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THE SCOTTISH OFFICE DEVELOPMENT DEPARTMENT

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THE DEPARTMENT OF THE ENVIRONMENT FOR
NORTHERN IRELAND

Vehicle Speed Measurement on All Purpose Roads

Summary: This Advice Note provides advice on vehicle speed measurement for determining speed limits, for the improvement of alignments and major/minor junctions and accesses, for the layout of new major/minor junctions and accesses on existing roads, and for traffic signal design.

VOLUME 5	ASSESSMENT AND PREPARATION OF ROAD SCHEMES
SECTION 1	ASSESSMENT OF ROAD SCHEMES

TA 22/81

VEHICLE SPEED MEASUREMENT ON ALL PURPOSE ROADS

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1. INTRODUCTION

1.1 The Department's current advice on speed limits (Ref 1) contains a reference to detailed guidance on the "measurement and analysis of speed". This note provides some further advice on vehicle speed measurement for the purpose of determining speed limits. It discusses in detail techniques for carrying out measurement of speed using recently developed methods and for analysing results and supersedes paragraphs 27 and 28 of Ref 1.

1.2 There are also applications for improvement of alignments on all purpose roads such as at bends and short diversions. Whereas for new works and major improvements the Department's Highway Link Design Standard (Ref 2) details the necessary techniques for geometric design using as a basis recent speed/flow/geometry relations, minor scheme design can better be based on the use of the measured 85 percentile vehicle speed of approach to the improvement section.

1.3 The layout of major/minor junctions and accesses as described in Departmental Advice Note TA 20/81 (Ref 3) is also, in a number of ways, dependent on a correct assessment of the 85 percentile vehicle speed. The advice herein should therefore be used as a basis.

1.4 Additionally there are applications for the design of traffic signal installations. Here the position of the speed measurement is important, especially for new installations.

2. SCOPE

The methods described herein are

Radar speedmeter measurement.

Measurement using vehicle detectors/timers such as inductive loops or noisy cables.

This note is concerned with "when?", "where?", "how much?" and "how accurate?". Although the note generally applies to vehicles the sample can be confined to cars. Mention of this is made in the text at the appropriate points. Other publications such as Ref 4 provide useful information though of earlier date.

3. EXPLANATION OF TERMS AND CONCEPTS

The following explanations are given to amplify terms and concepts used in this Advice Note.

3.1 Spot speed/Journey speed

The former is the instantaneous vehicle speed measured at a point as distinct from the latter which is measured over a length of road. Spot speeds are measured using devices such as radar speed meters or inductive loops. Journey speeds are measured by moving observer methods or by recording and matching registration numbers at times of passing.

3.2 Free flow

There is no generally accepted definition of this term. However, it may be stated that in free flow conditions headways and lateral displacements are usually so large as to ensure that drivers are in no way prevented, by the close proximity of other vehicles, from driving at the speed of their own choice. These conditions cannot be measured precisely and so it must be a subjective judgement as to whether or not traffic is in a free flow condition. For the purposes of this document it is considered more helpful to suggest times and circumstances when free flow conditions are most unlikely to occur -

Well defined directional morning and evening peaks

Times of high heavy vehicle flow

Directional weekend peaks

Local events (market days,sports events, etc.)

Roadworks

Bad weather

Additionally, sections of the road under consideration where the layout is likely to restrict speeds to a level markedly below that at other points should be avoided. However, if most of the length consists of such features it is neither desirable nor possible to avoid them.

3.3 Speeds (speed limits)

For determining speed limits the 85 percentile dry weather spot speed of cars is used as a yardstick. This is the speed only exceeded by 15% of the cars. When the 85 percentile spot speed has been arrived at, as described later in this Advice Note,it is used to determine the speed limit in the way described in Ref 1.

3.4 Speeds (improvement of alignment and junctions)

Whereas for speed limits the 85 percentile dry weather spot speed of cars is required, for improvement of alignments and major/minor junctions or accesses, and for new major/minor junctions or accesses on existing roads, the normal design methods are based on the 85 percentile wet weather journey speed of vehicles. The precise point at which the measurements are taken and the timing is important. A point just before the scheme length and a time of free flow are suitable. Measurements must be taken at both ends of the scheme so that traffic approaching from both directions is covered. If different values are obtained the higher speed value should be used in the design process. To get from the dry weather spot speed of vehicles measured to the wet weather journey speed used in design one of the following correction factors should be used -

For AP Dual carriageways ... deduct 8kph

For AP Single carriageways ... deduct 4kph

3.5 Speeds (traffic signal design)

These remarks are confined to areas outside 30mph speed limits. Two types of signal equipment are currently in use related to the following conditions:-

a) 85 percentile dry weather spot speed of vehicle approach between 55 and 72kph, double vehicle extensions with speed discrimination.

b) 85 percentile dry weather spot speed of vehicle approach between 72 and 105kph with either triple vehicle extensions with speed discrimination or double vehicle extension with speed assessment.

For a) above measurements should be taken at not less than 80m in advance of the stop line (as seen by traffic) nor more than 100m.

For b) above the values should be 150m to 200m.

To ensure accuracy certain conditions are necessary which are listed at Appendix 1.

4. SOURCES OF VARIABILITY IN SPEEDS

4.1 The results of the measurements are likely to be taken as representative of the speeds of all vehicles using the road in some undefined period - probably a whole year - but the measurements will have been taken within a much shorter period - perhaps no more than two or three hours. The way in which the measurement periods are chosen is every bit as important as the size of the sample.

4.2 Speeds vary from hour to hour, from day to day, from month to month, and from year to year, in a fairly systematic way. They have also been found to vary from one occasion to another more than would be expected from their variability on any one occasion. The total effect of all these variations, even when the times mentioned in paragraph 3.2 above are excluded and only one year is considered, may produce a difference of more than 5kph between the highest and lowest levels of speed. It is essential, therefore, that more than one set of measurements be taken. At least two (and preferably more) recording periods at the site are required, at different times of day and on different days of the week. If measurements cannot be taken in different months, they should be taken in a month that is "neutral" as far as seasonal variation in traffic is concerned - late Spring and early Autumn are recommended, avoiding Bank Holidays - though this is less necessary for urban roads.

4.3 During each recording period at the site, the number of speeds measured will affect the reliability of the result as an estimate of the true value at that time, obviously the larger the sample the better. A sample of 200 vehicles would normally give an estimate of the 85 percentile speed for that period to within + or - 3% at the 95% confidence level, eg, 65 kph + or - 2.0 kph. The value for another period may well be less than 60 or more than 70 kph.

4.4 When using vehicle detectors/timers (inductive loops/noisy cables) at least whole hour periods of free flow (see para 3.2) can be examined at any one time, if not more.

4.5 Measurement error may also arise from the choice of sites, from the way in which the recording device is set up and used, and from the way in which the data are analysed.

4.6 Finally, it cannot be emphasised too strongly that a small total sample from a radar speedmeter is perhaps much more useful than a large sample obtained with little thought provided the survey is carefully planned, executed and analysed by the methods described in this Advice Note. With vehicle detectors/timers, given measurement in free flow periods, the sample problem does not arise to the same extent as it can be very large.

5. SETTING-UP AND USE OF RECORDING INSTRUMENTS

5.1 General

5.1.1 If there is any doubt that the traffic in one direction only, at one site, can be regarded as representative of free flowing traffic on the length of road in question, measurements will have to be made at other places, or in the other direction. Roughly equal samples should be obtained for each site/direction/occasion. In the case of measurement for improvement of alignments and major/minor junctions or accesses, and for new major/minor junctions or accesses on existing roads, the directional samples should be taken at either end of the proposed scheme.

5.1.2 Weather conditions and any unusual circumstances should be recorded at the time and not left until later.

5.2 Radar Speedmeters

5.2.1 When using a radar speedmeter the first requirement is that a chosen site should have sufficient space to accommodate the meter and the observers (usually in a car) without disturbing the traffic. A verge, an unused entrance, or the beginning of a layby, are suitable. The installation should be an inconspicuous as possible, and if the meter's antenna unit can be mounted on a car window instead of on a tripod it will be less noticeable.

5.2.2 The site should not be near junctions (unless readings are being taken in connection with improvements to the junction) or bus stops, see paragraph 3.2 above. Situations where the radar beam may be obstructed by parked cars, or where vehicles are likely to be accelerating or braking, should also be avoided. Except at very light flows, it is not advisable to measure the speeds of vehicles on the far side of a single carriageway (and especially not on the far carriageway of a dual carriageway road).

5.2.3. The operating instructions for the meter should be carefully followed, especially in relation to interference and calibration. Some meters can be adjusted to ignore vehicles travelling in the "wrong" direction. With most meters, however, the response to those vehicles should be minimised by careful aiming of the antenna or by reducing the range setting. The aiming of the antenna is important, since a meter measures speeds along the centreline of the beam and then allows for any intended angle between that and the direction of the road. With meters that are designed to be aimed straight along the road, an error of 10 degrees either way (towards the road, or away from it) will cause the meter to underread by 1.5%. With meters that have a built-in offset correction, and are designed to be set with the beam at a particular angle to the road direction (say 20 degrees) an error of 10 degrees will cause the meter to overread by 5% or underread by 8%. When correctly set, the error of the meter is probably less than 2 kph.

5.2.4 It is best to have two observers, one reading the meter and the other recording the values. Using this method measurements can be confined to cars only if required. Provided that the traffic flow is light enough, and the observers have had enough practice, the speed readings for all vehicles (in one direction) should be recorded if possible. If the flow is too heavy for all vehicles (cars) to be measured some sort of sampling procedure is needed. To avoid bias, the sampling must be based on an attribute that is not related to speed, and is easily decided. The most satisfactory bases are colour (white cars for instance have been found to be representative in type and age, and to give approximately a 20% sample but this will change over the years), or registration number (where odd or even numbers will give a 50% sample, and specified first or last digits will give 10%, 20%, etc - approximately). The latter method is necessary if all vehicles are being sampled.

5.2.5 A value should be recorded for every vehicle that satisfies the sampling criterion. Ideally, that value would be a steady reading on the meter, but except at very low flows, it will not be possible to get a steady reading for every vehicle that passes. Sometimes the meter will give a brief indication - a flick of the needle, or a flicker of the digits - that can be recognised and accepted as the speed of the vehicle in question. Sometimes there will be no response at all. There are two different situations where readings are likely to be missed completely:-

a) where a vehicle is overtaking another vehicle while both are in the radar beam.

b) where a vehicle is following closely behind other vehicles,and the observer cannot be sure that the meter gave a separate reading for each.

If the missed readings are simply ignored, or recorded as a vehicle passing but no speed registered and then omitted from the analysis, it is equivalent to assuming that the true speeds of these vehicles have the same distribution as those that were measured, and with the same mean. But if these missed speeds are likely to form a significant proportion of the total (say, more than 10%) some alternative assumptions are preferable. They are:-

a) that vehicles travelling in a fairly compact bunch all have the same speed; and

b) that overtaking vehicles are travelling (say) 15 kph faster than the overtaken vehicle. Since the overtaken vehicle will often be a large vehicle, and since it is in any case closer to the meter, it will probably give a reliable reading.

Values arrived at in this way should carry a distinguishing mark in the records.

5.2.6 On dual carriageways, an alternative procedure is to record the lane of travel for all vehicles passing, and to assume that missed vehicles in either lane have the same speed distribution as those recorded in the same lane. Speeds in the two lanes would then be analysed separately, and combined in the proportions of the numbers of vehicles passing in each lane, not the numbers with speeds recorded.

5.2.7 These practices may seem complicated, and if they are not necessary (as at low flows), they should be avoided. However, if a lot of speeds are missed, to ignore them may bias the answer. The best time to estimate an individual speed is when the vehicle passes - not later, when the observer's memory of the circumstances will have faded. It is reasonable to expect that a sensible observer's estimate is better than the assumption that the missed vehicles are average.

5.2.8 Where measurements are required for modifying an existing traffic signal installation a different technique may be used with radar speedmeters or other methods which require an operator to be present. The sample should include only those vehicles that pass (at a point 150-200m back from the stop line) while a green signal is showing and no queue is present.

5.3 Vehicle Detectors/Timers

5.3.1 Speed measuring equipment based on vehicle detectors is entirely automatic in operation. It can provide mean speeds and frequency distributions, and other traffic data. However, unlike radar speedmeters, it cannot distinguish cars from other vehicles, although vehicle separation by length is possible. Pairs of inductive loops or noisy cables are stuck to (or installed in) the road surface and connected to a detector/timer/counter unit which is securely fastened to some convenient roadside furniture. The passage of a vehicle over a loop/cable generates an electrical signal. The time interval between the start of the signal from the first loop/cable and the start of the signal from the second loop/cable is measured and, using the separation distance of the loops/cables, converted into a speed, which is recorded.

5.3.2 In one version of this sort of equipment, the detector/timer/counter unit is very small and inconspicuous. A separate control/output unit is temporarily connected to it to enable site information (including loop/cable spacing) to be programmed and the equipment to be tested, and is then removed. At the end of the measurement period, the control/output unit is reconnected to extract the results and it will then display them on command, or output them to a printer or VDU. The output can consist of a frequency distribution, or mean speed and various percentile speeds, for preset intervals over a period (eg, every hour for two weeks). Up to three lanes of traffic can be dealt with.

5.3.3 Where inductive loops are used each loop should consist of 4-6 turns if possible, at least 2m wide (ie, across the road) and 1m long (along the road), accurately laid and securely fastened - loose loops can be a traffic hazard.Two loops about 1m apart are laid in each lane of travel, so that the separation of their leading edges is about 2m, but this will vary with the type of equipment used. On dual carriageways each loop pair should be at least 2m laterally from the loop pair in the adjacent lane, to minimise double counting of straddling vehicles. On single carriageways one loop pair will generally be used for each direction, and vehicles crossing the loops in the wrong direction will not be recorded.

5.3.4 The manufacturer's installation and operating instructions should be carefully followed and these will include checks to ensure that the equipment is working properly. Wherever possible a vehicle with a calibrated speedometer should be used for a broad check on the readings given.

5.3.5 If the equipment can distinguish short vehicles, say those less than 5m long, longer vehicles may be excluded. If all vehicles are included a correction can be applied later in order to estimate the 85 percentile speed of cars only (see paragraph 6.6).

6. ANALYSIS AND ASSESSMENT OF RESULTS

6.1 Appendix 2 gives a check list to apply to results before analysing and assessing them. It is emphasised that the value finally arrived at is reliable only if the surveys were carefully planned, the measurements carefully taken and the results carefully assessed. The checks in Appendix 2 are therefore important and must not be overlooked.

6.2 There are several ways of estimating the 85 percentile speed from sets of measurements. The most direct way is to list all the speeds in ascending order, and count from the highest value until 15% of the total number of values have been passed. The speed arrived at is the 85 percentile speed. A quicker method is to group the values into, say, 10 kph groups and then plot the "cumulative frequency distribution" as explained in Appendix 3.

6.3 A quite different way of estimating the 85 percentile speed, and the only way that can be recommended for total samples of less than, say, 200 speeds such as may be obtained with a radar speedmeter is to make use of the well known shape of speed distributions. They are, for all practical purposes, Gaussian (ie, Normal). For a Normal Distribution, the 85 percentile is 1.037 standard deviations above the mean, where the standard deviation of speed, v, is estimated as-

$$\sqrt{\frac{(v-mean)^2}{n-1}}$$

It is sufficiently accurate to take

85 percentile = mean + standard deviation

Some electronic speed measuring equipment gives the mean and standard deviation (and/or the 85 percentile) in its output and many pocket calculators will give the mean and standard deviation of values entered in case they are needed; however, the formulae are given in Appendix 3.

6.4 Separate calculation of either the 85 percentile speed (as in para 6.2) or the standard deviation (as in para 6.3) provides a useful check on the reliability of the measurements, since the ratio

$$\frac{\text{85 percentile}}{\text{mean}} \quad \text{or} \quad \frac{\text{standard deviation}}{\text{mean}}$$

can then be compared with its expected value.

Because the standard deviation of speeds is usually equal to about one sixth of the mean speed, the ratio:-

85 percentile/mean

usually lies in the range 1.1-1.25. (In Highway Link Design, Ref 2, this ratio is taken as the fourth root of 2 or 1.18 approximately. Further advice is given in the Advice Note on Highway Link Design.)

6.5 Where measurements are required for modifying an existing traffic signal installation and all the vehicles have been included (rather than the restricted sample defined in paragraph 5.2.8) the mean speed will reflect the lower speed of vehicles approaching a red signal or a queue. In these circumstances the 85 percentile speed must be derived directly as in paragraph 6.2 and not from the mean speed. The ratios

$$\frac{\text{85 percentile}}{\text{mean}} \quad \text{and} \quad \frac{\text{standard deviation}}{\text{mean}}$$

given above will not apply.

6.6 The 85 percentile speed of cars required for speed limit setting may be estimated from the 85 percentile speed of all vehicles (including long vehicles) by adding 1kph on single carriageways or 2 kph on dual carriageways for every 15% of heavy vehicles.

7. REFERENCES

1 DTP Circular Roads 1/80: "Local Speed Limits".

2 TD 9/81 Highway Link Design: DTp: 1981.

3 TA 20/81 The Layout of Major/Minor Junctions: DTp: 1981.

4.. Research on Road Traffic: HMSO: 1965.

8. ENQUIRIES

MEASUREMENT OF SPEEDS FOR DESIGN OF TRAFFIC SIGNAL LAYOUTS

PRECAUTIONS TO ENSURE ACCURACY

Further to the advice in paragraph 3.5 the following precautions should ensure accurate results -

a) There should not be a parked vehicle or other obstruction, such as roadworks, within 100m of the measuring point.

b) Measurements should be taken as close to the 80m and 160m points as possible.

c) Only those vehicles which can be expected to be anticipating a clear run through the junction should be included. Any which deliberately speed up to go through on amber should be included using subjective judgement.

d) Care should be taken by any enumerators to be as inconspicuous as possible so as not to influence traffic behaviour.

e) Because the (proposed) equipment does not come into use at higher flows, as the signals run to maximum, measurements should be taken when flow does not exceed 50% of maximum flow.

f) The ideal arrangement is to take speed measurements when flows are 20-40% of maximum.

CHECKS ON RESULTS BEFORE CALCULATION

The first question to be answered in assessing the measurements is were the conditions (eg, site, timing, weather) likely to have prevented normal traffic operation? If they were the measurements should not be used. Several other questions arise when the measurements have been obtained by manual recording of radar meter readings. They are:-

a) If speeds have not been estimated as in paragraph 5.2.5 above, were more than 10% missed? If so, consider rejecting the measurements, and trying again.

b) Have more than 20% of speeds been estimated in the way suggested? If so, it may be concluded that a radar speedmeter is not suitable for measuring speeds in such difficult conditions. In that case, can the traffic fairly be described as free flowing?

c) Do the speeds recorded (excluding those estimated) show any obvious bias towards round numbers like 30, 35, 50? If so, check more carefully. About 10% of the values should end in "5", and 10% in "0", but up to twice those proportions would be acceptable in a sample of 100 or so. Beyond that, regard the measurements with suspicion.

d) Do the speeds recorded show any obvious bias towards odd or even numbers? This is especially likely with meters that have a needle on a scale display, rather than a digital display, and is not important.

Data recorded by measurement using vehicle/detector timers such as inductive loops or noisy cables are not prone to the faults above, but other faults are possible. Some equipment, for example, may give spurious readings for closely spaced vehicles. These faults may be obvious in the output - perhaps through a suspiciously high number of very low speeds. They may, however, be detected during the analysis of results.

STATISTICAL FORMULAE AND METHODS

If n values of speed (v) are measured, the mean and standard deviation of the speed distribution from which the sample was taken are given by:-

Mean, m, = Σ v/n where Σ denotes summation over all values

Standard deviation, s $= \sqrt{\Sigma v - m^2 / n - 1}$

For calculation purposes, a useful relationship is:-

$$\Sigma(v-m)^2 = \Sigma v^2 - (\Sigma v)^2/n$$

For example, if 150 speeds are measured, and the sum of the speeds is 7,500 and the sum of the squares of the speeds is 385,765, then:-

$$m = \Sigma v/n = 7{,}500/150 = \underline{50.0}$$

$$\Sigma v - m^2 = \Sigma v^2 - (\Sigma v)^2/n = 385{,}765 - 7{,}500^2/150$$
$$= 385{,}765 - 375{,}000 = 10{,}765$$

$$s = \sqrt{\Sigma(v-m)^2/n-1} = \sqrt{10{,}765/149} = \sqrt{72.25} = \underline{8.5}$$

Note that the standard deviation, 8.5, is approximately one sixth of the mean:

$$50 \div 6 = 8.3$$

the 85 percentile is then given by

$$v = m + s = 50 + 8.5 = \underline{58.5}$$

which should be rounded to 59. (If use in minor scheme design is intended the caveats/corrections given in paragraph 3.4 need taking into account).

GENERAL CHECKLIST FOR THOSE PLANNING TO SET UP VEHICLE DETECTOR/TIMERS OR RADAR SPEEDMETERS FOR TAKING MEASUREMENTS TO ASSESS THE NEED FOR SPEED LIMITS

(The implications of various points below are discussed in the main text)

1 Take readings where possible in late spring or early autumn.

2 Take readings at different times of the day and on different days of the week. A minimum of two sets is required, for instance,during the morning on one day and during the afternoon on another day.

3 A set of readings must include a minimum of 200 vehicles. However, the longer the period measured the more accurate will be the results. Always take as many measurements as is practical.

4 The preferred times for taking readings are 10.00 - 12.00 and 14.00 - 16.00 hours.

5 Do not take readings during:-

morning and evening peaks if these cause congestion

local events, eg market days, local holidays, fetes, race meetings, etc.

bank holidays

weekends

bad weather

high heavy goods vehicle flows

This procedure should enable an accurate assessment to be made of the speed of vehicles along the road in "free flow" conditions.

6 Do not set up the equipment at or near:-

a junction

traffic lights (including pelicans)

roadworks

pedestrian crossings

parked or stationary vehicles

considerable frontage access

features where traffic has to slow down, eg, a sharp bend, where the road narrows, a steep gradient, etc.

7 In addition to the points above read the manufacturer's instructions regarding setting up the equipment and follow them carefully. Check that the equipment and the operators are not conspicuous to drivers as this could affect speeds.

8 When vehicle detector/timers having peripheral logic and print-out facilities are being used the 85 percentile speeds printed out can be used with confidence for subsequent determination of speed limits provided items 1-7 above have been fully complied with and the advice for converting vehicle speeds to car speeds in paragraph 6.6 of the Advice Note is followed. In other circumstances the instructions in paragraph 6 and appendices 2 and 3 should be taken into account as applicable.

9 Refer to DTp Circular Roads 1/80 "Local Speed Limits" for general advice in determining speed limits.