



Traffic Safety and Security Division

3M Center, Building 235-3A-09

P.O. Box 33225

St. Paul, MN 55133-3225

www.3M.com/mvss

**3M™ Average Speed Camera System Distance over
Time Average Speed Measurement System**

Distance Measurement Manual Issue F

AMENDMENT RECORD

ISSUE	DATE	BRIEF DETAILS OF CHANGE
A	4/12/2005	First draft
B	11/08/2005	Updated with Corrsys-Datron details
C	9/6/2008	Update following operational review
D	25/6/2009	Update to remove bicycle wheel method.
E	5/8/2009	Update to make terminology consistent
F	29/11/2013	Rebrand to 3M

The overall issue status of this document is the latest issue shown in the table above.

This manual is intended as a guide to those persons interested in measuring and certifying link distances for the purpose of distance over time speed measurement.

Prepared By: Brian Smith

TABLE OF CONTENTS

1	Introduction	4
2	Equipment.....	7
3	Measurement Method Outline	8
3.1	Choose the datum point for each site.....	8
3.2	Lay out an accurate calibration course.....	9
3.3	Pre-measurement calibration of the CORREVIT-L350.....	9
3.4	Measure the Link distance	9
3.5	Post-measurement calibration of the CORREVIT-L350	9
3.6	Determine the link distance between the datum points	9
4	Laying Out a Calibration Course	11
4.1	Method of Measurement	11
4.2	Siting your Calibration Course	11
4.3	Recording your Calibration Course	11
4.4	Measuring Your Calibration Course With a Steel Tape	12
4.5	Stretching the Tape.....	12
4.6	Basic Taping Technique.....	12
4.7	Counting the Tape Lengths	13
4.8	The Tape's True Zero Point	13
4.9	Correcting for Temperature	14
5	Calibration of the Corrsys-Datron L-350.....	15
6	Measuring the Link Distance	16
7	Appendix 1	18

1 Introduction

3M™ Average Speed Camera System requires the distance between sites to be accurately measured since the fundamental accuracy of the system depends upon this. Within this document the following nomenclature will be used:

- **'Datum point'** – that point on the road, within the field of view of the respective camera, which is designated by means of a permanent pavement nail, and centred upon which a 50mm thermo plastic marking is fixed to the road orthogonal to the line of the road.
- **'Link distance'** – the distance between two datum points. This is the **'Uncorrected'** link distance.
- **'Corrected'** link distance – the minimum distance between two sites where the plate is just visible in each site. The corrections are associated with each camera as described in the following.

This document describes the procedure for physically measuring the link distance. Entry of the link distance into the Offence Viewing and Decision Station (OVDS) by means of the Enforcement Manager (EM) program, and it thereby being transferred to the Evidence Retrieval and Control Unit (ERCU) is covered in the Enforcement Manager Manual.

SpeedSpike operates upon the principle of always favouring the driver, i.e. it works on the basis of a minimum distance measurement between the last possible point at which the licence plate could have been seen at the 'entrance' site of the link to the first possible point at which the vehicle could be seen the 'exit' site. At each site a datum point is marked orthogonally across the road such that it is guaranteed to be within the field of view of each camera on the site. Cameras are consistently deployed reading either front or rear license plates as is desired and as the details of the sites may dictate. Only front or rear plates may be processed by any one ERCU. The system requires a certified 'baseline table'. In SpeedSpike this comprises of an entry per link (the link distance), plus two entries per camera (the top and bottom offsets). At each location a datum point is marked on the road with a visible mark within the field of view of each IR camera. The link distance is the longitudinal distance between the respective datum points.

The system operates by enforcing the minimum distance the vehicle could have travelled. Thus for each camera, the longitudinal distance from the datum point to the point where a number plate is just wholly visible as a vehicle enters the field (t_{offset}) of

view and the longitudinal distance from the datum point to the last point at which a number plate is wholly visible as it leaves the field of view (b_{offset}) are measured. If a camera is re-aligned for any reason, e.g. upon replacement, then the t_{offset} and b_{offset} distances **must** be re-measured. The link distance does not need to be re-measured providing it is confirmed that the datum points are confirmed to continue to be within the field of view. If this is not the case the link distance must be re-measured.

The calculation of the corrected link distance depends upon the direction of flow of the traffic. If the camera is reading oncoming plates (with the plate moving down the image on successive images) then the enforcement distance between number plate reads at either end of a link are calculated as follows:

For oncoming (front plate reading) traffic the minimum distance between two sites is as in the case for X' and Y' in figure 1.

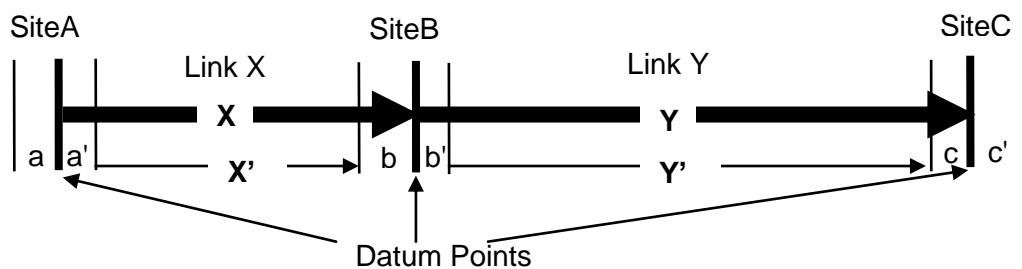


Figure 1 Link Distance Correction Method

Consider Link X which has a link distance of X between the datum point at Site A and the datum point at Site B, and a further Link Y which has a link distance of Y between the datum point at Site B and the datum point at Site C:

Traffic flows from Site A to Site B to Site C. The distances X and Y are used as the certified link distances, with the b_{offset} (a' , b' , c' ...) and t_{offset} (a , b , c) for each camera. The actual enforcement distance on Link X and Link Y are computed according to:

$$X' = X - a' - b$$

$$Y' = Y - b' - c$$

Thus the minimum possible distances are used in each case giving the driver the benefit of the measurement error. In general it may be stated as:

$$\text{Enforcement Distance} = \text{Link Distance} - b_{\text{offset of entrance site}} - t_{\text{offset of exit site}}.$$

For rear plate reading the minimum distance between two sites is:

$$\text{Enforcement Distance} = \text{Link Distance} - t_offset \text{ of entrance site} - b_offset \text{ of exit site.}$$

Sites are configured as front or rear facing within the Enforcement Manager. The SpeedSpike speed measurement engine operates on the basis of links between entrance and exit sites. A particular site, e.g. site B above, may be an entrance site for one link and an exit site for another, but for any single link the assignment is unambiguous and the enforcement distance is calculated in the same way for every link.

In general link distances are relatively large and always exceeding the minimum link distance of 100m (250m for pole-mounted multi-lane deployments), whilst the b_offset and t_offset distances are short, of the order of a few metres, and readily measured with a calibrated steel tape measure. This document primarily addresses the measurement of the link distance between sites.

The basic method of measurement is to use a 100m calibrated, temperature compensated steel measurement tape to generate a calibration course. The calibration course is used to check the calibration of a Corrsys-Datron CORREVIT-L350, a specialist electronic measurement device. This instrument has > 0.1% accuracy when measuring distances >200m. It has the advantage that it can be attached to the tow-bar of a car and driven along a motorway where other measurement methods are not feasible.

Short links, e.g. enforcement across a school entrance of a few hundred metres may be measured directly using the tape.

2 Equipment

1. **Steel Tape.** A calibrated steel tape is essential as the primary measurement instrument, e.g. a 100m tape: Richter 415W-R/100m. The tape should be provided with a calibration certificate showing that calibration was carried out within the last year. The steel tape is used to lay out the calibration course.
2. **Spring Scale.** A spring scale, capable of a 50 Newton (5 kilograms-force or 11 pounds-force) pull, is needed for the steel tape to be under proper tension as was used when the tape was calibrated. The spring scale need not be a precision instrument; the inexpensive variety sold at sporting goods stores for use by fishermen is fine.
3. **Thermometer.** A small thermometer is used to take temperature readings so that steel tape measurements can be corrected for temperature.
4. **Notebook and Pencils.** A small notebook easy to use while cycling and several pencils or pens are needed to record data.
5. **Laptop PC.** An Excel 'Link Distance Measurement.xls' spreadsheet is available for the entry of all results.
6. **Chalk.** Used for temporary pavement markings.
7. **Pavement Nails & Hammer.** Used for making permanent course marks.
8. **Masking Tape.** Masking tape is used for temporary marks while laying out the calibration course.
9. **Safety Equipment.** A BS EN 471 compliant safety vest and helmet should be worn.
10. **Corrsys-Datron CORREVIT-L350.** This is the secondary measurement instrument and is fixed to the measurement vehicle in accordance with the manufacturer's instructions such that it is aligned with the direction of travel.
11. **Laser Pacific Systems PLS5X** This is an outdoor 5 direction plumb laser, which is used to accurately traverse the road so that measurements may be carried out on the inside of each and every bend. Although not strictly necessary, for ease of use in bright sunlight it is most readily used with the companion PLS5x laser detector.

3 Measurement Method Outline

There are seven basic steps involved in measuring the link distance between two datum points as follows. An Excel spreadsheet, Link Distance Measurement.xls, should be used for ease of data entry and calculation, and as a guide to the measurement process.

3.1 Choose the datum point for each site

The datum point (or strictly its projection at right-angles to the linear length of the road) must be chosen to be within the field of view of all of the cameras at a site. A permanent point of measurement should be marked by fixing a permanent pavement nail within 1m of the kerbside, or in a convenient crack in the concrete kerb. Measurements are made to this point. A 50mm white line is fixed across the entire carriageway, centred on the stud. The respective orthogonal white line must be checked as being clearly visible in the field of view of each camera co-located at a site.

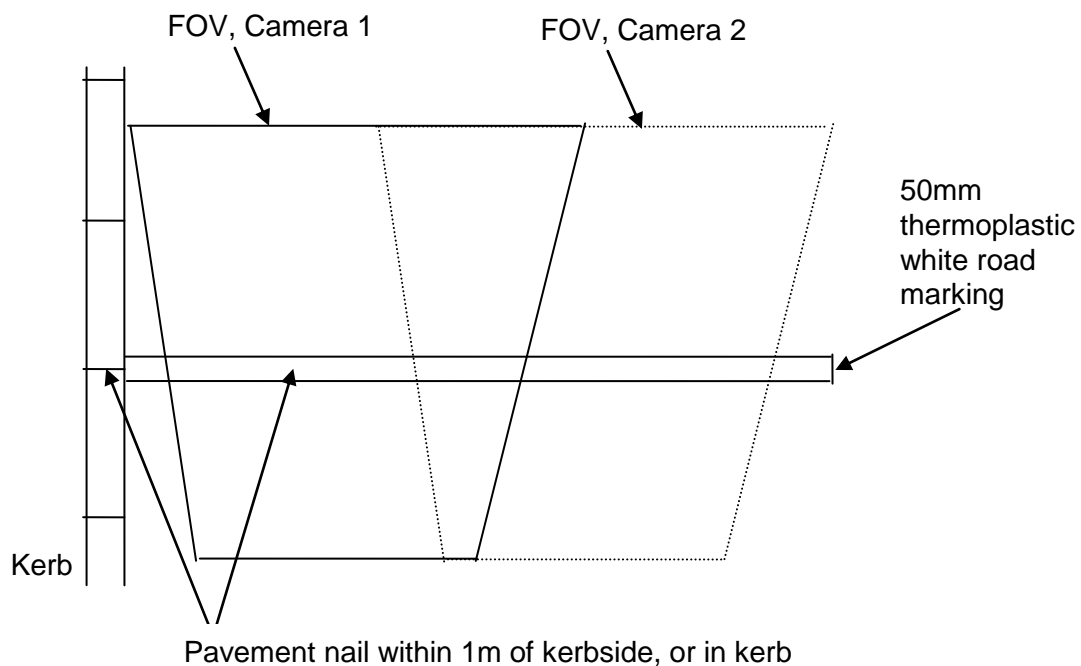


Figure 2 Datum point road marking (plan view)

3.2 Lay out an accurate calibration course

The calibration course must be a straight stretch of paved road that is level and relatively free of traffic and of at least 500 metres in length. The longer it is the more accurate will be the calibration. It has to be located such that the Correvit L-350 instrument may be calibrated on the measurement vehicle before and after the link distance measurement. A carefully selected calibration course will be useful for many link distance measurements.

3.3 Pre-measurement calibration of the CORREVIT-L350

Drive the measurement vehicle over the calibration course. At least three calibration journeys must be made prior to measuring the link distance and after measuring the link distance.

3.4 Measure the Link distance

Drive the measurement vehicle over the course, following the route according to the principles prescribed in the HOSDB guidelines. At least three measurements must be made over the course. Do not make new marks on the road during the measurements.

3.5 Post-measurement calibration of the CORREVIT-L350

Drive the measurement vehicle over the calibration course at least three times after the course measurement(s). After recalibrating, determine your **calibration constant**, which is the **larger** of the pre-measurement (working) constant, or post-measurement (finish) constant. This will result in the minimum distance being measured thus favouring the driver. Calibration runs do not need to immediately precede and succeed the link distance measurement. However delaying in particular the post-measurement calibration run increases the risk that an error negates a whole set of measurements. In any event the post-measurement calibration must be carried out for the link distance measurement to be valid.

3.6 Determine the link distance between the datum points

The spreadsheet will re-calculate each measured distance using the appropriate calibration constant for the day. Three independent measurements of the link distance must have been carried out, with all answers within 1% of the average. The proper measured length is the smallest value (favouring the driver). E.g., you obtain distances

of 10,000.1, 9998.2 and 9,993.7 metres on successive measurements the proper measured length is 9993.7 metres.

4 Laying Out a Calibration Course

The measurement accuracy of the calibration course is vital since any error introduced may be transferred to the measurement of a link distance. A calibration course must be on a straight, paved, level, and lightly travelled stretch of road, and must be at least 300 metres in length and ideally ≥ 500 metres. Greater accuracy will generally be achieved by using a longer calibration course.

4.1 Method of Measurement

The standard method of measuring a calibration course is to use a calibrated steel tape with a thermometer to measure the temperature. Use the 'Calibration Course Setup' page within the Excel 'Link Distance Measurement.xls' spreadsheet to enter your measurements.

4.2 Siting your Calibration Course

Choose a location that will be safe and convenient for calibrating the measurement vehicle. You will need access to the course prior to and after the link distance measurement. Calibration courses are usually measured along the edge of a straight road--the same distance from the edge as you would drive the measurement vehicle. On a street where vehicles may park, you may wish to measure far enough from the edge to avoid any parked vehicles. The marks defining the endpoints of your calibration course must be in the roadway. In general, endpoints should be marked by pavement nails driven into the road. Urban areas, however, often have numerous permanent objects in the street (sewers, manholes, etc.) that may serve as one or both endpoints of a calibration course. Your calibration course will be most resistant to getting obliterated when the road is resurfaced if both endpoints are permanent objects such as sewers or manholes, etc. In this case, you will have an odd-distance calibration course such as 643.64 meters--which is perfectly acceptable.

4.3 Recording your Calibration Course

Record the GPS co-ordinates at each end of the calibration course in the spreadsheet as a quick and easy way to find it again. Record sufficient detail so that the end points can readily be accessed again, e.g. Edge of manhole nearest to lamp-post A123.

4.4 Measuring Your Calibration Course with a Steel Tape

You can tape a calibration course with just two people, but it generally will go more smoothly with a third person (for example, to watch for traffic and take notes). Standard highway safety precautions should be observed with a yellow jacket conformant to BS EN 471 being worn. You must tape the course four times, twice in each direction. Use a new set of intermediate taping points (new pieces of masking tape) for each measurement. Treat the subsequent measurements as a check of the distance between the same endpoints you measured the first time. Thus, the subsequent measurements should result in a number indicating the distance between your original endpoints. Your final result will be based on the average of all four measurements, corrected for temperature automatically calculated by the spreadsheet.

4.5 Stretching the Tape

Just as steel tapes are manufactured to be most accurate at a particular temperature, they are also most accurate when stretched with a specified amount of force. Adjust the force you apply to the tape to match the correct force for your tape. (Unfortunately, the proper force varies from tape to tape.) You can find out how hard you are stretching the tape by using a spring balance. The errors due to slight variations in applied force are very small, and therefore the spring balance you use for checking tape tension need not be a precision or calibrated instrument. The correct force for stretching a particular tape is written on the calibration certificate. The correct tension is independent of the length of tape used. If a tape requires a tension of 50 N, you must pull with a force of 50 N, regardless of how much or how little of the tape you are using. It is sufficient to do a few trials beforehand to get a feel for the correct tension. The spring balance does not need to be used for the actual course measurement.

4.6 Basic Taping Technique

For each tape length, the Lead and Rear tapepersons first lay out the tape until it lies straight and flat on the road. Intermediate taping points are marked with ballpoint pen on masking tape. After stretching the tape to its approximate position, the Lead tapeperson sticks a piece of masking tape on the road, covering the position where the mark will be made. The Lead tapeperson then starts pulling on the tape with proper force (see below).

When the Rear tapeperson has his endpoint firmly positioned over the mark (with the tape under tension), he shouts "mark." At this signal, the Lead tapeperson draws a fine line on the masking tape to mark the exact endpoint. Long steel tapes are generally

designed so that the tape may be easily detached from the reel. Taping is easiest if you do this. Don't panic if you see that a car is about to ride over your tape. If the Lead and Rear tapepersons hold the tape flat and firmly against the road it will minimise the risk of damage to the tape. When walking from one taping position to the next, only the Lead tapeperson holds onto the tape, which is allowed to drag freely on the road. (If Lead and Rear tapepersons attempt to hold both ends off the ground, it may drag at a spot in the middle, resulting in one extremely worn area!)

4.7 Counting the Tape Lengths

Miscounting the tape lengths in a calibration course must be avoided at all costs on account of the potential for it directly contributing very significant errors to the link distance measurement.

It is straightforward to guard against such counting errors by pre-numbering the pieces of masking tape 1, 2, 3 on the roll before you tear them off. As pieces of masking tape are used, the Lead tapeperson adds more numbers to the roll, so it always has at least two or three numbered segments that haven't been used yet. (Be sure to write the numbers so they won't be confused with the fine lines that will denote actual tape endpoints.) After the taping, walk the course to check the tape count. Record the results in the spreadsheet.

4.8 The Tape's True Zero Point

Many steel tapes (especially construction-style tapes) don't have their zero point on the graduated portion of the tape. Misjudging the tape's zero point is harder to catch than miscounted tape lengths, but the effect can be insidious.

Before using any tape, examine its markings carefully. If zero is not on the graduated portion of the tape, then take a ruler (or another portion of the same tape) and measure to find out where the true zero is. On construction-style tapes, it's usually at the outer edge of a "hook-ring" as in figure 3. While examining your tape, make sure you also understand all its other markings.

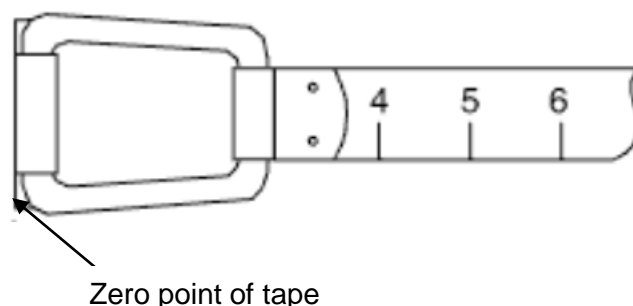


Figure 3 Tape true zero point

4.9 Correcting for Temperature

Steel tapes are manufactured to be accurate at 20 °C (68 °F) and calibrated at this temperature, but the tape expands when heated and contracts when cooled. To correct your taped distance for temperature, set out a thermometer on the pavement and shaded from the sun. Read the thermometer before you start taping, and after you finish taping and enter into spreadsheet, making the units selection. A temperature corrected measurement in yards or metres is automatically provided by the spreadsheet and fed forward to subsequent pages.

5 Calibration of the Corrsys-Datron L-350

The Corrsys-Datron L350 requires the use of the manufacturer's CeCalWin Pro 1.6 (or later) software which is available for download on http://www.corrsys-datron.com/software_downloads.htm. Ensure that 'SI/American' units are selected prior to calibration in accordance with those used for the calibration course. Ensure that the device has a live connection to the PC and that the test configuration file PIP_01.dls containing the pre-defined 'PIPS Test' is loaded.

The device must be fixed to the measurement vehicle in accordance with the manufacturer's handbook recommendation. It is greatly to be preferred that the device is permanently fitted to the measurement vehicle on a hard fixing, being carefully aligned with the length of the vehicle. If this cannot be achieved, e.g. if the device is fixed to the vehicle with suction cups, then the device should not be removed from the vehicle or it's alignment adjusted between the pre-calibration and post-calibration measurements using the calibration course. If the device is attached with suction cups, ensure the safety lanyard is properly secured.

Arrange a retro-reflective trigger at both ends of the course (e.g. on a tripod), on a line orthogonal to the road line and going through the position marking stud. Use either a metal square or a Pacific Laser PLS 5x orthogonal plumb laser to achieve this. The retro-reflective trigger should be placed as close to the edge of the road as possible. Drive the measurement vehicle slowly past the trigger to test the trigger.

Calibration is by means of measuring the calibration course three times. Select the Measurement Device Calibration page of the spreadsheet and drive over the course three times accelerating and braking very gently. Take additional care to drive past the reflective targets very slowly to maximise the trigger accuracy.

Enter each measurement into the spreadsheet in metres/yards as used by the calibration course. The spreadsheet will calculate a working 'Corrsys distance per metre' (or per yard) which should be between 0.999 and 1.001, and will be automatically ratified with "CORRSYS-DATRON CALIBRATION ACCEPTABLE" or a message to the contrary. Do not proceed to measure the link distance until the calibration is acceptable.

6 Measuring the Link Distance

The link distance calculation uses the 'Link Measurement' page of the Excel 'Link Distance Measurement.xls' spreadsheet. The measurement units on this page may be independently selected from those used for the calibration course. A minimum of three measurements must be taken utilising the same method as for the calibration of the measurement device. The spreadsheet will automatically highlight if the measurements are not within 1% of the average value, and will select the minimum measured distance in the selected units as the (uncorrected) link distance.

Measurements must be in accordance with HOSDB guidance "Distributed Automatic Distance/Time Speedmeters Requirements for base line locations and measurement – 14 July 2008" as included in Appendix 1. In particular measurements must be carried out using the outside lane of clockwise bends (i.e. by travelling in the reverse direction, if a bi-directional road) and the inside lane of anti-clockwise bends, thus always measuring on the 'inside' of the bend. To achieve this, the road has to be traversed at each point of inflection. This is most readily accurately achieved by the use of an accurate outdoor orthogonal plumb laser so that a retro-reflective target for the reverse direction trigger is correctly aligned on the opposite verge. The use of the Pacific Laser PLS 5x model is recommended, with a calibrated accuracy of 1/8" at 100' (3mm at 30m). In this case the trigger device does not need to be re-aligned on the measurement vehicle and the trigger will not be obscured by intervening traffic.

Special care is required on dual-carriageways, when measuring the distance on the outside lane. There may be obscuring traffic in the inside-lane and this may cause difficulty in achieving a retro-reflective beam trigger. On the other hand placing the retro-reflective trigger in the central reservation may well require a method statement specific to the site for the operation to be carried out safely. If in any doubt, please contact Stephen Gest, (Installation & Service Manager) for further guidance.

At both sites associated with the link and upon any camera replacement or re-alignment, measure and record the b_offset and t_offset for each camera from the datum point by placing a licence plate on a cone 0.5m above the ground such that it is just visible in the top of the field of view for the t_offset and just inside the bottom of the field of view for the b_offset. Enter the t_offset and b_offset distances for the upstream

(start) and downstream (end) of the link into the Link Measurement page in the spreadsheet.

When the link distance is <500m the bottom of the field of view must be marked with a white 50mm x 100mm thermoplastic road marking. An additional marking must also be placed 1m from the first marking, co-linear with the road and within the field of view of the IR camera.

This completes link distance and top/bottom offset measurements.

7 Appendix 1

Distributed Automatic Distance/Time Speedmeters Requirements for base line locations and measurement

S R Lewis HOSDB

14th July 2008

1. Introduction

- 1.1 The Home Office requirements for the type approval of automatic distance over time speedmeters for the enforcement of speed limits in the United Kingdom are given in HOSDB publication "Automatic Distance/Time Speedmeter Handbook" No 02/06. Additional Home Office requirements for automatic distance/time speedmeters that enable the enforcement of a common speed limit applying to a number of road sections sharing a common speed limit and recording the evidence at a remote location are given in an HOSDB note "Requirements for distributed automatic distance/time speedmeters with remote control and recording of evidence" dated 4th January 2004.
- 1.2 For each road section, these devices use image detectors⁽¹⁾ at the entry and exit point of a measurement base line over which the average speeds of vehicles are measured. The image detectors shall be located only on road sections where one traffic route is possible between them. The accuracy of such systems depends critically on the accurate measurement of the base line length and this length must relate to the shortest possible path between the entry and exit points.
- 1.3 The Home Office requirements for the location and measurement of baseline distances for distributed automatic distance/time speedmeters are given below. These requirements should be read in conjunction with the HOSDB publications referred to in 1.1 above.

2. Requirements

- 2.1 The entry and exit point for all base lines used for enforcement shall be located at road sections where only one traffic route is possible for traffic to travel between them.
- 2.2 The measured base line between the entry and exit points shall be the shortest distance that can be travelled between these points as defined in 2.3 below.
- 2.3 For all types of road with all lanes adjoining, the base line shall be measured in sections along the inside edge of each curve in the road as follows. The base line shall be measured from the entry point to a line normal to the road edge at the first point of inflection or the exit point if before the first point of inflection, and then in sections to each point of inflection until the exit point is before the next point of inflection. For each section so defined the shortest distance measured equidistant from the nearside or offside edge of the road at a distance no greater than 3 feet from it from the lines normal to the road edge defining the start and the end of each section shall be measured. The base line used for all lanes shall be the sum of all the measurements from each section between the entry point and exit point. This is illustrated for a four-lane single carriageway in figure 1 where the base line from point A to C is the sum of the

distance from point A to point B and the distance from point B to point C measured equidistant from the edge of the road.

- 2.4 Where ever lanes are not adjoining or movement between carriageways is prohibited, the base line shall be measured for and apply within only one carriageway. This is illustrated in figure 2 for a section of road which includes both single and dual carriageways and the base line for vehicles travelling from A to E. Where contraflow is involved, the entry and exit points shall be within the length of the contraflow and each route separately enforced.
- 2.5 The base line length shall exceed the approved minimum base line for the device being used. Cameras may be mounted on existing lamp posts using only mountings approved by HOSDB. Whenever the base line is less than or equal to 500m, two permanent datum marks 1m apart shall be used at the entry and exit camera with the nearest mark just within the bottom of their field of view.
- 2.6 The base line length shall be measured using a calibrated surveying instrument, such as a theodolite, total station, measuring wheel, steel tape, surveyor's chain or where there is no restricted view of the sky through out the length of the base line, with a vehicle mounted GPS system acceptable to HOSDB or another method acceptable to HOSDB. The base line shall be measured three times and if all measurements agree within 1% of the average value, the shortest distance shall be used as the measured base line distance. Where they do not agree within 1%, another method acceptable to HOSDB or a calibrated measuring wheel shall be used.
- 2.7 Any base line table used for speed enforcement shall be certificated as specified in the HOSDB note "Requirements for distributed automatic distance/time speedmeters with remote control and recording of evidence" dated 4th January 2004. The certificate shall also specify the method of measurement used.

Note (1) Image detector

The automatic detection of the presence, time and identity of a vehicle as it passes a datum point at the entry or exit of a baseline using image recognition techniques.

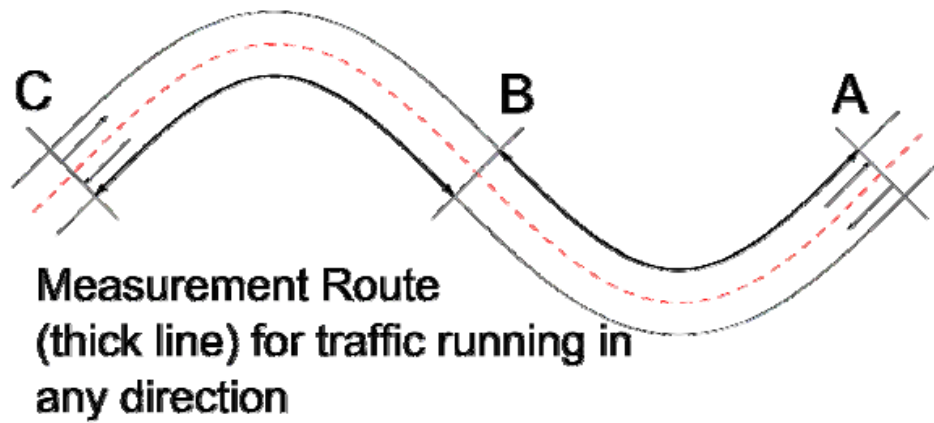


Figure 1 Single carriageway with two lanes.

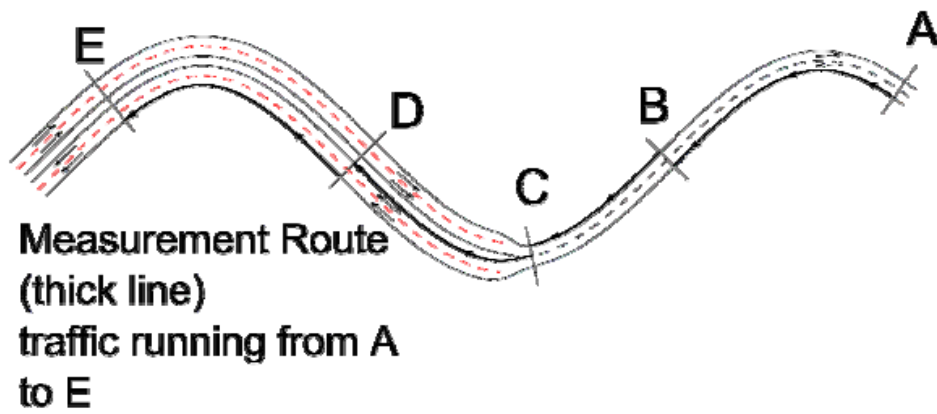


Figure 2 Dual and single carriageway.