. The most usual type of survey is a classified count in which, as vehicles pass the observation point, an observer records each vehicle on a survey form according to the vehicle type. A survey period of one week is the most common and is usually recommended (but see Chapter 4) and each direction should be recorded separately. It is also normal practice to record the data separately for each hour of the count. An example form is shown in Appendix A.

The results of a manual classified traffic count should show the total traffic and its composition by vehicle type in each direction. Thus the count should accurately reflect the traffic flow on the road *at a particular location and time of the year*. Table 2 is an example of the results of a classified traffic count.

Table 2 Example of summarised results from a manual classified traffic count

<i>Location</i>	<i>Road:</i>	BETWEEN EAST TOWN AND WEST VILLAGE	
	<i>At:</i>	KM 34 NEAR JULO BRIDGE	(exact location details)
<i>Time and date</i>	<i>Survey date:</i>	4TH FEBRUARY 2002	(day/month/year)
	<i>Survey duration:</i>	7 DAYS	<i>Hours each day:</i> 6.00 to 22.00
<i>Vehicle type</i>	<i>To: East Town</i>		<i>To: West Village</i>
	<i>Average number per day*</i>		<i>Average number per day*</i>
Non motorised traffic	5		8
1a Motorbikes and motor tricycles	21		17
1b Cars	447		480
1c Small buses	0		0
1d Light trucks	15		10
2a Large buses	78		67
2b Medium trucks	24		22
2c Heavy trucks	165		186
Number of commercial vehicles	267		275
Total motorised	750		782
Percentage of commercial vehicles	35.6%		35.2%

Average two-way flow in the counting period i.e. in the 16 hours from 6.00 to 22.00 = 1532

** Note this is not the ADT at this stage because the night-time traffic has not been measured.*

3.2 Automatic counts

Automatic counters comprise a counting device connected to a sensor that is mounted in or on the road and which produces a signal every time a vehicle passes over it. They can be either permanent or temporary installations and their main advantage is that they can record data over a long period at relatively low operational cost. Such long-term data collection minimises the sampling errors caused by fluctuations in traffic flow. It also enables studies to be made of the magnitude,

frequency and possible causes of day-to-day and month-to-month fluctuations in flow, for example, regular seasonal variations. With permanent installations, measuring long-term trends is relatively straightforward.

A single automatic counter can be used at many locations throughout the year because the sensors can be left in place at each site and only the counter unit itself needs to be moved. For example, if a count is made at each site for a week every month then four sites can be covered.

In their basic form, and depending on the sensor type, automatic traffic counters record only the total number of axles or the total number of vehicles passing over the sensor. In order to classify the vehicle flow into vehicle types, a classified count has also to be carried out to determine the proportions of the different vehicle types.

Some sensors are able to detect the size of a vehicle in broad terms and some automatic counters can make use of the time between the passage of individual axles to estimate vehicle types. Such systems are relatively more expensive and not considered sufficiently robust for use in many rural applications. All automatic counters require maintenance and power considerations (batteries or mains supply). These will increase with the more sophisticated counters.

There are two main types of automatic counter in common use, based either on a pneumatic tube sensor or on a sensor consisting of a buried loop of electrical wire. A third type using piezo sensors is becoming increasingly common.

3.2.1 Pneumatic tube systems

This type of counter consists of a hollow rubber tube fixed to the road surface and attached to a counter at the roadside. The tube is usually stretched across the full width of the road and measures two-way flow. As a vehicle passes, the tube is compressed and a pulse of air triggers the counter. Each axle that is detected is normally recorded as a half count, so the final count has to be scaled to account for multi-axle vehicles. Thus errors in vehicle counts can result when vehicles have more than two axles. More expensive pneumatic tube counters, which use two tubes, have the facility to measure axle spacing and hence classify vehicles according to their axle configuration.

Pneumatic tube counters are relatively cheap and easy to install. However, the tubes require regular maintenance (mainly to check that the tube has not been cut or holed) and can be subject to vandalism. In hot climates, the rubber can perish quickly. The counters themselves can be protected in lockable cabinets attached to solid permanent objects, but the tubes cannot be protected from deliberate interference, which can result in errors in the counts. This type of system is unsuitable for gravel roads or for very rough surfaces.

3.2.2 Buried loop systems

In this type of counter, an insulated wire loop is buried beneath the surface of the road (although it can also be fixed to the surface for a temporary installation). The wires are connected to a counter located in a secure metal or concrete cabinet at the side of the road, to protect it from the weather and vandalism. When a vehicle passes over the loop, the metal of the vehicle causes the inductance of the loop to change and this is sensed by the counter. To measure two-way flow, one loop can be buried across the centre of the road or loops can be placed in each lane and connected together. A typical loop is a 2m × 2m square consisting of three turns of wire. Different sizes may be used providing the manufacturer's guidelines for inductance range are followed. Loops of less than 2.8m in the direction of travel may cause double counting with some articulated HGVs. Multi-channel counters are available which can record vehicles passing over loops in a number of different lanes. Buried loop systems are less able to classify vehicle types.

The usual method of installing loops in an asphaltic concrete paved road is to cut a narrow slot, typically 20 mm deep, using a pavement saw. The loop wires are placed at the base of the slot and protected with epoxy resin. The slot is then sealed with bitumen. For surface dressed roads, or where epoxy resin is not available, the wires can be threaded into plastic tubing (e.g. water hose) for protection. A deeper slot of 40 to 60 mm has to be made and the tubing covered with premix material. This technique of using plastic tubing for protection of the loop wires can also be used for gravel roads where the loops can be buried to a depth of 150 to 200 mm below the gravel surface (Parsley, 1994).

3.2.3 Piezo systems

A piezoelectric sensor may be constructed in a number of ways e.g. contained in an aluminium extrusion or embedded in a rubberised former or T-section. When a force or stress is applied to the sensor surface, an electric charge is generated proportional to the applied force. This charge can be used to determine vehicle numbers and axle or wheel loads, through the use of an appropriate electronics interface. Piezo sensors can also detect light axles such as bicycles, etc.

The piezoelectric sensor is installed in a slot cut into the pavement surface at right angles to the flow of traffic. The slot is then filled with an epoxy compound so that the sensor is flush with the surface. Normally a 50 mm deep by 70 mm wide channel is cut in the pavement to accommodate the piezo sensors. The piezoelectric cable is connected to a coaxial feeder cable which is fed to the counter/weighing equipment in a conduit. During installation, the epoxy surface is levelled as much as possible using a trowel. If the sensors are to be used for estimation of loads, the surface is ground using a rotary or belt sander to remove any high points and ensure a smooth transition with the surrounding pavement. A T-section piezo sensor can be moulded to the contour of the road pavement. However the 'T' top wears off under the passage of traffic.

By use of more than one sensor and recording the passage of each axle, a piezo system can identify different types of vehicle by axle configuration.

3.2.4 Reliability and sensitivity

Automatic counters can provide continuous data over a period of time, but require regular maintenance and either battery replacement or mains power, depending on type and complexity.

Buried systems are often preferred because they are more reliable and should last for many years. They are, however, more expensive than pneumatic tubes and installation beneath the road surface is more time consuming and expensive. Buried loops are considered to be more reliable than piezo sensors, which may require a replaceable sensor arrangement at permanent sites. The permanent installation of buried loop or piezo detectors is not normally justified for short-term traffic counting.

Different types of sensors and counters will have different sensitivities, which may or may not be adjustable. It is therefore recommended that the counter is observed for a period of time to determine how it is working. For example, whether the counter is triggered by particular types of vehicle e.g. fast vehicles, and also whether any vehicles are counted twice e.g. slow or large vehicles. Some sensors may detect pedestrians, bicycles, motorcycles or three-wheeled vehicles, whereas others may not detect these at all. Adjustments to the results may have to be made if these vehicle types are to be included or excluded in the count.

To avoid errors in the counts, count sites should be located carefully, where there is free flowing traffic, away from junctions, bus stops, etc.

In addition to the basic automatic counters described above, weigh-in-motion (WIM) and permanent weigh stations can provide vehicle flows and axle load data simultaneously. These are discussed in Chapter 9.

4 Variation in traffic flows and accuracy of counts

Traffic counts carried out over a very short time period can produce large errors because traffic flows often have large hourly, daily, weekly, monthly and seasonal variations (Howe, 1972). These variations are described in the following sections.

4.1 Hourly variation

An example of hourly traffic variation throughout one day is shown in Figure 1.

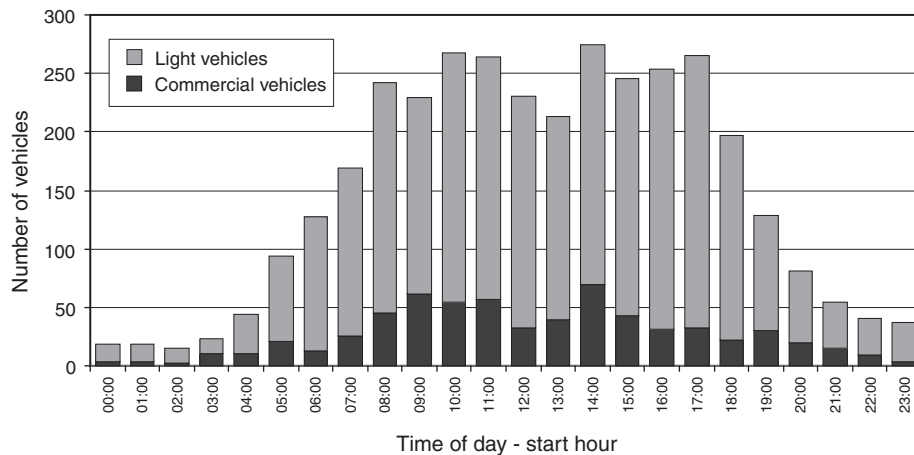


Figure 1 Hourly traffic flow distribution (for light and commercial vehicles)

In this example it can be seen that the majority of traffic travels between approximately 05.00 and 21.00 hours. In practice, traffic counts will usually be carried out for 12, 16 or 24-hour time periods although there is no reason, in principle, why other periods should not be selected. Typically, in tropical countries, a 12-hour traffic count (e.g. from 06.00 to 18.00) will measure approximately 80% of the day's traffic whereas a 16-hour count (e.g. from 06.00 to 22.00) will measure over 90%. In order to obtain estimates of 24-hour flows from counts of less than 24 hours duration, it is necessary to scale up the counts of shorter duration according to the ratio of the flows obtained in 24 hours and the flows measured in the shorter counting period. Thus some 24-hour counts will be necessary to determine this scaling factor (see Section 6.1 for more details).

The overall accuracy of the 24-hour estimate will therefore depend upon:

- a) the *number of hours* of counting on 'normal' count days or, more strictly, the percentage of the total daily traffic that is actually counted;
- b) the *number of days* of counting;
- c) the accuracy of the scaling factor (i.e. the number of 24-hour counts used to obtain the scaling factor).

It is common practice to use the same scaling factor for a number of roads. Whilst this may be acceptable in most cases, especially if the night-time traffic is low, it is often advisable to check this factor by including at least one 24-hour count in every survey.

4.2 Daily and weekly variation

The amount and type of traffic will also vary throughout the week. For example, on Saturdays and Sundays the number of commercial vehicles will often decrease significantly. In rural areas, traffic flows can often be higher at weekends but in urban areas this is often reversed. The daily variability in traffic flows will, frequently, also depend on the volume of traffic. For example, on roads carrying less than 1000 vehicles per day there is usually a higher variability than on busier roads.

An example of daily traffic flow variation is shown in Figure 2.

The day-to-day traffic flows tend to vary more than the week-to-week flows over the year. Hence large errors can be associated with estimating average daily traffic flows (and hence annual traffic flows) from traffic counts of only a few days duration, or which exclude the weekend. Thus there is a rapid increase in the accuracy of the survey as the duration of the counting period increases up to one week. For counts longer than one week, the increase in accuracy is less pronounced. This is illustrated in Figure 3 (Howe, 1972).

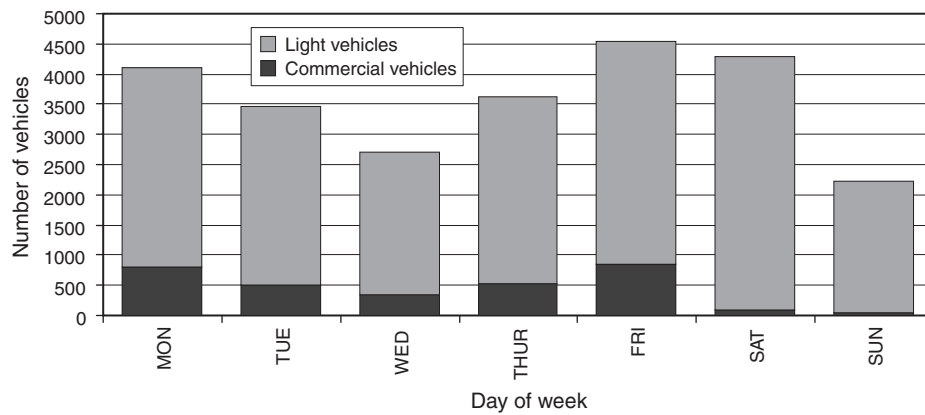


Figure 2 Example of daily traffic flow variation (for light and commercial vehicles)

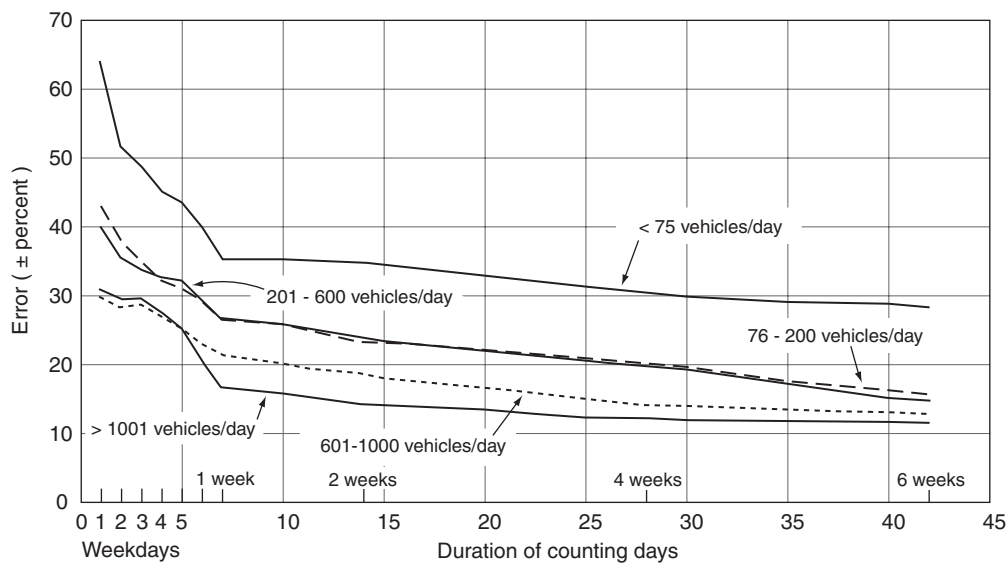


Figure 3 Errors in ADT estimates from random counts of varying duration

Thus a survey of seven consecutive days appears to be an optimum length and surveys beyond this length do not increase the accuracy very rapidly. It can also be seen that the likely accuracy of even a week's survey is in the range $\pm 16\%$ for traffic flows greater than 1000 vehicles per day, increasing to $\pm 36\%$ for traffic less than 75 vehicles per day. These large potential errors are caused by monthly and seasonal variations.

4.3 Monthly and seasonal variation

Traffic flows will rarely be the same throughout the year and will usually vary from month-to-month and from season-to-season. The seasonal variation can be quite large and is caused by many factors. For example, an increased traffic flow usually occurs at a harvest time, and a reduced traffic flow is likely to occur in a wet season.

To reduce error in the estimated annual traffic data caused by seasonal traffic variations, it is desirable to repeat the classified traffic count at different times of the year. A series of weekly traffic counts repeated at intervals throughout the year will provide a much better estimate of the annual traffic volume than a continuous traffic count of the same duration.

An example of seasonal variation is shown in Figure 4 for a one-week traffic count carried out each month. A seasonal factor (SF) of unity indicates average flow. A seasonal factor greater than unity indicates a higher proportion of traffic than the average (e.g. 1.1 indicates 10% higher). It can be seen that the traffic is lower than average between July and September. These are the main wet season months in this particular location. The variation in flow for different classes of vehicle may not be the same and this will be revealed in the classified traffic surveys.

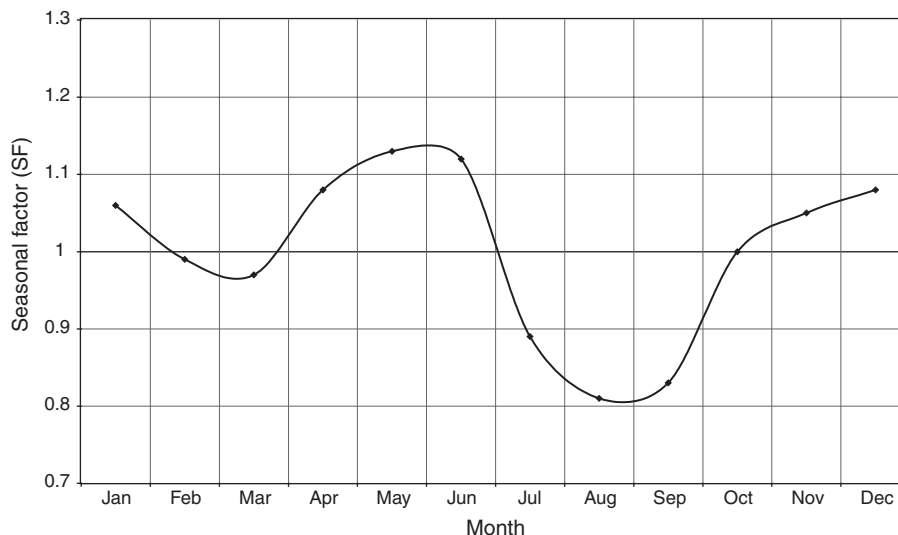


Figure 4 Example of seasonal variation in the flow of commercial vehicles against the average traffic flow

From these seasonal data, seasonal adjustment factors can be derived for each month of the year. These factors can be used to convert traffic counts carried out at any time of the year to average annual counts. An example is discussed in Chapter 6.

4.4 Summary and recommendations

The recommended duration of a traffic count depends primarily on the accuracy required; the greater the accuracy, the longer and more frequent the count needs to be (Parsley and Ellis, 2003). The following recommendations provide general guidelines.

A traffic count should be carried out for seven consecutive days for 24 hours a day. Where counting for 24 hours is not possible or practicable, for example, if a preliminary traffic count shows a negligible vehicle flow at night, or if the local situation makes night working very difficult, then the survey time will have to be reduced. However, vehicles should be surveyed for 16 hours per day (e.g. 06.00 to 22.00) and at least one 24-hour count on a weekday and one during a weekend are necessary. Counts for less than 24 hours are then grossed up to 24-hour values in the same proportion as the 24-hour/16-hour traffic split on those days when full 24-hour counts were undertaken.

Some days of the week are often better than others for a 24-hour survey because they are less prone to traffic flow variation and are closer to the average daily traffic for the week. The best days depend on local customs, road use, work patterns and often on the predominant religion. In some countries, for example, traffic on Friday afternoons and evenings can be much higher than normal and so it may be prudent to treat this separately. In other countries or regions, different patterns of traffic will occur.

Surveys of less than seven days are not recommended. Much human activity, especially commercial activity, is based around a weekly cycle and traffic patterns reflect this with pronounced variations

for weekends, market days, wage days and so on which need to be captured accurately in the traffic count. In extreme circumstances when a 7-day count is impossible, the count should be for at least three weekdays and one weekend day.

Periods of *abnormal* traffic flow should be avoided, (i.e. periods when relatively rare short-term events occur such as public holidays and election days). However, in locations where a large seasonal variation occurs e.g. rural areas with a dominant harvest crop, surveys should be repeated at different times of the year to reduce errors in estimating annual traffic. Thus although a seasonal effect may be considered abnormal in this context, it occurs over an extended period of time and therefore has a significant effect on annual traffic. If data such as that shown in Figure 4 are available, seasonal adjustment factors can be calculated to adjust traffic counts carried out at any time of the year to give more accurate annual values.

5 Planning a classified traffic count survey

There are many aspects to a traffic count survey that must be considered at the planning stage, including when to carry out the survey, the duration of survey, staffing, equipment and choice of site.

5.1 When to carry out the survey and its duration

The timing of a survey will often depend upon the reason for it, but obtaining accurate representative data is one of the primary reasons for the choice of dates for a survey. Surveys in some months may provide a better estimate of the annual average traffic than in other months, and an understanding of local traffic flow variation, as discussed in Chapter 4, is one of the key factors in obtaining representative traffic flow data. Section 4.4 provides recommendations on the duration and timing of traffic counts.

5.2 Traffic counts in conjunction with an axle load survey

Whenever an axle load survey is carried out, it is common for the flow of commercial vehicles to decrease, sometimes dramatically so. To detect this, it is essential to carry out a classified traffic count before the axle load survey. A second traffic count during the axle load survey will then indicate whether a difference in traffic flow has actually occurred. If so, suitable tactics need to be adopted to obtain a reliable survey, as described in Chapter 10.

A traffic count before the axle load survey will also help to plan the axle load survey itself. The information about commercial vehicle flows per hour throughout the day will indicate whether it will be possible to weigh all commercial vehicles or whether it will be necessary to sample the vehicles, at least in some hours of the day. The survey can also indicate whether it is necessary to weigh commercial vehicles for all hours throughout the night.

During the axle-load survey, traffic count observers should be sited near but not adjacent to the team carrying out the weighing and interviewing operations, so that their attention is not distracted by these activities.

5.3 Location of survey

The location of the site for a traffic count survey will depend upon the type of road being surveyed and its location. If junctions or settlements occur along the road, then the traffic flow can be very different within the length of the road. Traffic counts at major junctions are particularly useful as one survey can effectively cover several road links, however more staff will be needed to cover the site.

The site should be chosen primarily because of the need to determine the traffic level on that particular road link. An important factor is to provide the observers with shelter and a safe position that will also give a clear view of the road and traffic, especially at night.

If the survey is in an urban area, it may be possible to use a house or shop as a survey base. The location of street lighting might also be a factor in the site location to assist with night survey work. If the survey is in a semi-urban environment with no street lighting, then it may be possible to connect lights to a local house and pay the householder an agreed sum for electricity. In a rural environment, tents, a generator and lights may be required. Access to facilities such as water, food and toilets should also be a consideration in the choice of site.

Common sense will be an important factor in choosing a site location. The safety and health of survey staff is always a priority. This includes avoiding hazardous traffic sites and other problem areas such as sources of stagnant water that may harbour a mosquito risk.

5.4 Staffing and equipment

The number of staff required will depend on the traffic flows at the particular site, the duration of the surveys, and the complexity of the data required. For most roads, at least two observers with separate count forms are needed at all times – one for each direction of traffic.

Based on experience, traffic counts on medium trafficked roads are best carried out by a team of three or more, working in shifts. This type of work can be particularly tedious and short shifts of four or six hours are recommended.

As a rough guide to counting traffic, one person can usually count 500 to 600 vehicles per hour (in one direction). When traffic flows are high, it may be easier to record the passing of vehicles on hand counters and to transfer the totals to the field sheets at the end of each hour. A single hand counter can be used for the commonest type of vehicle. Alternatively, multiple hand counters can be used, with one for each class of vehicle. For very high traffic volumes, two people may be needed to count traffic in the same direction. When this happens it is essential to assign each person a particular type or types of vehicle to count.

The equipment required for the survey will, to a large extent, depend upon the location of the survey and whether existing shelter is available. A list of recommended equipment is given in Appendix C.

5.5 Recording traffic count data

An example of a form for recording classified traffic counts is given in Appendix A. As each vehicle passes the count station, the observer places a line or tick in a box in the appropriate column. At the end of each hour, a new column should be started using a continuation sheet, if required. Each sheet should record details of the time, date, traffic direction and observer's name. A note should also be kept of any events which seriously affect flow in any hour, e.g. bad weather, road works, accidents, etc. This will alert the person analysing the data to the fact that these flows may not be typical.

If traffic flow is high, two counts can be recorded in each box by making half an X mark (i.e. /) with the first count and the other half (i.e. \) with the second.

6 Analysis of results

Corrections and adjustments of the data will usually be necessary to determine a best estimate of AADT. Methods used to adjust the data and example calculations are given below.

6.1 Converting a partial day's count into a full day's traffic count

As can be seen in Figure 1 (Chapter 4), traffic flows vary throughout the day and therefore a traffic count for 12 hours cannot simply be doubled to give an estimated count for 24 hours. The count will depend upon the specific hours that the data have been recorded e.g. a traffic count from 06.00 to 18.00 hours is likely to be significantly different to a count from 08.00 to 20.00 hours.

To convert a partial-day count to a full-day count, the count is grossed up using a 24-hour traffic count and taking the ratio of traffic in the same counting period to the full 24-hour count. For example, for a 12-hour survey from 06.00 to 18.00, then:

$$\text{Estimated full-day count} = \frac{\text{Partial-day count (06.00 to 18.00)} \times (\text{Full 24-hour count})}{(\text{Count from 06.00 to 18.00 hours in the 24-hour survey})} \quad \dots \text{Equation (1)}$$

It is very important that traffic counts from the same periods of the day are used in the numerator and denominator of this equation. If, for example, a count is from, say, 08.00 to 20.00 hours, then the traffic in this time period during the 24-hour count must be used in the scaling process, not the traffic in any other 12-hour period.

Since there is usually a different pattern of traffic at weekends compared with weekdays, especially for commercial vehicles, a partial-weekday count should be grossed up based on a weekday 24-hour count and a partial-weekend day should be grossed up based on a weekend 24-hour count.

A full weeks traffic count will be the sum of five full 24-hour weekdays and two full 24-hour weekend days. The average daily count (i.e. ADT) is calculated by dividing the weeks count by seven.

6.2 Correction for seasonal variation

Season variations in traffic flow, as illustrated in Figure 4 (Chapter 4), are used to determine seasonal adjustment factors (SF). These factors enable a traffic count carried out at any time of the year to be adjusted to give a more representative value of the annual average. An example of derived seasonal factors is shown in Table 3 and represented graphically in Figure 4.

Table 3 Seasonal Factors (SF)

<i>Month</i>	<i>SF</i>	<i>Month</i>	<i>SF</i>
Jan	1.06	Jul	0.89
Feb	0.99	Aug	0.81
Mar	0.97	Sep	0.83
Apr	1.08	Oct	1.00
May	1.13	Nov	1.05
Jun	1.12	Dec	1.08

The SF values are simply the ratio of the average daily traffic in the month in question and the annual average daily traffic. Thus if a one-week traffic count is carried out in January (which has slightly higher than average traffic) then the results need to be decreased to give a better approximation of the true annual average one-week traffic. This 'correction' is achieved by dividing the traffic count data by the seasonal factor, SF, for January i.e. 1.06.

In this example, it can also be seen from Table 3 / Figure 4 that the easiest month for a traffic survey is October because no seasonal adjustment is necessary in this period, or February / March, when the traffic levels are very close to the average.

The seasonal factors may not be the same for all classes of vehicle. For example, the variation in the flow of freight vehicles may differ from that of passenger vehicles, hence different seasonal factors for the two types can be derived to improve the accuracy of the estimates. It is also important to note that the monthly variations may also be significantly different in different regions of a country hence, if sufficient data are available, the most appropriate seasonal factors should be used.

6.3 Automatic count data

The data from automatic traffic counters are often recorded in ‘blocks’ of *cumulative* counts obtained over a fixed time period. A first step in the analysis is to separate these cumulative data into individual time period counts. Automatic counters can often record data in blocks of 1 hour, 4 hours, 6 hours, 12 hours, 24 hours, etc. hence it is essential to know the time interval selected for the counter. Additionally, the count recorded may be cumulative or discrete for that time period.

It is important to know whether the counter is measuring one-way or two-way flow and, because of the varying sensitivity of some counters, which vehicles are actually being counted (e.g. are bicycles included in the data?). This can usually only be determined in the field by observing the traffic counter in action. Adjustment of the totals to include or exclude a particular group of vehicles may be necessary, depending upon the vehicle categories to be used and also which vehicles are (or are not) recorded by the counter.

The example below, Table 4, shows data from a basic automatic counter that has been set to record one-way data in blocks of 24 hours. The data in rows (a) and (b) comes directly from the counter, but the data for each time period (in this case 24 hours) often needs to be calculated manually to obtain the data shown in row (c). A computer spreadsheet can be very useful for these calculations.

Table 4 Data from automatic traffic counter (one way)

Raw data from traffic counter:					
(a) Block number:	1	2	3	4	etc.
(b) Count (cumulative total traffic):	782	1522	2356	3168
Calculated:					
(c) Total traffic (per 24 hrs):	782	740	834	812	...
(d) Average vehicles per day (1 way) = mean of (782, 740, 834, 812 ...) = (say) 804					

After the cumulative traffic counts have been separated into fixed time periods, the average daily traffic flow can be determined as in (d) above. These data may need to be adjusted, for example, to remove non-motorised traffic, or to adjust for seasonal variation.

Since the cost of an automatic traffic count is not closely related to the duration of the count, long counts are relatively inexpensive and hence more accurate estimates of AADT are possible. However, whilst the total amount of traffic can be measured more accurately, there may be little or no information on the composition of the traffic. Thus the automatic count may need to be combined with traffic composition data from a manual classified count in order to obtain total traffic flows of each vehicle type. By combining the results of the automatic counter with a classified count, an improved estimate of traffic flow for each vehicle type can be derived.

If the automatic data have been collected (either intermittently or continuously) over a long period, e.g. a year, then they can also provide useful information about seasonal variation. By plotting these data, determining whether a distinct seasonal variation is apparent, and calculating seasonal factors, future surveys, carried out at any time of the year, can be adjusted to give a more accurate estimation of average annual traffic flows as described above. Data for several years is required to give any level of certainty of seasonal variation because the pattern may change from year to year, depending on the reason for the variation.

6.4 Traffic forecasting

When designing a new road pavement or rehabilitating an existing one, the measurement of current traffic levels is an important step in the process. The next step is to estimate the amount of future traffic that the pavement will carry over its design life. With pavement design lives of up to forty years, traffic forecasting is a very important part of the design process. Traffic forecasting is outside the scope of this Overseas Road Note but is included in detail in Overseas Road Note 5 (Transport and Road Research Laboratory, 1988).

7 Common errors in traffic count surveys and data analysis

Listed below are some of the most common errors made during traffic count surveys and the associated data analysis.

a) Not carrying out a classified traffic count.

If only the total traffic flow (e.g. ADT) is known, it is not possible to determine the numbers of each type of commercial vehicle, or even the total number of commercial vehicles; information that is essential for pavement design purposes.

b) Not distinguishing between two-way traffic data (e.g. ADT) and one-way traffic data.

Traffic flow data are normally presented as total two-way flow, except where the flow is markedly different in each direction. Pavement designs are usually based on one-way traffic data and so, if the two are confused, it could lead to an error of 100% in the design traffic loading. This, in turn, could lead to an inappropriate pavement design with high financial costs. Note that this is a surprisingly common error.

c) Not distinguishing between directions in a traffic count.

It is important to keep separate the traffic data for each direction of travel because large differences in total traffic and vehicle type can occur. If the traffic loading is much higher in one direction than in the other, e.g. at a port, and if the pavement is designed on the average traffic flow and loading, one lane may be under-designed.

d) When using an automatic traffic counter, not correcting axle count to give vehicle count.

Automatic counters often record the number of axles or assume vehicles have two axles, hence the data may need to be corrected using the average number of axles per vehicle obtained from a classified traffic count.

e) Incorrectly converting a partial-day traffic count to a full-day count.

A traffic count of 12 hours cannot be simply doubled to estimate the count for 24 hours. For a 12-hour count, the result will depend on which period of 12 hours during the day the data were actually recorded e.g. a count from 06.00 to 18.00 will not be the same as a count from 9.00 to 21.00. To scale a count for less than 24 hours to obtain a 24-hour value the method described in Chapter 6 must be used.

f) Incorrect counting through lack of concentration.

Concentrating on counting traffic for as little as half-an-hour has highlighted the difficulty of concentrating when traffic flows are moderate or higher. There is no substitute for continuous rotation of staff and short shifts.

Part 2: Axle load surveys

8 Introduction

A sufficiently accurate estimate of the current traffic loading is essential for an appropriate pavement design. Traffic volumes can be determined by traffic counts, but for current vehicle loads, where no recent reliable data are available, the information can only be obtained by an axle load survey. It is not sufficient to base designs on legal axle load limits because of the widespread problem of overloading and because of the unknown proportion of vehicles that may be only partially loaded.

An axle load survey is carried out to determine the axle load distribution of the heavy vehicles using the road. These survey data are then used to calculate the mean number of *equivalent standard axles* (Chapter 12) for a typical vehicle in each vehicle class. These values are then combined with traffic flows and forecasts to determine the total predicted traffic loading that the road will carry over its design life in terms of millions of equivalent standard axles (msa).

If the flow of such vehicles is too high, a sample will need to be selected for weighing. However, not all types of vehicle need to be weighed. This is because almost all of the structural damage to a road pavement is caused by the heavy goods vehicles, medium goods vehicles, and large buses. Thus it is not necessary to weigh vehicles of less than 1.5 tonnes unladen weight, for example; motorcycles, cars, small buses or small trucks with single rear tyres.

Large buses often have quite high axle loads and should be weighed in the survey. However, since many buses will pass the survey station repeatedly during the day with fairly similar payloads, to avoid unnecessary inconvenience it is often sufficient to weigh a smaller sample of buses than the sampling rate chosen for other vehicle types.

There are three main ways of measuring axle loads, using:

- i) a fixed weighbridge;
- ii) portable weighpads;
- iii) weigh-in-motion equipment.

If a fixed weighbridge exists near to the study road, then making use of this specialised facility and equipment is often a good idea. However, if there is no weighbridge in the area, directing traffic to the nearest weighbridge will be impractical, especially if large distances are involved.

The most common method of carrying out an axle load survey is to weigh a sample of vehicles at the roadside using portable weighpads. Using this method, it is possible to weigh about sixty vehicles per hour per set of weighpads. In some circumstances up to a hundred vehicles per hour can be weighed but this will depend upon many factors including traffic levels, site layout, type of equipment, number of staff and their experience.

Weigh-in-motion equipment has also become quite popular but it is less accurate and more expensive.

If hourly classified traffic count data are available before the axle load survey is carried out, an estimate should be made of the maximum hourly flow of heavy and medium goods vehicles for the site. This information can be used to determine whether (for each hour throughout the day) all commercial vehicles can be weighed or if sampling is necessary.

On many roads it will be necessary to consider whether the axle load distribution of the traffic travelling in each direction is the same. Significant differences between the two flows can occur on many roads, particularly, for example, on roads leading to docks, quarries, cement works, timber or oil extraction areas and mining areas. The survey results should be kept separate for each direction and the results from the more heavily trafficked direction should be used for pavement design purposes.

An axle load survey will also provide important information about the degree of overloading. However it is important that the drivers of overloaded vehicles are not prosecuted during the survey. Any indication that this is likely to happen will cause the drivers to alter their routes to avoid the survey and will lead to inaccurate data. Indeed, special precautions might need to be taken to ensure that the survey does not influence traffic flows or loading patterns unduly (Chapter 10).

Legal axle load limits vary from country to country. In most countries there will be a maximum gross vehicle weight and a maximum permitted legal axle load (usually 8, 10 or 13 tonnes for single axles). There may also be a maximum permitted axle load for multiple axles, i.e. two or three closely spaced axles, and this is usually lower than the total that would be permitted if each axle were separated. However, the amount of damage caused to the road by multiple axles can be either more *or* less than would be caused by the axles if they were to be separated, depending on the spacing of the axles and the design of the road. For simplicity it is recommended that each axle in a multiple set is treated as a separate axle and the specific effects of multiple axles in close proximity are not considered.

9 Equipment

9.1 Permanent weighbridges

Permanent weighbridges are large, fixed weighing platforms used for vehicle and axle load regulation and certification. They are usually located at purpose-built sites on the main arterial routes of a network, and are often operated by a Government department. An example is shown in Figures 5a and 5b.



Figure 5a Fixed weighbridge site



Figure 5b Axle on fixed weighbridge

Permanent weighbridges have the advantages of specialised site and staff and a large weighing platform that is usually level with the surrounding ground. These factors can increase the speed and accuracy of the axle load survey within a safe environment. However, their fixed location means that they are only appropriate for surveys on a small number of roads near to each weighbridge site.

There are various designs of permanent weighbridge but most comprise a single large weighing platform. With such a design, the vehicles must be driven onto the platform and must be stopped and weighed as each axle in turn mounts the platform. In this way the weight of each axle can be calculated by difference. To check the weights it is advisable to repeat the process as the lorry drives off the platform, one axle at a time.

When using a permanent weighbridge for an axle load survey, it is important to ensure that the weighing equipment has been recently calibrated. It is also important that the normal policy of issuing fines or penalties for overloading at the weighbridge is temporarily suspended during the survey. If fines continue then drivers will often seek alternate routes and survey results will be incorrect.

9.2 Portable weighpads

Portable weighpads are small loadometers that can be used singly or in pairs to measure the individual wheel or axle load of a vehicle. They have the advantage of being able to be set up almost anywhere and are available at a relatively low cost, hence they are the tools most frequently used for axle load surveys. The disadvantages are:

- i weighing at the roadside is not as safe as at an off-site location;
- ii there will almost certainly be more disruption to traffic; and
- iii the weighing rate will be slower than can be achieved at a fixed weighbridge, hence the sample size of the vehicles that are weighed will be smaller.

There are many different types of weighpad available around the world, varying in size, complexity and cost. Variations in design include; the weighing mechanism (e.g. hydraulic, hydrostatic load cell, and strain gauge mechanisms); the readout display (e.g. dial or digital LCD); the ability to connect weighpads together (to give axle loads rather than two separate wheel loads); use of cable or cable-less technology; battery size and working time; the ability to store data; the ability to print data; and methods of downloading data to a computer.

Many of the differences are simply differences of convenience and ease of use, but it is vital that the weighing range of the weighpad is sufficient to weigh the heaviest axles, taking into account the severe overloading that occurs worldwide.

Some examples of different types are shown in Figures 6a to 6e.

A study of portable weighpads (Eastman, 1988), included the following findings:

- when used on a slight slope (up to 5% transverse or 2% longitudinal), any errors are small with 94% of tests showing an error of less than 100 kg (i.e. 0.1 tonne) per axle;
- the effect of strong cross winds on static, high-sided vehicles can cause a variation of up to 0.5 tonne per wheel load;
- mis-reading of wheel load by the operator is more frequent with a dial gauge than a digital display.



Figure 6a Portable weighpad, type 1



Figure 6b Portable weighpad, type 2

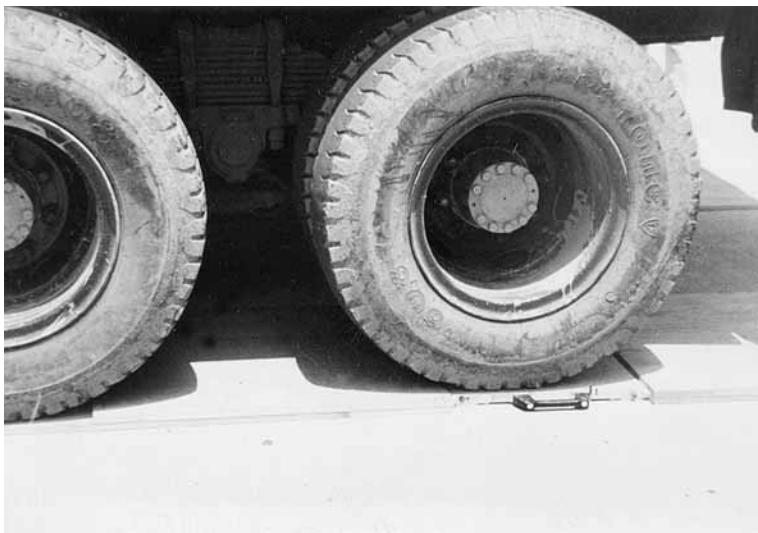


Figure 6c Portable weighpad, type 3



Photo courtesy of Haenni and Co. Ltd.

Figure 6d Portable weighpad, type 4



Photo courtesy of Haenni and Co. Ltd.

Figure 6e Portable weighpad, type 5

The study also produced a suggested specification for portable weighpad equipment. This information is still useful and together with study findings has been reproduced in Appendix G.

It is important that weighpads are regularly and accurately calibrated. This is usually carried out by the manufacturer using a calibrated proving ring. It is also prudent for the user to check the calibration from time to time using the same vehicle of known axle load.

9.2.1 Use of a recessed pit for the weighpads

The size and thickness of the weighpads can affect both the speed and accuracy of the survey because one of the main problems with the use of portable weighpads is the difficulty of getting the vehicles to mount the weighpads properly. The thickness of many weighpads is such that ramps are needed either side to enable a vehicle's wheels to mount and dismount smoothly. Alternatively the weighpad can be placed inside a small pit constructed in the road to such a depth that the surface of the weighpad can be made level with the road surface. Such a pit is essential for very thick weighpads (> 60mm) but it is usually well worth the extra effort even for thinner ones. A pit ensures that all of the vehicle wheels being weighed are level and eliminates the errors that can be introduced by even a small twist or tilt of the vehicle. More importantly, it also eliminates the large errors that can occur if all the wheels on one side of a multiple axle group are not kept in the same horizontal plane, thereby distorting the normal operation of the suspension system.

The pit should have a concrete base with adequate drainage. A channel should be provided for the cable to prevent it being damaged by tyres, and the pit should be sufficiently wide to allow the weighpad to be moved laterally by about 200 mm to enable the wheels of large vehicle and trailer combinations to be aligned more easily. The sides should also be lined with concrete to prevent the edges from collapsing.

Before use, the weighpad(s) should be levelled using a spirit level. It is often a good idea to place levelled sand under the weighpads; this will make levelling easier and provide uniform support. Care is required because a weighpad resting on sand may slide out from under a spinning wheel and could cause injury.

9.2.2 Weighing without constructing a pit

If only one weighpad is being used, and it is not in a pit, then a level platform should be provided to support all wheels on one side of the vehicle that are part of the same suspension unit. This ensures that the wheel being weighed remains level (in the longitudinal direction) with the others in the unit. It does not prevent a slight transverse tilt from one side of the vehicle to the other (camber effect) but the errors created by this tilt are very much less than those that occur if the wheel is not level, longitudinally, with the others in its suspension group. Raising an individual wheel by only

20 mm can lead to errors in the axle load of greater than 10%. For even greater accuracy the transverse tilt can also be eliminated by placing a dummy weighpad and platform to support the opposite wheels of the axle being weighed. This keeps the axle level and reduces any possible error due to a camber effect. Errors due to longitudinal tilt (i.e. a hill effect) are negligible provided that the site itself is level.

Some modern weighpads are now becoming so thin that they do not need either a pit or a ramp at all, using only a small chamfered edge that is usually integral with the weighpad itself.

9.2.3 Width of weighpads

When weighing heavy vehicles the size of the weighpad is important, especially the width. This should be as wide as, or wider than, a set of twin tyres; these are usually about 45 to 55 cm wide. If the whole base of each tyre is not resting on the weighpad, then the loading of the vehicle is concentrated on only part of each tyre. This could cause a tyre blow-out, especially if the tyre is worn or damaged, and hence constitutes a safety hazard for any staff nearby. With the variations in tyre and wheel sizes that have occurred in recent years, selecting a weighpad that is of adequate size to cover the vehicle population is more important than ever.

In addition to the safety aspect, the weighing operation will be slower because it is more difficult to line up and manoeuvre a vehicle onto a small weighpad. The additional time taken to weigh each vehicle is likely to reduce the number of vehicles that can be weighed. An example of a weighpad that is too small is shown in Figure 7 (the width of the weighpad in the figure is only 33 cm).



Figure 7 A narrow weighpad may be a safety hazard

9.3 Weigh-in-motion

Weigh-in-motion systems use a weight sensor set into the road surface so that all vehicle axle loads are recorded at low (or sometimes normal) traffic speeds. This system is capable of giving the most complete information but it is less accurate and often the most expensive of the three options. However, the technology associated with weigh-in-motion devices has progressed rapidly in the past few years and this type of survey is becoming increasingly popular (see COST Report 323 edited by Jacob *et al.* 2002). The accuracy of many systems is now quite good, but care must be taken with the installation site to minimise possible errors. An axle load measured at normal traffic speed can be very different to the measured static load because of dynamic effects caused by the motion of the vehicle. These depend on undulations in the pavement, the axle load itself, the suspension system and the speed of the vehicle. For a smooth road the dynamic effects should be relatively small, but could be significant for an undulating surface. Often multiple sensors are used and an average taken.

The most common types of WIM are either a recording weighbridge or piezo sensor system.

9.3.1 Recording weighbridge

A recording weighbridge is set into or on the road surface. The weighpad for a typical weigh-in-motion system is similar to a thin static weighpad and so no separate photographs are shown.

9.3.2 Piezoelectric cables

Weigh-in-motion systems that use piezoelectric cables as the weight sensor look rather like traffic counters. As a vehicle passes over the cable, instead of a pulse of compressed air being produced, an electrical signal proportional to the load at a particular instant of time is generated (see Chapter 3). To determine the total load on a wheel the speed of the wheel (vehicle) passing over the cable is also required and this is normally obtained as an integral part of the weigh-in-motion system.

Extra care must be taken with piezoelectric sensor installations because they are sensitive to possible errors, especially those deriving from an uneven profile of the road surface and the speed of the vehicles.

9.3.3 Calibration

Weigh-in-motion systems are relatively sophisticated methods of data collection. They require the most controlled operating environment (strong, smooth, level pavement in good condition), and the most costly equipment and calibration procedures.

Calibrations of WIM equipment, particularly systems using piezoelectric cables, are more demanding than calibration of other types of traffic monitoring equipment. WIM scale calibration must account for the vehicle dynamics at the data collection site. Because vehicle dynamics are affected by pavement roughness, the ‘correct’ calibration value for a scale is a function of the pavement condition and the sensor installation at each site. Since these differ with each placement, a significant calibration effort is required each time WIM equipment is placed on the ground. If the scale is not calibrated, the static weight estimates provided by the scale can be very inaccurate, even if the scale accurately reports the vertical forces applied to its surface. The expense of calibrating portable WIM scales each time they are installed is another significant impediment to their regular use.

Because pavement conditions change over time, and because these changes affect WIM scale performance, even permanently installed WIM sensors need to be periodically calibrated. Piezo sensors will deteriorate over time giving less accurate and noisier electronic signals. Their life is usually quite short in comparison with more robust systems. To ensure that the equipment is operating effectively, the data must be promptly produced and analysed. Changes in vehicle weight over time must be examined quickly to understand whether the equipment is malfunctioning, calibration is needed, or the scales are simply reflecting changes in freight movement.

10 Planning a survey

An axle load survey needs to be carefully planned in order to achieve and maintain high safety levels, to obtain accurate data with a minimum of traffic delays, and to keep costs to a minimum.

Preparation work will almost certainly be needed in advance of the survey. Sites may need to be temporarily improved to ensure safety, or permanent lay-by sites could be constructed to make it easy to carry out surveys in the future. Advance works could include constructing a suitable pit to house the weighpads and should include levelling any unevenness or bumps in the road and repairing potholes to ensure that the site is adequate for both the weighing operation and also for vehicles to queue.

A brief classified traffic count carried out in advance of an axle load survey provides valuable information about commercial vehicle flow rates throughout the day, which is useful for planning the axle load survey. This flow rate data will enable sampling strategies to be planned in advance. At low traffic flows all commercial vehicles could be weighed but, at peak flows, sampling may be required with, say, every second, third, or fourth vehicle being weighed (Chapter 11). In addition to the measurement of loads, an interview survey may be relevant, requiring additional staff. An example of suitable forms for this are shown in Appendix B.

10.1 Duration and timing of a survey

The relationship between accuracy and the duration of a survey is similar to that described in Chapter 4 for traffic counting and so the duration of the survey should be based on the same considerations. Ideally an axle load survey should be carried out for seven consecutive days for 24 hours a day. Where it is not possible or practicable to work at night, the survey time should be reduced, but vehicles should still be surveyed for as long as necessary to weigh at least 80% of the traffic. This will normally require surveys of at least 12 hours and more probably 16 hours per day. Surveys containing less than seven days of data are not recommended.

However, it is very important to note that it is rarely sensible to weigh vehicles for seven days consecutively. The reason for this is that the drivers of vehicles that are regularly overloaded quickly become aware of the survey and either avoid the weighing site altogether or temporarily alter their normal operating behaviour. This can easily be observed by plotting the loading pattern as a function of time and the flow level of heavy vehicles. Where overloading is endemic, quite dramatic decreases can be seen irrespective of the normal daily fluctuations that would naturally occur. For example, on one trunk road linking a sea port to a capital city, the average esa per commercial vehicle was observed to decrease to less than 60% of its normal value within 24 hours of the axle load survey beginning. Thus although seven days of weighings are recommended, it is often advisable to weigh for, say, a half-day at a time and to cover the full seven days by weighing for 14 half-days selected over an extended period of several months. This may not of course, always be possible and so accuracy will be reduced.

As with traffic counts, short periods of unusual traffic flow should be avoided, e.g. public holidays. In locations where a large seasonal variation occurs in traffic loads, e.g. rural areas with a dominant harvest crop, then surveys should be repeated at different times of the year and the results weighted according to the length of the 'seasons' to increase accuracy.

10.2 Survey location and site layout

The accuracy, ease and safety of an axle load survey will depend very largely on the choice of site. The site must be chosen carefully to enable traffic to be sampled and stopped easily and safely.

Ideally the survey site should be located on a clear stretch of road with good visibility in both directions. It is often useful to site the survey at the crest of a hill, provided that the approaches on both sides have good visibility, because this is where the heavy vehicles will have had to slow down to cope with the gradient. Sites should always be positioned on stretches of road with no junctions or other turnings.

It is important that traffic is made aware of the survey that is taking place well in advance to provide ample time to slow down and to stop. Advance warning signs should always be displayed for the safety of the survey team and road users (Section 10.3).

Another factor that may influence the location of the site is the provision of shelter for survey staff. Shelter is important because the survey must continue uninterrupted, even during high temperatures or inclement weather. Shelter can be provided by umbrellas or raincoats for actively mobile staff and by a tent, caravan or vehicle for other staff (e.g. the data recorder and staff not on duty). Shelter should be positioned near enough to the survey point for the data recording staff and any separate readout unit.

For dual carriageways, the pavement design should be based on the lane with the highest traffic loading. In many countries, the near-side lane (i.e. the lane furthest from the central reservation) will often carry the bulk of the commercial vehicles, however this may need to be confirmed with a separate classified traffic count for each lane. Sampling vehicles for weighing from a dual carriageway can be difficult. One method to make the sampling and stopping of vehicles easier is to channel traffic into one lane. This will have the effect of reducing traffic speed and is only possible if unacceptable traffic queues do not occur.

10.2.1 Medium to high traffic flows, using two sets of weighpads

For medium to high traffic flows (over 30 commercial vehicles per hour in both directions), the most comprehensive system is to have two sets of weighpads and staff weighing vehicles in each direction with a weighing bay on each side of the road as shown in Figures 8a and 8b. It is not necessary for the two weighing bays to be directly opposite each other, but they should be between the same pair of junctions to ensure that sampling is from the same road section.

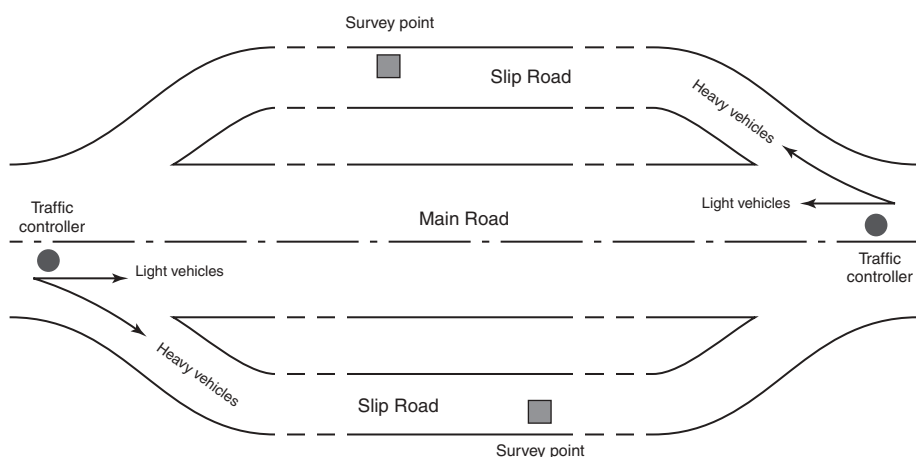


Figure 8a Layout for medium/high traffic flow, weighing one lane, using slip road

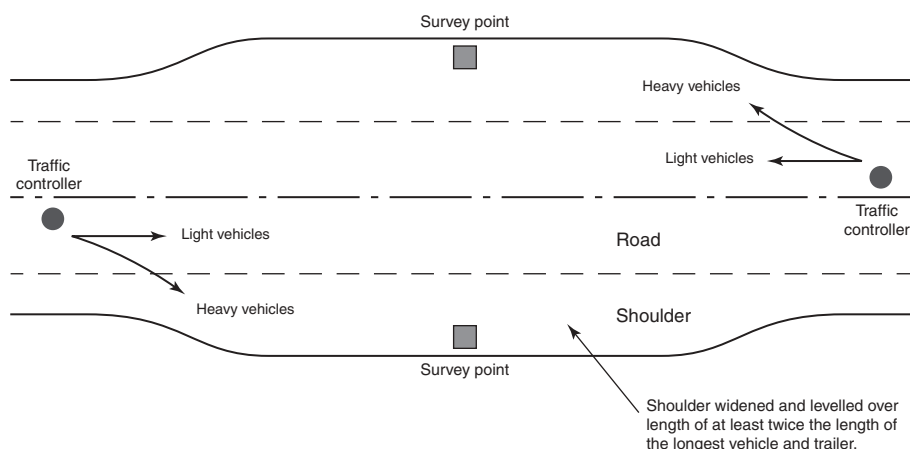


Figure 8b Layout for medium/high traffic flow, weighing one lane, using a hard shoulder

If a slip road or service road parallel to the survey road exists, this can be used for queuing and for weighing the vehicles safely away from the main road. The site arrangement is shown in Figure 8a. This is a particularly convenient arrangement since the vehicles being weighed are isolated completely from the main traffic flow and should not create a safety hazard.

If no suitable slip road exists at the required location, then a hard shoulder can often be used for the weighing. This site arrangement is shown in Figure 8b. The shoulder will usually need to be widened so that the vehicle being weighed is kept well clear of other traffic on the road. It is important that the shoulder is levelled so that all of the wheels of the vehicle to be weighed are in the same plane. The widening and levelling should be done over a length of at least twice the length of the longest vehicle and trailer to be weighed.

There are several different methods of organising the survey. The best method will depend upon the traffic flows, the site layout and the availability of equipment and personnel. Depending upon the site and the length of the weighing bay, it may be possible to have several vehicles in a queue to be weighed.

10.2.2 Medium to high traffic flows, using one set of weighpads

For medium to high traffic flows (over 30 commercial vehicles per hour in both directions), and one set of weighpads, vehicles travelling in both directions can be weighed using alternate weighing.

For alternate weighing, vehicles travelling in one direction can be weighed on one side of the road for a period of time and then the team and weighpads can be moved to the other side of the road to weigh vehicles travelling in the opposite direction. The sites do not have to be directly opposite each other but they should be on the same length of road, usually between the same road junctions to ensure that the same traffic is being sampled. This method is more suitable for busier roads where trucks crossing from one side of the road to the other may cause a hazard. It can be a good idea to alternate directions on different days in order to reduce errors that could occur if, for example, morning traffic is heavier than afternoon traffic. An example is given in Table 5 for a 12-hour per day survey.

Table 5 Example of alternate direction axle load survey

<i>Survey duration</i>	<i>Day of week</i>		
	<i>Weekday 1</i>	<i>Weekday 2</i>	<i>etc...</i>
Morning 06.00 - 12.00	Direction A	Direction B	
Afternoon 12.00 - 18.00	Direction B	Direction A	

10.2.3 Low traffic flows using one set of weighpads

For low traffic flows (less than 30 commercial vehicles per hour in both directions) and one set of weighpads, vehicles travelling in both directions can be weighed using either simultaneous or alternate weighing. Survey site layouts are shown in Figures 8c and 8d.

i) Simultaneous weighing.

For simultaneous weighing, vehicles are stopped from both directions and weighed in a slip road or on a hard shoulder. This method is suitable for low volumes of traffic where trucks crossing from one side of the road to the other are unlikely to cause a hazard.

As for high flows, use is made of either a slip road or a weighing bay constructed by widening and levelling a shoulder. If a slip road or service road parallel to the survey road exists, this can be used for queuing and for weighing the vehicles safely away from the main road. The site arrangement is shown in Figure 8c. If the site geometry permits, the operation can be simplified by directing all vehicles to face the same way when they approach the weighing platform. This will reduce the need to co-ordinate two vehicle queues and will also simplify the process of interviewing drivers.

With only one queue, care must be taken to record the vehicle's direction of travel, usually obtained from the driver.

If no suitable slip road exists at the required location, then a hard shoulder can often be used for the weighing. This site arrangement is shown in Figure 8d. As described for high flows, the shoulder will usually need to be widened over a length of at least twice the length of the longest vehicle and trailer to be weighed.

There are several different methods of organising the survey. The best method will depend upon the traffic flows, the site layout and the availability of equipment and personnel. Depending upon the site and the length of the weighing bay, it may be possible to have several vehicles from each direction in a queue to be weighed. A disadvantage of weighing vehicles from both directions is that additional staff may be required to co-ordinate the two queues and to carry out any questionnaire surveys.

ii) Alternate weighing.

For alternate weighing, vehicles travelling in one direction can be weighed on one side of the road for a period of time and then the team and weighpads can be moved to the other side of the road to weigh vehicles travelling in the opposite direction, as described above for high flows.

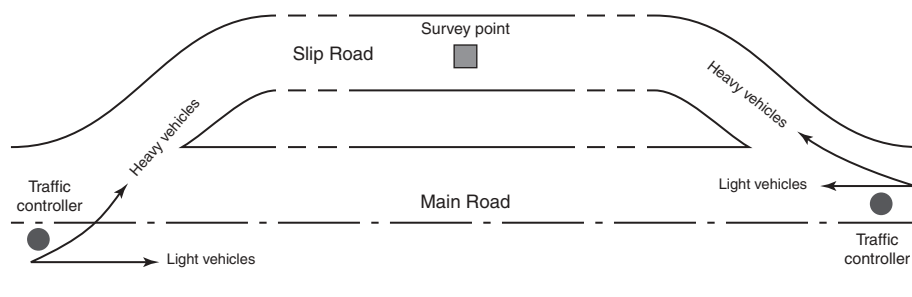


Figure 8c Layout for low traffic flow, weighing both lanes, using a slip road

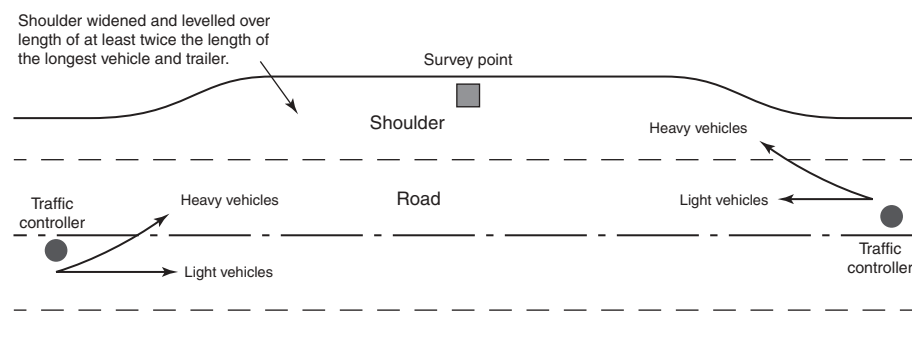


Figure 8d Layout for low traffic flow, weighing both lanes, using a hard shoulder

10.2.4 Position of weighpads or pit

The position of the weighpads should be firm and level with no 'high spots' and no risk of subsidence during the weighing. If a pit is used it should be lined with concrete as described in Section 9.2.1, both for stability of the weighpad and to prevent the edges of the pit from collapsing.

It is recommended that the weighpad or pit is placed on the driver's side of the vehicle to make it easier for him to position his vehicle correctly. A white line painted along the site can also help in this respect.

10.3 Safety and road signs

During the survey, staff have the potentially dangerous job of stopping traffic and working alongside moving vehicles. Special attention must be made to provide a site that is safe for the survey staff as well as road users.

Road signs to warn drivers must be placed on the road shoulder in advance of the survey. This is particularly important for portable surveys which are often carried out at locations where road users are not expecting them. The first warning sign should be placed at least 500m before the weighing site and a series of signs should direct drivers to slow down, whilst informing them that a weighbridge is ahead. Cones can also be placed in the centre of the road near the traffic controller in order to help slow down the traffic on the approach to the survey site. An example of a typical sign layout for each direction is shown in Figure 9.

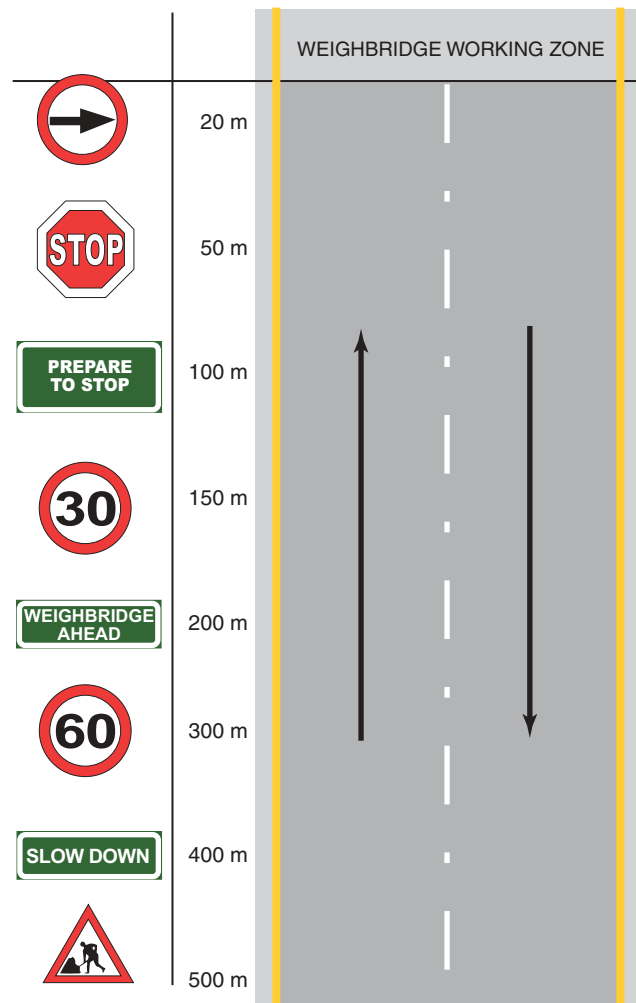


Figure 9 Example of road sign layout for axle load survey

The traffic controllers have the important task of stopping all of the vehicles that are to be weighed and, to do so, they need to stand in the road where they are clearly visible to the oncoming traffic. Directing vehicles to stop can be a difficult and dangerous task. It is particularly helpful if the controllers wear a distinctive uniform and have proper government authority to stop vehicles. It is also strongly recommended that they wear reflective safety vests or jackets, particularly at night. A whistle, reflective glove and a florescent baton or torch can also help in controlling the traffic.

When working at night, it is essential that adequate lighting is provided for the safety of road users, weighbridge staff and traffic controllers.

The type of portable weighpad used can also have safety implications. Although not recommended, if a narrow weighpad is used (i.e. only one tyre wide), all of the load of twin-tyre systems will be

taken on the outside tyre. If this tyre is in poor condition there is a small but possible danger that the tyre could burst.

When vehicles are trying to mount the weighpads, especially when the weighpads are thick and/or the road surface is loose, there is a danger of the wheels spinning and the pads being flung outwards. Staff should be aware of this possibility and keep to a safe distance as the vehicle mounts and dismounts the weighpads.

10.4 Police presence

It is often possible to obtain the services of the traffic police to assist in stopping vehicles. This has the advantage that police are familiar with the problems of stopping vehicles and drivers are also used to being stopped by them. It is, however, important that no vehicles being surveyed are fined by the police as this can discredit the survey and, more importantly, can affect the results (see Section 10.1).

10.5 Staffing and equipment

An axle load survey team should consist of at least four people, with each team working an eight-hour shift. These staff are in addition to any police requirement and more staff may be required, depending upon factors such as site layout, traffic flow and the complexity (thus time required) of the questionnaire survey.

Each shift should generally consist of:

- i One or two person(s) to control traffic on the road and direct selected vehicles into the weighing area.
- ii One person to direct the vehicle slowly onto the weighpads and position each wheel centrally on the platform.
- iii One person to record the vehicle details and the wheel or axle loads.
- iv One person to carry out the driver questionnaire, e.g. origin-destination, type of goods carried, etc.

It is recommended that jobs are rotated periodically to reduce tiredness. If a traffic count is being carried out at the same time, then a further two people are required per shift.

A list of recommended equipment is given in Appendix C.

11 Survey procedure

The main purpose of the survey is to determine an average equivalency factor (EF) for each type of vehicle. This represents the average damaging effect of a vehicle in each class, not the damaging effect of the average vehicle. Because average values are required, it is important that empty, partially loaded and fully loaded vehicles are all taken into account. This will mean weighing some empty vehicles and also counting all vehicles.

Small buses (less than 40 seats), mini-buses, jeepneys, etc, do not usually attain significant loading and so are not usually weighed during a survey. On the other hand, large buses (40+ seats) often have high axle loads and should be weighed. Buses, however, are a special case because the load carried, i.e. people and their possessions, is usually fairly constant for similar sized buses and there are a high number of repeat journeys. For these reasons, it is often sufficient to weigh only a relatively small random sample of buses to give a representative value thereby avoiding unnecessary inconvenience to passengers. A minimum sample of 20 buses is suggested which should then be extrapolated to cover the whole survey duration. Because it is the average bus loading that is being determined, the survey should include empty, partially full and full buses.

On most roads the axle load distribution of the traffic travelling in one direction is seldom exactly the same as that of traffic travelling in the opposite direction and sometimes the differences can be large, particularly for roads to ports, refineries, quarries, cement works, and similar. Any structural design for the pavement should be based on the lane with the highest traffic loading. If the average data from both directions are used, the pavement may be under-designed and this could lead to costly premature failure of the lane with the higher traffic loading. It is therefore essential that the direction of each vehicle being weighed is clearly identified on the survey form, so that the data for each direction can be identified and analysed separately. This can be done by recording the data for each direction on different survey forms or having an extra column on the form noting the direction of travel.

11.1 The number of vehicles to weigh

The accuracy of the survey increases with each vehicle that is weighed. Therefore as many vehicles should be weighed as possible, provided safety to the road user and survey staff is maintained. It is better to weigh fewer vehicles than to cause a safety hazard. If the situation develops whereby the weighing process is leading to long traffic tailbacks and delays, the operation should be halted until normal traffic flows have been resumed.

The number of vehicles that can actually be weighed every hour will depend on:

- i) the volume and flow of commercial vehicles;
- ii) the speed of weighing. This will depend on:
 - type of equipment (Chapter 9);
 - number and skill of staff;
 - complexity of any interview survey.
- iii) site layout (Chapter 10).

For various reasons an hourly traffic count should have been carried out before the axle load survey began (Chapter 10). It should be possible to weigh at least sixty vehicles per hour per set of weighpads, although this will depend on the factors given above. Table 6 gives an indication of sampling rates for different commercial vehicle flows. It should be noted that these figures are for estimation purposes only. If more vehicles can be weighed, then this is better. The selection of vehicles should be strictly by rotation, i.e. every 3rd vehicle. If the traffic controller is allowed to select vehicles in a random manner, bias is likely to occur.

If a traffic count has not been carried out before the axle load survey, the number of vehicles to be stopped will have to be determined during the survey, usually by the person responsible for stopping the traffic. Decisions will need to be based on the actual situation and so the sampling

Table 6 Sampling and site layout for different hourly commercial vehicle flows

<i>Maximum hourly flow of medium and heavy goods vehicles</i>	<i>Sample to be weighed of medium and heavy goods vehicles</i>	<i>Type of site layout recommended</i>
0 - 30	All	Figure 8c or 8d
31 - 60	All	Figure 8a or 8b
61 - 120	Alternate	Figure 8a or 8b
121 - 180	One in three	Figure 8a or 8b
180 - 240	One in four	Figure 8a or 8b
etc.	etc.	Figure 8a or 8b

rates and the duration of weighing at each sampling rate must be recorded accurately and promptly when any changes are made.

Details of recommended site layouts are given in Chapter 10.

11.2 Reducing the number of vehicles to weigh and increasing survey accuracy by selective sampling

For large axle load surveys, particularly on busy roads, it is possible to reduce the number of vehicles that need to be weighed.

The main variation in axle loads will be caused by the loaded vehicles. Unloaded vehicles of a particular class will have fairly constant axle loads (that will be the same for both directions). Therefore, the number of vehicles that need to be actually weighed can be reduced by weighing a smaller sample of the unloaded vehicles. Once a representative sample of unloaded vehicles from each vehicle type has been weighed, the average EF per vehicle (of these weighed vehicles) can be calculated. This average EF can then be applied to all future empty vehicles in that particular vehicle category.

After an average EF has been determined for empty vehicles in each vehicle category, it is extremely important that unloaded vehicles are still stopped and interviewed in the same way as loaded vehicles and that their details are recorded (although they will not have to be weighed). Otherwise there will be no indication of the ratio of loaded to empty vehicles and the true average EF for any class of vehicle will be incorrect.

A consequence of this technique is that a larger sample of the *loaded* vehicles can be weighed in the time available and this will increase the overall accuracy of the survey and the precision of the average EF values for each vehicle class.

An example of this technique is as follows. Suppose that during a one-week survey the first 30 empty 3-axle trucks are weighed. All of the following empty 3-axle trucks are still stopped and the normal questionnaire survey carried out, but they are not weighed. Suppose that during the week there were 270 of these. Also suppose that there were 900 full or part full 3-axle trucks that were all weighed. When it comes to the analysis, the EF per vehicle will be calculated for the 30 empty vehicles, and this EF value will also be applied to the 270 vehicles that were not weighed. When calculating the average EF per vehicle (for 3-axle trucks), this will be based on the 300 empty vehicles and the 900 weighed vehicles. Similar calculations can be used for the other vehicle categories.

Details concerning the techniques for using the different types of weighbridge have been covered in Chapter 9. Specific details relating to each type are contained in the manufacturer's literature and in the operating instructions. Copies of these should *always* be available on site and a master copy *must* be kept in a safe place back at headquarters.

11.3 Survey data forms

There are usually two main forms that are used to record axle load survey data (in addition to any traffic count information that may be recorded at the same time). These are the Axle Load Survey Form and the Vehicle Survey Form.

11.3.1 Axle load survey form

An example of this form is shown in Appendix B. This should be used to record items such as: time, registration plate number, axle configuration, individual wheel or axle loads, and other details as required, such as load type.

If wheel loads rather than axle loads are being measured, then these are the values that should be recorded on the survey sheet. Attempting to convert wheel loads directly into axle loads inevitably leads to errors. Each survey sheet should be clearly marked to show that wheel loads have been recorded. At a later stage, these wheel loads should be converted to axle loads using the assumption that the axle load is twice the wheel load.

11.3.2 Vehicle survey form

This form (an example of which is shown in Appendix B) is used to record such items as: time, registration plate number, axle configuration, vehicle tare (unladen) weight, load level (empty, part-full or full). The date, survey time and vehicle registration number are essential so that vehicle information can be matched with the axle load form.

For all data collected, it is important to record the direction of travel of the vehicle. This can be done by using a separate column on the form e.g. 'Towards

Even though some axle load weighbridges can store information or print out some of the survey data, it is always good practice to keep written records of each axle load weighed and all other relevant information because these electronic data can be accidentally erased or lost.

11.4 Axle classification

The axle configuration of the vehicle should always be recorded. The classification system uses a simple code as follows:

Each axle is represented by a '1' or '2' depending on the number of wheels at each end of the axle. Tandem axles are indicated by recording the digits directly after each other. To separate the front axle from the rear axles, a decimal point is placed between the numbers. For example,

1.1 is a two-axle vehicle with single front and rear wheels (tyres).

1.22 is a three-axle vehicle with tandem rear axles each with twin tyres.

A trailer can be denoted by a '+' sign. Semi-trailers or articulated vehicles can be denoted by a '-' sign. Thus,

1.2+2.2 is a four-axle vehicle, comprising a two-axle vehicle with twin rear tyres pulling a two-axle trailer with twin tyres on both axles.

These vehicles and others are shown graphically in Figure 10.

11.5 Driver questionnaire

Additional useful information can be obtained from a questionnaire survey of drivers. This will inevitably require one or two additional staff but the survey can be carried out quite quickly either before or after the vehicle is weighed. The information gained can range from simple origin-destination data to a complex survey which can be used to determine vehicle operating costs. Some examples of additional useful data that can be collected for each vehicle include: origin and destination, age of vehicle, average annual mileage, the main type of goods carried, etc., (Appendix B).

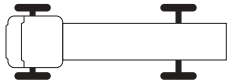
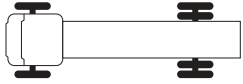
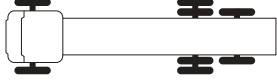
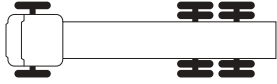

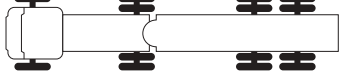

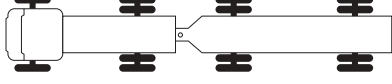
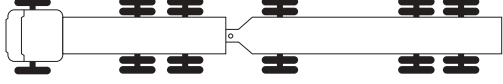
	1.1
	1.2
	1.21
	1.22
	1.2-2
	1.2-22
	1.22-22
	1.2+2.2
	1.22+2.22

Figure 10 Axle configuration

12 Analysis of results

This section provides illustrative examples of processing the data from the axle load survey. The main aim of an axle load survey is usually to determine an average equivalency factor (EF) for each type of vehicle in the survey. To do so it is now normal practice to calculate the EF for each axle of each vehicle and to sum these to obtain the EF for each and every vehicle. The equivalency factor represents the average damaging effect of a vehicle on the pavement and is expressed as the number of standard (80 kN) axles that would cause the same amount of damage. An example of this is given in Table 7.

Table 7 Example of EF values obtained from an axle load survey

Vehicle type	Average EF per vehicle	
	Direction	
	From town Y	To town Y
Large bus	1.69	1.67
Medium trucks 2 axles (GW <11.5 tons)	0.82	0.76
Heavy trucks 2 axles (GW >11.5 tons)	2.44	2.28
Heavy trucks (3 axles (GW >11.5 tons)	7.19	5.68
Heavy truck-trailer combinations (4 axles)	7.81	5.85
Heavy truck-trailer combinations (5 axles)	2.27	2.19

Various computer programs have been written to assist with the analysis of the results from axle load surveys. These programs provide a detailed tabulation of the survey results and determine the mean equivalence factors for each vehicle type. If such a program is not available, a standard computer spreadsheet program can be used very effectively to analyse axle load data. As with all computer programs, care must be taken to make sure errors are eliminated, especially with data inputs and calculation formulae. The general steps that should be used in the analysis are as follows.

12.1 Calculating the EF/vehicle (for each vehicle class)

The following method of analysis is based on the use of a simple spreadsheet program using automatic calculations. For manual calculations, the same general method can be used although, when converting from axle loads to EF per axle, it may be easier to use tabulated values, as shown in Table 8, rather than the standard conversion equation, both of which are given in this section.

12.1.1 Data input

The axle load data should be input in the same format as they were collected. This enables easy checking. For example, if wheel loads rather than axle loads were recorded, these should be input. In the analysis sheet there should be a separate row for each vehicle with each column being used for information about that vehicle. For some of the variables, for example, direction, vehicle type, loaded/unloaded, etc, it may be better to use code numbers because this simplifies sorting the data e.g. bus = 1, truck = 2 can be used to sort two-axle buses from two-axle trucks (see Figure 11).

12.1.2 Data check

Data must be checked for errors against the original survey sheets. It is especially important to check all values for axle loads over 20 tonnes (or wheel loads over 10 tonnes) because such values are unusual and may indicate an input error and because high values affect the average value disproportionately. The use of simple data checking formulae can be useful. These checks can be very simple, for example, a range check comprising a column of data showing the maximum value for all wheel or axle loads for each vehicle. This will indicate if someone has mistakenly omitted a decimal point, for example, inputting 56 tonnes rather than 5.6 tonnes for a wheel load.

Table 8 Equivalence factors for different wheel and axle loads (from Equation 2)

<i>Wheel load (single & dual) (tonnes)</i>	<i>Axle load (tonnes)</i>	<i>Equivalence factor (EF) per axle</i>
1.5	3.0	0.01
1.75	3.5	0.02
2.0	4.0	0.04
2.25	4.5	0.07
2.5	5.0	0.11
2.75	5.5	0.17
3.0	6.0	0.25
3.25	6.5	0.36
3.5	7.0	0.50
3.75	7.5	0.68
4.0	8.0	0.91
4.25	8.5	1.20
4.5	9.0	1.55
4.75	9.5	1.98
5.0	10.0	2.50
5.25	10.5	3.11
5.5	11.0	3.83
5.75	11.5	4.68
6.0	12.0	5.67
6.25	12.5	6.82
6.5	13.0	8.13
6.75	13.5	9.64
7.0	14.0	11.35
7.25	14.5	13.29
7.5	15.0	15.48
7.75	15.5	17.94
8.0	16.0	20.70
8.25	16.5	23.77
8.5	17.0	27.19
8.75	17.5	30.98
9.0	18.0	35.17
9.25	18.5	39.78
9.5	19.0	44.85
9.75	19.5	50.41
10.0	20.0	56.50

12.1.3 Converting to axle loads (if necessary)

If wheel loads (rather than axle loads) were recorded during the survey, columns need to be added for converting wheel loads into axle loads.

12.1.4 Data sorting

The data must be sorted by direction, vehicle type and number of axles. Spreadsheets allow this to be done easily.

The screenshot shows an Excel spreadsheet titled "AXLE LOAD SURVEY DATA". The data is organized into columns: Direction (R or L), Time (e.g., 7.05), Truck category (3H), Axle config (1.22), E=empty (E), F=full or part full (F), LOAD Type (Gravel, Sand, Bottles, Feeds, Fertilizer), and Axle load (metric tonnes) for 5 axles. The first 10 rows of data are as follows:

Direction	Time	Truck category	Axle config	E=empty	F=full or part full	LOAD Type	Axle 1	Axle 2	Axle 3	Axle 4	Axle 5
R	7.05	3H	1.22	E	none	Gravel	3.66	3.32	2.51		
R	9.57	3H	1.22	E	none	Gravel	2.68	4.38	2.71		
R	11.36	3H	1.22	E	none	Gravel	4.00	2.81	2.64		
R	14.48	3H	1.22	E	none	Gravel	4.20	5.46	5.45		
R	14.50	3H	1.22	E	none	Gravel	4.04	4.80	4.53		
R	15.07	3H	1.22	E	none	Gravel	4.11	3.86	2.49		
R	8.10	3H	1.22	F	Gravel	Gravel	4.03	6.85	6.99		
R	8.14	3H	1.22	F	Gravel	Gravel	5.92	13.31	13.14		
R	8.55	3H	1.22	F	Bottles	Bottles	4.51	6.23	4.73		
R	9.21	3H	1.22	F	Gravel	Gravel	6.30	12.94	14.36		

Figure 11 Example of data analysis – initial data

12.1.5 Calculating the EF for each axle

Columns are needed in which to calculate the EF for each axle (see Figure 12). To convert axle loads to EF per axle the relationship given in Equation (2) is used:

$$EF = \left(\frac{\text{axle load (in tonnes)}}{8.16} \right)^{4.5} \quad \dots \text{Equation (2)}$$

Values from this equation have been tabulated for manual calculations and are given in Table 8.

It is important to note that the relationship between axle load and damage is a power relationship. This means that doubling the axle load will not simply double the damaging effect, but will increase it by over 22 times. For example, whilst a standard axle load of 8.16 tonnes will have an EF = 1, an axle load of 16.32 tonnes will have an EF = 22.6.

12.1.6 Calculating the EF for each vehicle

A column is needed to calculate the EF per vehicle by summing the EFs for all the axles of each vehicle. It should be noted that each axle of a multiple axle set should be treated as a single separated axle (Chapter 8).

12.1.7 Calculating the average EF per vehicle for each vehicle type

Keeping the directions separate, the average EF per vehicle for each vehicle type is calculated. This must include all vehicles in the category, whether loaded or empty.

The definition of vehicle classes may vary between countries. For example, in many countries there are several classes for vehicles with five axles or more, usually depending on the precise configuration of axles, whilst in other countries these categories may be combined.

12.2 Example of data analysis

The data in Figure 11 are part of an axle load survey which have already been sorted. Only the data for 3-axle trucks travelling in one direction are shown.

When inputting the axle load data, it can sometimes be useful to input some of the other information from the survey such as load type, even though it may not be required for the calculation of EFs. This information can be useful during additional analysis, for example, to determine the types of goods carried by vehicles that are overloaded.

Microsoft Excel - Axle load example figs final

File Edit View Insert Format Tools Data Window Help

Arial 10 B I U

A1

	C	E	F	G	H	I	J	K	L	M	N	P	Q	R	S	T	U	V	W	X	Y																			
2	AXLE LOAD SURVEY DATA																																							
4	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21																			
5													Equivalency Factor (EF) per axle																											
6													EF = (axle load / 8.16) ^ 4.5																											
7	Direction		Truck category		Axle config		E=empty		Axle load (metric tonnes)					over-					Total					Avg EF		Avg EF		Based												
8	To Rosales		category		config		F=full or		LOAD		Axle		Axle		Axle		Axle		Axle		loaded		Axle		Axle		Axle		Axle		EF per		veh		per veh		on no.			
8	or Umingan		Time				part full		Type		1		2		3		4		5		= X		1		2		3		4		5		vehicle		E or F		all		vehicles	
68	R	7.05	3H	1.22	E	none	3.66	3.32	2.51				0.027	0.017	0.005			0.050																						
69	R	9.57	3H	1.22	E	none	2.68	4.38	2.71				0.007	0.061	0.007			0.074																						
70	R	11.36	3H	1.22	E	none	4.00	2.81	2.64				0.040	0.008	0.006			0.055																						
71	R	14.48	3H	1.22	E	none	4.20	5.46	5.45				0.050	0.164	0.163			0.377																						
72	R	14.50	3H	1.22	E	none	4.04	4.80	4.53				0.042	0.092	0.071			0.205	empty																					
73	R	15.07	3H	1.22	E	none	4.11	3.86	2.49				0.046	0.034	0.005			0.085	0.1403																					
74	R	8.10	3H	1.22	F	Gravel	4.03	6.85	6.99				0.042	0.455	0.498			0.995																						
75	R	8.14	3H	1.22	F	Gravel	5.92	13.31	13.14			X	0.236	9.041	8.532			17.809																						
76	R	8.55	3H	1.22	F	Bottles	4.51	6.23	4.73				0.069	0.297	0.086			0.452																						
77	R	9.21	3H	1.22	F	Gravel	6.30	12.94	14.36			X	0.312	7.963	12.723			20.999																						
78	R	9.36	3H	1.22	F	Gravel	6.33	15.49	15.32			X	0.319	17.891	17.024			35.233																						
79	R	9.39	3H	1.22	F	Gravel	6.07	14.75	14.56			X	0.264	14.354	13.540			28.158																						
80	R	9.55	3H	1.22	F	Sand	6.50	14.56	14.24			X	0.359	13.540	12.251			26.151																						
81	R	9.58	3H	1.2-2	F	Feeds	3.93	9.54	6.00				0.037	2.020	0.251			2.308																						
82	R	10.15	3H	1.22	F	Gravel	3.80	6.09	6.18				0.032	0.268	0.286			0.586																						
83	R	10.44	3H	1.22	F	Gravel	4.52	7.59	7.63				0.070	0.722	0.739			1.531																						
84	R	10.52	3H	1.22	F	Gravel	4.26	7.17	6.88				0.054	0.559	0.464			1.076																						
85	R	10.54	3H	1.22	F	Gravel	3.80	7.45	6.05				0.032	0.664	0.260			0.956																						
86	R	14.32	3H	1.22	F	Sand	6.61	15.36	14.36			X	0.388	17.225	12.723			30.335																						
87	R	14.38	3H	1.22	F	Gravel	5.87	13.92	11.64			X	0.227	11.060	4.945			16.233																						
88	R	14.45	3H	1.22	F	Sand	6.00	13.61	11.55			X	0.251	9.994	4.775			15.020	full or																					
89	R	15.19	3H	1.22	F	Sand	6.33	16.13	13.43			X	0.319	21.466	9.413			31.198	part full																					
90	R	15.50	3H	1.22	F	Fertilizer	6.44	12.53	7.62			X	0.345	6.889	0.735			7.963	13.9418																					

Fig 1 Fig 2

Draw AutoShapes

Ready

NUM

Figure 12 Data analysis example – completed analysis table

It can be seen that the above data have already been sorted according to whether the truck was empty (E) or full/partially full (F). These data came from a driver questionnaire survey.

By following the steps described above, the data analysis yields a table of information as shown in Figure 12.

The results show that, for this vehicle type in this direction, the average EF/vehicle was 10.34. This means that an average truck in this category causes the same pavement damage as over ten standard 8.16 tonne axles. This is high in this example and is due to the large number of overloaded vehicles.

Additional information obtained from the data includes:

- the percentage of loaded and unloaded 3-axle trucks. These were 74% loaded, 26% unloaded;
- almost 60% (10 out of 17) of the loaded 3-axle trucks were overloaded;
- almost all of the overloaded 3-axle trucks were carrying gravel or sand.

It is important to note that the information in this example is from a very limited axle load survey of less than 12 hours. This would not be sufficiently accurate to represent the traffic loading on this road; a proper survey would follow the guidelines described in Chapters 10 and 11.

13 Some common errors made during axle load survey and data analysis

Listed below are some of the most common errors made during axle load surveys and the corresponding data analysis. It is hoped that by emphasising the problems here, they can be avoided in future:

1) Not recognising the influence of the survey itself on the axle load distribution and vehicle flows.

Drivers of overloaded vehicles may either avoid a survey site as soon as they learn of its existence or alter their loading behaviour on a temporary basis until the survey has finished. This is a very common error that is responsible for low estimates of the normal loading patterns.

2) Survey too short.

Another very common error is to carry out a limited survey for only one or two days. This is useful for avoiding the problem described in 1) above but does not provide a statistically reliable estimate. Whilst it may be argued that a small amount of data is better than no data, such limited data may have a large in-built error. Having gone to the effort of setting up the survey it is better to obtain more representative data. This can only come from a survey carried out over a larger number of days, not necessarily consecutively.

3) Weighpads or weighbridges not accurately calibrated before use.

If the weighing devices have not been properly calibrated, then all of the survey results may be inaccurate. Depending on the magnitude of the inaccuracies, this could lead to significant errors.

4) Not distinguishing between directions of travel.

It is essential that the direction of travel of each vehicle is clearly identified on the survey form, or separate forms are used for each direction. This is because large directional variations can exist in axle loads, e.g. vehicles travelling to or from a port.

5) Assuming that all roads carry a similar distribution of axle loads.

This error is similar in nature to the previous error. Just as directions can differ, so can roads. For example, the loading patterns on a road to a port will be very different to that on a rural road. Examples of average EFs/vehicle obtained as a national average being applied to individual roads are not unusual and can cause huge errors.

6) Not clearly stating whether data are for wheel loads or for axle loads.

The survey sheet must make it clear whether wheel loads or axle loads have been recorded. If the data are being recorded manually, the surveyor must *always* record the raw data and must never carry out any mental arithmetic before committing the data to paper, however simple it may appear to be. Mistakes will always occur unless this rule is strictly followed.

7) Not converting wheel loads to axle loads.

This error is often a corollary of error number 6. The formula for calculating the EF is based on the axle load, which is assumed to be twice the wheel load. An error in these units will lead to a very large error in the estimated total traffic loading.

8) Not weighing (or accounting for) empty vehicles.

If empty or partially loaded vehicles are not stopped, recorded and weighed if necessary during the survey, then the average EF per vehicle will be determined only for loaded vehicles. When this average is applied to all commercial vehicles it will lead to a large over-estimate of traffic loading because, at any one time, between 10-60 per cent of commercial vehicles will be empty, or nearly so. However, genuinely empty vehicles do very little damage and hence a particularly accurate estimate of their weights is not necessary. It is usually necessary to actually weigh only a few (of each type) to obtain a representative EF but it is essential to account for them all to obtain an accurate average EF for each vehicle type.

9) Inputting incorrect data.

It is very easy to enter (or omit) just one digit or to put a decimal point in the wrong place. This will cause a significant error, so some form of checking must be carried out.

10) Calculating the average EF for a vehicle type using the average axle load.

Although a rare error these days, it does still occur. This is clearly not the correct way to calculate the average EF and serious errors will be produced in the calculation of total traffic loading. The correct method is to calculate the EF values for each individual axle, to sum these for each vehicle to give the EF for the vehicle and then to calculate the average for each vehicle type.

14 Total traffic loading during the pavement design life

14.1 Pavement design life

It is impossible to design a road pavement which does not deteriorate with time and traffic. The pavement design life is a specified period of time for which the road pavement layers themselves should not deteriorate to any serious extent and pavement distress (in the form of roughness, rutting and cracking) is restricted to predetermined values. It is usually assumed that routine and periodic maintenance activities are carried out throughout the design life.

For most road projects, a design life (sometimes called the economic analysis period) of between 10 and 40 years from the date of opening to traffic is appropriate. For major projects this period should be tested as part of the appraisal process (Overseas Road Note 5, TRRL, 1988). Whatever time period is chosen for the appraisal of a project, the road will always have some residual value at the end of this period. The design life does not mean that at the end of the period the pavement will be completely worn out and in need of reconstruction. It means that towards the end of the period the pavement will need to be strengthened so that it can continue to carry traffic satisfactorily for a further period.

14.2 Total traffic loading

In most countries, the axle load distribution of the heavy vehicle population using the road system will remain roughly constant from year to year, although there may be long-term trends resulting from the introduction of new types of vehicles or changes in vehicle regulations and enforcement. It is therefore customary to assume that the axle load distribution of the heavy vehicles will remain unchanged for the design life of the pavement and that this distribution can be determined by undertaking axle load surveys on existing roads of the same type and which serve the same function. In most developing countries the probable errors in these assumptions for a design life of 15 years are unlikely to result in a significant error in design.

On roads with more than one lane in each direction, it should be assumed that the slow traffic lanes will carry all the heavy vehicles unless local experience indicates otherwise or the traffic flow exceeds about 2000 heavy vehicles per day in each direction. In the latter case, a proportion of heavy vehicles should be assigned to the slow lane according to the principles outlined in Overseas Road Note 5 (TRRL, 1988). The design thickness required for the slow lane is usually applied to all lanes, but there may be situations where a tapered roadbase or sub-base is appropriate.

In some countries, often in rural areas, single-lane bituminous roads are built to economise on construction costs. On such 'narrow mat' roads the traffic tends to be more channelled than on two-lane roads. The effective traffic loading in the wheelpath in one direction has been shown to be *twice* that for a wider road. Therefore, taking into account the traffic in both directions, the pavement thickness for these roads should be based on *four* times the total number of heavy vehicles that travel in one direction.

In the past, the calculation of total traffic loading would have been done with a specialist computer program such as ALSA, produced by TRRL in 1975. However with the wide availability of personal computers, the analysis can be done quite simply using a spreadsheet program.

To determine the cumulative equivalent standard axles over the design life of the road, the following procedure should be followed:

1) Average daily traffic flow for each vehicle class.

From the results of a classified traffic count (as well as any other recent traffic count information that is available), the average daily traffic flow for each class of vehicle in each direction is calculated.

2) Average EF per vehicle (for each vehicle class).

From the axle load survey, the average equivalence factor (EF) per vehicle for each class of vehicle in each direction must be calculated.

3) *Average ESA per day (for each vehicle type).*

Again keeping the two directions separate, for each vehicle category, the average ESA/day must be calculated by multiplying the average EF per vehicle by the average traffic flow for that category.

4) *Daily traffic loading (one way).*

The sum of the ESA/day for all vehicle categories gives the total daily traffic loading (in ESA/day) for each direction.

5) *Annual traffic loading (one way) if required.*

Some designs require annual traffic loading. By multiplying the total daily traffic loading (ESA/day) values by 365 the annual traffic loading for each direction is obtained. This figure is normally presented as millions of equivalent standard axles per year (MESA/year) for each direction. The larger of the two directional values should be used for pavement design purposes.

6) *Design life and traffic growth:*

- i The required design life of a pavement or rehabilitation treatment in terms of years is usually clearly specified in project documentation. Most design manuals cater for varying traffic levels in terms of millions of ESA over the design period.
- ii The design life will usually start at the anticipated opening year for the pavement, which might not be for several years due to the processes of gaining approval, funding and actually building the pavement. For example, if a road is not expected to open for a further three years, the design loading will be the sum of traffic loading from year 4 to year 18 inclusive. If this is not done, and the design life is calculated from current traffic levels, the error in ESA over the design life is likely to be sufficiently large to affect the design.
- iii An estimate must be made of future traffic growth over the chosen design life, which should consider normal traffic, diverted traffic and generated traffic. Future traffic growth is usually expressed as a fixed percentage rate (e.g. 5% per year). For further information on determining growth rates the reader should refer to Overseas Road Note 5 (TRRL, 1988).

7) *Total traffic loading over design life.*

Using data from the lane with the highest traffic loading the total traffic loading over the design life is calculated. The following equation can assist in the calculations:

$$\text{Total cumulative ESA (one way)} = \left(\frac{a \times 365 \times 100}{b} \right) \times \left[\left(1 + \frac{b}{100} \right)^{c+d} - \left(1 + \frac{b}{100} \right)^d \right] \quad \text{Equation (3)}$$

where: a = current average annual daily traffic loading in ESA per day (one way)

b = annual growth rate (%)

c = design life (years)

d = number of years to start of design life

The results are usually expressed in units of millions of equivalent standard axles, one way. An example is shown in Appendix D.

14.3 Data accuracy and pavement design









All survey data are subject to errors. Traffic data, in particular, can be very inaccurate and predictions about traffic growth are also prone to large errors. Accurate calculations of cumulative traffic are therefore very difficult to make. To minimise these errors, there is no substitute for carrying out specific traffic and axle load surveys for each project for the durations recommended in Chapters 4 and 10.

Fortunately pavement thickness design is relatively insensitive to cumulative ESA. Many pavement designs such as those in Overseas Road Note 31 (TRL, 1993) provide a separate design for each range of design traffic (cumulative ESA). If the estimated design traffic is near to the centre of one of the pavement design traffic ranges, then any errors are unlikely to affect the choice of pavement design. However, if the estimated design traffic is close to the upper or lower boundary of the traffic range then the chosen design may not be the most appropriate and the traffic estimates should be re-examined using the principles of sensitivity testing. Formal risk analysis can also be used to evaluate a design choice as described in Overseas Road Note 5 (TRRL, 1988).

15 References

- Eastman C R (1988).** *Evaluation of portable weighpads.* Contractor Report CR114. Crowthorne: TRL Limited.
- Hartanto B and Sastrowiyoto S (1990).** *Axle load measurement at the toll road in Jakarta.* 6th REAAA Conference, Kuala Lumpur, 1990.
- Highway Research Board (1962).** *The AASHO Road Test, Report No. 7: Summary Report.* Special Report No. 61G. Washington DC: National Research Council.
- Howe J D G F (1972).** *A review of rural traffic-counting methods in developing countries.* Laboratory Report LR427. Crowthorne: TRL Limited.
- Jacob B, O'Brien E J, Jehaes S (Eds.) (2002).** *Weigh-in-motion of road vehicles: final report of the COST 323 action (WIM-LOAD).* ISBN 2-7202-3096-8. Paris: Laboratoire Central des Ponts et Chausses.
- Jones T E (1977).** *Axle loads on paved roads in Kenya.* Laboratory Report LR572. Crowthorne: TRL Limited.
- Jones T E and Gizaw Gulilat (1977).** *The commercial traffic loading on five trunk roads in Ethiopia.* Joint Road Research Project Report No. 10, Addis Ababa: Ethiopian Roads Authority.
- Liddle W J (1962).** *Application of AASHO road test results to the design of flexible pavement structures.* First International Conference on the Structural Design of Asphalt Pavements. Ann Arbor, USA: Michigan University.
- Parsley L L (1994).** *A guide to using simple inductive loop detectors for traffic counters in developing countries.* TRL Information Note (Unpublished). Crowthorne: TRL Limited.
- Parsley L L and Ellis S D (2003).** *Guidelines for short period traffic counts in developing countries.* Project Report PR/INT/270/2003. Crowthorne: TRL Limited. (*Unpublished report available on direct personal application only*).
- Rolt J (1981).** *Optimum axle loads of commercial vehicles in developing countries.* Laboratory Report LR1002. Crowthorne: TRL Limited.
- The Highways Agency (1996).** *Design Manual for Roads and Bridges.* Volume 7: Pavement Design and Maintenance, Section 2: Part 1: HD24/96 Traffic Assessment. United Kingdom: The Stationery Office.
- Transport Research Laboratory (TRL) (1993).** *A guide to the structural design of bitumen-surfaced roads in tropical and sub-tropical countries.* Overseas Road Note 31. Crowthorne: TRL Limited.
- Transport and Road Research Laboratory (TRRL) (1988).** *A guide to road project appraisal.* Overseas Road Note 5. Crowthorne: TRL Limited.

Appendix A: Form for manual classified traffic count

TRAFFIC COUNT FORM for Manual Classified Count												
Location of survey:				Time of count: From to								
Day of week: Mon / Tues / Wed / Thurs / Fri / Sat / Sun				Date of count (DD/MM/YYYY):								
Enumerator name:				Weather: mainly: heavy rain / light rain / dry								
		TRAFFIC DIRECTION: To										
		HOURS ENDING										
MOTORBIKE, + motor tricycle, etc 												Total:
CAR, + taxis, etc 												Total:
SMALL BUS (+ jeepney, etc) 												Total:
SMALL TRUCK (2 axles, single rear tyres) 												Total:
SUBTOTAL												
Commercial vehicles (for pavement design purposes):												
LARGE BUS 												Total:
MEDIUM TRUCK (2 AXLES, with twin rear tyres) 												Total:
HEAVY TRUCK (3 AXLES) 												Total:
HEAVY TRUCK (4 or more AXLES) 												Total:
OTHER (to be defined)												Total:
SUBTOTAL												
Sheet no. _____ of _____												Total:

Appendix B: Forms for axle load survey

[illegible]

FORM A FOR RECORDING VEHICLE SURVEY DATA

[illegible]

B

DATE _____

COMMENTS

53

Appendix C: Equipment list for traffic count and/or axle load survey

Traffic count

- Shelter (for day and night, if required): including tent, blankets, large umbrella and chairs.
- Night-time lighting (if required). This is required to illuminate both the road (to aid identification of vehicle type) and the camp so that observers can see the forms.
- Generator for lighting (if necessary), plus fuel.
- Food and water. A large water container is essential. Cooking facilities may also be needed.
- Access to toilet facilities.
- Survey sheets (enough copies for the whole duration, plus spares).
- Clipboards and pens, pencils.
- Hand-counters (if required, for high traffic flows).
- Alarm clock (useful to mark the end of each hour and denote shift changes).

Axle load survey

- Axle load survey forms.
- Pens and stationery plus clipboards, folding table.
- Reflective safety vests.
- Road signs (for both directions if required) – e.g. 2x: ‘men at work’, ‘slow down’, ‘60 km/h’, ‘weighbridge ahead’, ‘30 km/h’, ‘prepare to stop’ and ‘stop’.
- Traffic cones.
- Red stop flags.
- Lights and cables (to light the weighing area, the data recording table and, if possible, the vehicle stopping area).
- Generator plus fuel.
- Torches (including spare batteries).
- Spade.

Additional equipment for surveys using portable axle load equipment

- Weighpads.
- Ramps (if required for weighpads).
- Fine sand for levelling weighpads.
- Spirit level.
- Pickaxe.
- Broom.
- Table and chairs.
- Large umbrella(s) for shelter from sun or rain.
- Walkie-talkies (optional). Useful for communication between staff stopping vehicles and staff weighing vehicles.

Appendix D: Example of analysing traffic count data

A manual classified traffic count was carried out during a week in September on a site where there is equal traffic flow in both directions. The data have been separated into commercial vehicles and non-commercial vehicles (e.g. cars, etc). Table D1 shows the data for commercial vehicles. The information for non-commercial vehicles has already been analysed and gave an average number of 1200 non-commercial vehicles per day. Using this information and some automatic traffic data recorded over a year, shown in Table D2, calculate:

- The current ADT and percentage of commercial vehicles for this site with no seasonal correction.
- The seasonal variation factors from the annual traffic data in Table D2 and the seasonally adjusted average number of commercial vehicles per day.

**Table D1 Manual classified traffic count data – combined data,
i.e. 2 way flow**

Time	<i>No. of commercial vehicles for each hour of the day</i>						
	<i>Mon</i>	<i>Tue</i>	<i>Wed</i>	<i>Thur</i>	<i>Fri</i>	<i>Sat</i>	<i>Sun</i>
00.00-01.00	–	3	–	–	–	1	–
01.00-02.00	–	2	–	–	–	2	–
02.00-03.00	–	0	–	–	–	0	–
03.00-04.00	–	1	–	–	–	3	–
04.00-05.00	–	4	–	–	–	1	–
05.00-06.00	–	12	–	–	–	4	–
06.00-07.00	–	23	–	20	24	7	–
07.00-08.00	–	45	–	47	52	12	–
08.00-09.00	–	56	–	48	60	8	3
09.00-10.00	–	64	–	63	71	13	5
10.00-11.00	–	61	–	65	66	15	8
11.00-12.00	–	55	–	52	59	18	4
12.00-13.00	–	49	47	52	–	16	2
13.00-14.00	–	51	44	47	–	12	6
14.00-15.00	–	52	45	51	–	15	7
15.00-16.00	–	61	55	57	–	21	9
16.00-17.00	–	65	61	58	–	24	–
17.00-18.00	–	51	54	56	–	14	–
18.00-19.00	–	29	–	42	–	8	–
19.00-20.00	–	22	–	21	–	5	–
20.00-21.00	–	13	–	8	–	6	–
21.00-22.00	–	7	–	6	–	3	–
22.00-23.00	–	4	–	–	–	1	–
23.00-24.00	–	2	–	–	–	0	–
No. survey hours:	24	6	16	6	24	8	
24 hour count:	732	(A)	(B)	(C)	209	(D)	

Where (A), (B), (C), (D) need to be calculated.

Table D2 Monthly traffic count data (CV per day, two way)

<i>Month</i>	<i>CV/day</i>	<i>Month</i>	<i>CV/day</i>	<i>Month</i>	<i>CV/day</i>
Jan	718	May	765	Sep	561
Feb	665	Jun	758	Oct	674
Mar	652	Jul	599	Nov	705
Apr	725	Aug	545	Dec	725

Answers:

(i) Firstly, we need to calculate the average number of commercial vehicles (CVs) per day.

When estimating the daily traffic counts, the weekdays should be treated separately to the weekend days as the flows of commercial vehicles will be markedly different. The 24-hour counts for each incomplete day can be calculated using the ratio of the data for the survey hours to the complete 24-hour counts.

e.g. (A) (estimated traffic count for Wednesday)

$$\begin{aligned}
 &= (\text{actual traffic count for 12.00-18.00}) \times \frac{\text{total 24-hour count}}{(\text{traffic count for 12.00-18.00 of 24-hour count})} \\
 &= (47 + 44 + \dots + 54) \times \frac{732}{(49 + 51 + \dots + 51)} = 306 \times \frac{732}{329} = 681
 \end{aligned}$$

Similarly (B) (estimated traffic count for Thursday)

$$\begin{aligned}
 &= (\text{actual traffic count for 06.00-22.00}) \times \frac{\text{total 24-hour count}}{(\text{traffic count for 06.00-22.00 of 24-hour count})} \\
 &= (20 + 47 + 48 + \dots + 6) \times \frac{732}{(23 + 45 + \dots + 7)} = 693 \times \frac{732}{704} = 721 \\
 &(\text{C}) (\text{Friday}) = (24 + 52 + \dots + 59) \times \frac{732}{(23 + 45 + \dots + 55)} = 332 \times \frac{732}{304} = 799
 \end{aligned}$$

Hence the average weekday traffic = (Tue + Wed + Thur + Fri)/4 = (732+681+721+799)/4 = 733

(D) (Sunday) will be based on the 24-hour count for Saturday

$$(\text{D}) = (3 + 5 + \dots + 9) \times \frac{209}{(8 + 13 + \dots + 21)} = 44 \times \frac{209}{118} = 78$$

The average number of CVs in the week = (5 x average weekday traffic) + Saturday + Sunday traffic

$$= (5 \times 733) + 209 + 78 = 3952$$

Hence average number of CVs per day = 3952/7 = 565

Combining this with the information already given that the number of non-CVs per day is 1200, then:

The average number of vehicles per day (ADT) = $565 + 1200 = 1765$

Also, the % of CVs is $(565/1765) \times 100 = 32\%$.

ii Calculate the seasonal variation factors, using Table D2 as follows:

<i>Month</i>	<i>ADT(CV)(y)</i>	<i>Seasonal variation factors (SF)</i>
Jan	718	1.06
Feb	665	0.99
Mar	652	0.97
Apr	725	1.08
May	765	1.13
Jun	758	1.12
Jul	599	0.89
Aug	545	0.81
Sep	561	0.83
Oct	674	1.00
Nov	705	1.05
Dec	725	1.08
Annual mean:	674	1.0

From the ADT values recorded throughout the year, it can be seen that the September value (561) is lower than the annual average value (674), and so the results from traffic surveys carried out in this month should be increased to obtain a better approximation to the annual average value.

The traffic survey was carried out in September, hence the seasonal adjustment factor that should be used is $SF(\text{Sep}) = 0.83$.

Seasonally adjusted number of CVs per day = $565 / 0.83 = 681$ (2 way)

Appendix E: Manufacturers of portable axle weighing equipment

A list of potential manufacturers and suppliers are given below in alphabetical order. The authors do not in any way endorse or guarantee either the suppliers or their products. An internet search is also recommended. Many of these companies have distributors around the world.

Axtec - Axle Weight Technology Ltd.

Picow Farm Road, Runcorn, Cheshire, WA7 4UN, U.K.

Tel: +44 (0)1928 581575

Fax: +44 (0)1928 581574

<http://www.axtec.co.uk>

Email: salesadmin@axtec.co.uk

Central Weighing Ltd.

Unit 142, Hartlebury Trading Estate, Kidderminster, Worcestershire DY10 4JB, U.K.

Tel: +44 (0)1299 251242

Fax: +44 (0)1299 250002

<http://www.centralweighing.co.uk/>

Email: sales@centralweighing.co.uk

Haenni & Co. Ltd.

Postfach, Bernstrasse 59, CH-3303 Jegenstorf, Switzerland.

Tel: +41 31 764 9977

Fax: +41 31 764 9988

<http://www.haenni-scales.com/>

Email: info@haenni-scales.com

The company has many distributors around the world, e.g:

Five Feathers

Prime View (Flat 401), House No. SE(F)/7, Gulshan-1, Dhaka 1212, Bangladesh.

Tel: +880 2 8829641

Fax: +880 2 9893354

Email: feathers@bdonline.com

Irenco Electronics Pty. Ltd.

P.O. Box 520, Hennops Park (Centurion) 0169, South Africa.

Tel: +27 12 6711671

Fax: +27 12 6711637

PM Onboard Ltd.

Airedale House, Canal Road, Bradford BD2 1AG, U.K.

Tel: +44 (0)1274 771177

Fax: +44 (0)1274 781178

Email: uksales@pmonboard.co.uk

Hawkley International Ltd.

22 Woolmer Way, Bordon, Hampshire GU35 9QF, U.K.

Tel: +44 (0)1420 476500

Fax: +44 (0)1420 479090

<http://www.hawkleyint.co.uk>

Email: info@hawkleyint.co.uk

PAT GmbH.

Hertzstrasse 32-34, D-76275 Ettlingen, Germany.

Tel: +49 7243 7090

Fax: +49 7243 709222

<http://www.pat-group.com/>

Email: pat.ettlingen@pat-group.net

Talent Weighing Ltd.

Unit 3J, Mill Street West Industrial Estate, Anchor Bridge Way, Dewsbury WF12 9QS, U.K.

Tel: +44 (0)1924 438127

Fax: +44 (0)1924 438129

<http://www.talentweighing.co.uk/>

Email: info@talentweighing.co.uk

Appendix F: Manufacturers of traffic counting equipment

A list of potential manufacturers and suppliers are given below in alphabetical order. The authors do not in any way endorse or guarantee either the suppliers or their products. An internet search is also recommended. Many of these companies have distributors around the world.

Counters & Accessories Ltd.

Lodge Farm Business Centre, Castlethorpe, Milton Keynes, Buckinghamshire MK19 7ES, U.K.

Tel: +44 (0)1908 511122

Fax: +44 (0)1908 511505

<http://www.c-a.co.uk>

Email: sales@c-a.co.uk

Golden River Traffic Ltd.

Churchill Road, Bicester OX6 7XT, U.K.

Tel. +44 (0)1869 362800

Fax +44 (0)1869 246858

<http://www.goldenriver.com/>

Email: info@goldenriver.com

MetroCount

PO Box 1182, Freemantle, Western Australia 6959, Australia.

Tel: +61 8 9430 6164

Fax: +61 8 9430 6187

<http://www.metrocount.com/>

Email: sales@metrocount.com

Peek Traffic Ltd.

Kings Worthy, Winchester, Hampshire SO23 7QA, U.K.

Tel: +44 (0) 1962 883200

Fax: +44 (0)1962 884026

www.peek-traffic.co.uk

Email: ukinfo@peekglobal.com

Appendix G: Suggested specification for portable weighbridges

Specification for portable weighbridges:

- i Weight should be less than 15 kg.
- ii Thickness should be 15 mm or less.
- iii Surface weighing area should be at least 650 mm wide and 380 mm long (in the direction of vehicle movement).
- iv The base of the pad should ensure as much contact with the ground as possible to reduce slippage.
- v The option of having a central printout record should be available.
- vi A digital display should be provided on each weighpad in addition to any central printout record.
- vii Any centrally printed record should identify that zeroing checks have been undertaken.
- viii Evidence should be available that the accuracy of the weighpads is not affected by temperature, humidity, off-centre loads or electro-magnetic radiation within reasonable limits.

Specification for a suitable survey site:

- i A clear width of 5.5m - 6.0m fully segregated from other vehicles.
- ii A fully made-up even surface.
- iii Longitudinal gradient of 2% or under and transverse gradients of 5% or under.
- iv Sites should be surveyed before use and the records kept.

Specification for using weighpads:

- i Ensure that there are no loose stones under the weighpad.
- ii The zero calibration of each weighpad should be checked before each weighing.
- iii Staff should stand clear of the weighpads as the vehicle mounts or dismounts - there is a danger of the weighpads being spun-out by the drive wheels.
- iv Care should be taken to ensure that the whole weight of the wheel is carried by the active weighing surface of the weighpad.
- v All the wheels of axles forming part of a bogie should be weighed simultaneously.

On longitudinal gradients approaching 2%, weight transfer between axles due to the slope could change individual axle weights by up to 4% relative to the weights on level ground. It is recommended that individual axle weights should not be recorded when the longitudinal gradient is greater than 1%.

Reference: Eastman, 1988

***A guide to axle load surveys and traffic counts for
determining traffic loading on pavements***

ORN 40