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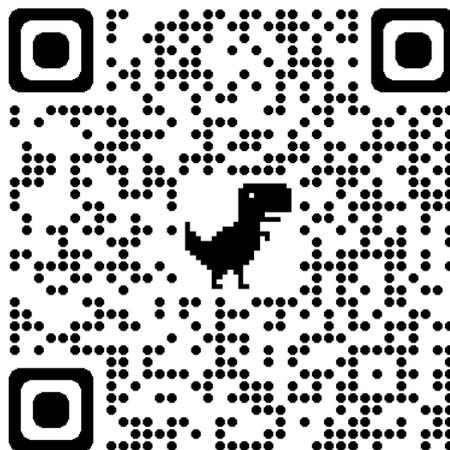
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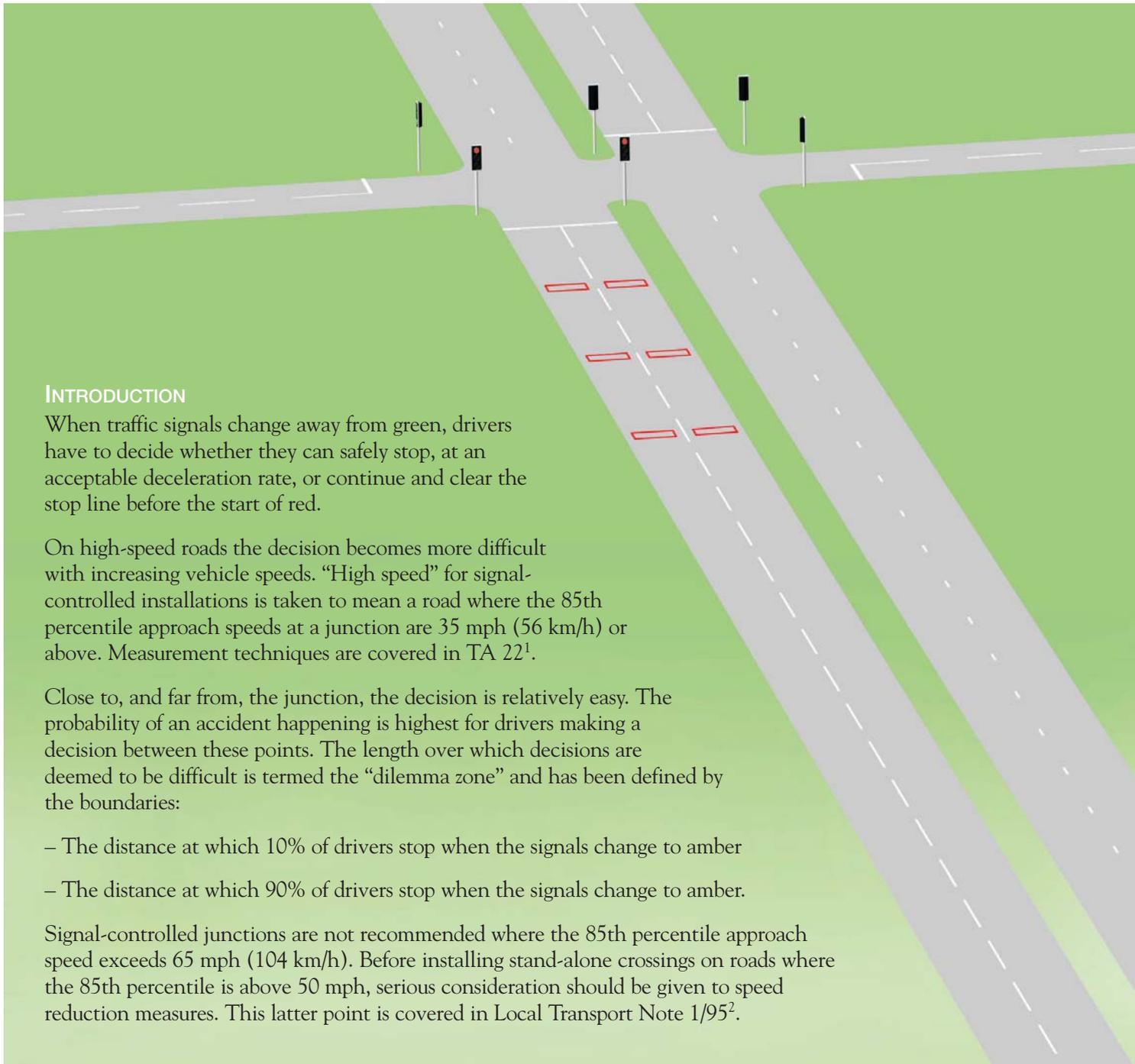
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Signal-control at Junctions on High-speed Roads



INTRODUCTION

When traffic signals change away from green, drivers have to decide whether they can safely stop, at an acceptable deceleration rate, or continue and clear the stop line before the start of red.

On high-speed roads the decision becomes more difficult with increasing vehicle speeds. "High speed" for signal-controlled installations is taken to mean a road where the 85th percentile approach speeds at a junction are 35 mph (56 km/h) or above. Measurement techniques are covered in TA 22¹.

Close to, and far from, the junction, the decision is relatively easy. The probability of an accident happening is highest for drivers making a decision between these points. The length over which decisions are deemed to be difficult is termed the "dilemma zone" and has been defined by the boundaries:

- The distance at which 10% of drivers stop when the signals change to amber
- The distance at which 90% of drivers stop when the signals change to amber.

Signal-controlled junctions are not recommended where the 85th percentile approach speed exceeds 65 mph (104 km/h). Before installing stand-alone crossings on roads where the 85th percentile is above 50 mph, serious consideration should be given to speed reduction measures. This latter point is covered in Local Transport Note 1/95².

BACKGROUND

Work in the early 1960's by the then RRL, now TRL Ltd., considered the problems associated with traffic signals on high-speed roads. They looked at measures like longer amber periods and advance warning of the change to amber but decided on the use of additional detection. Recent research, using sophisticated simulation techniques, has confirmed that their recommendations are still valid.

Their starting point was that the normal detectors (at the time a twin pneumatic tube, 130 feet, 39 metres, from the stop line) worked safely up to 30 mph. Over that speed, drivers could be in difficulty, in a dilemma zone, before reaching the detectors .

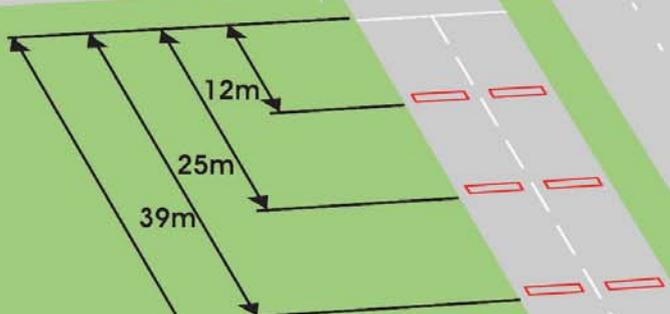
The solution was to measure the speed of approaching vehicles, using additional speed measuring detectors, further out from the stop line. These were used to calculate when the vehicle would reach the outer limit of the dilemma zone.

The philosophy was that before the driver reached the dilemma zone it was safe for the signals to change, but once in the dilemma zone they would be given a fixed extension of the green time to take them well within the normal detection range.

Once within the normal detection range the fixed extension would run in parallel with the normal speed-timed extension. This also gave a measure of fine-tuning to compensate for any acceleration/deceleration after leaving the speed measuring detectors.



Speed Assessment

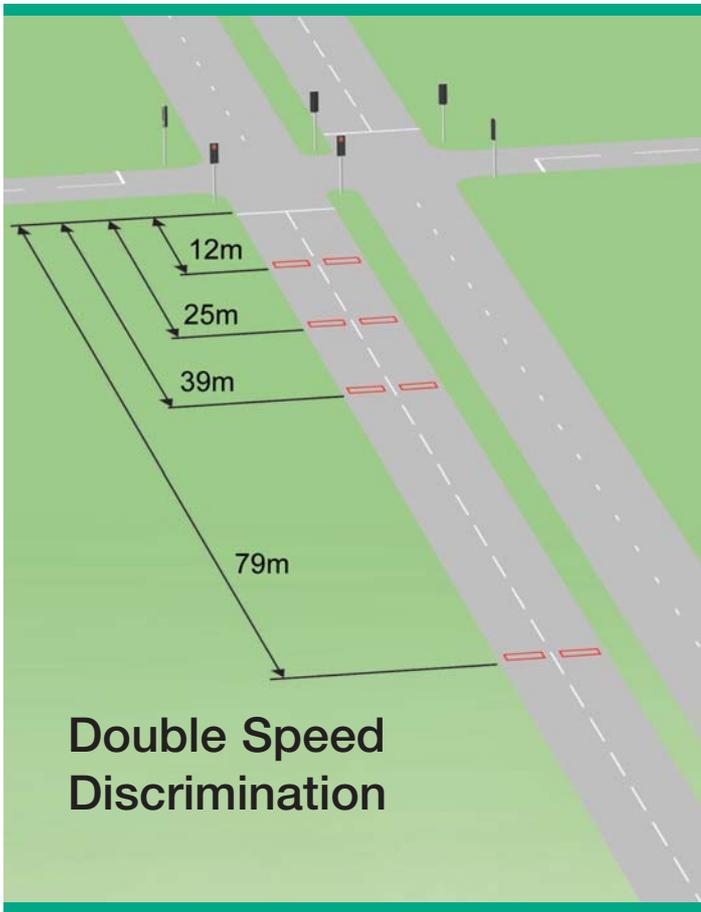


DETECTION SYSTEMS FOR HIGH SPEED SITES

The early work resulted in equipment specifications for use at high-speed sites. By the early 1970's, speed assessment (SA) and speed discrimination (SD) equipment was available utilising sub-surface inductive loop detectors. Two loops per lane are installed at each detection site to provide for speed measurement.

These were to be supplementary to the standard system "D" detector system. Loop detector spacing for system "D" and "SA" and "SD" can be found in specifications MCE0108C³ and TR2210A⁴. Both documents are essential reading. In addition to following the guidance on detector layout it is important that the standard timings, such as the maximum green and intergreen, are calculated correctly. Excessive green times encourage higher speeds, leading to an increase in accident potential and severity. SA is a direct consequence of the RRL work, giving a speed related period during which the signals can change, followed by a 5 second fixed extension which, at a constant speed, gets the driver to well within the system "D" detection area. There is a simple formula in TR2210A⁴, which gives the speed-timed period.

151m



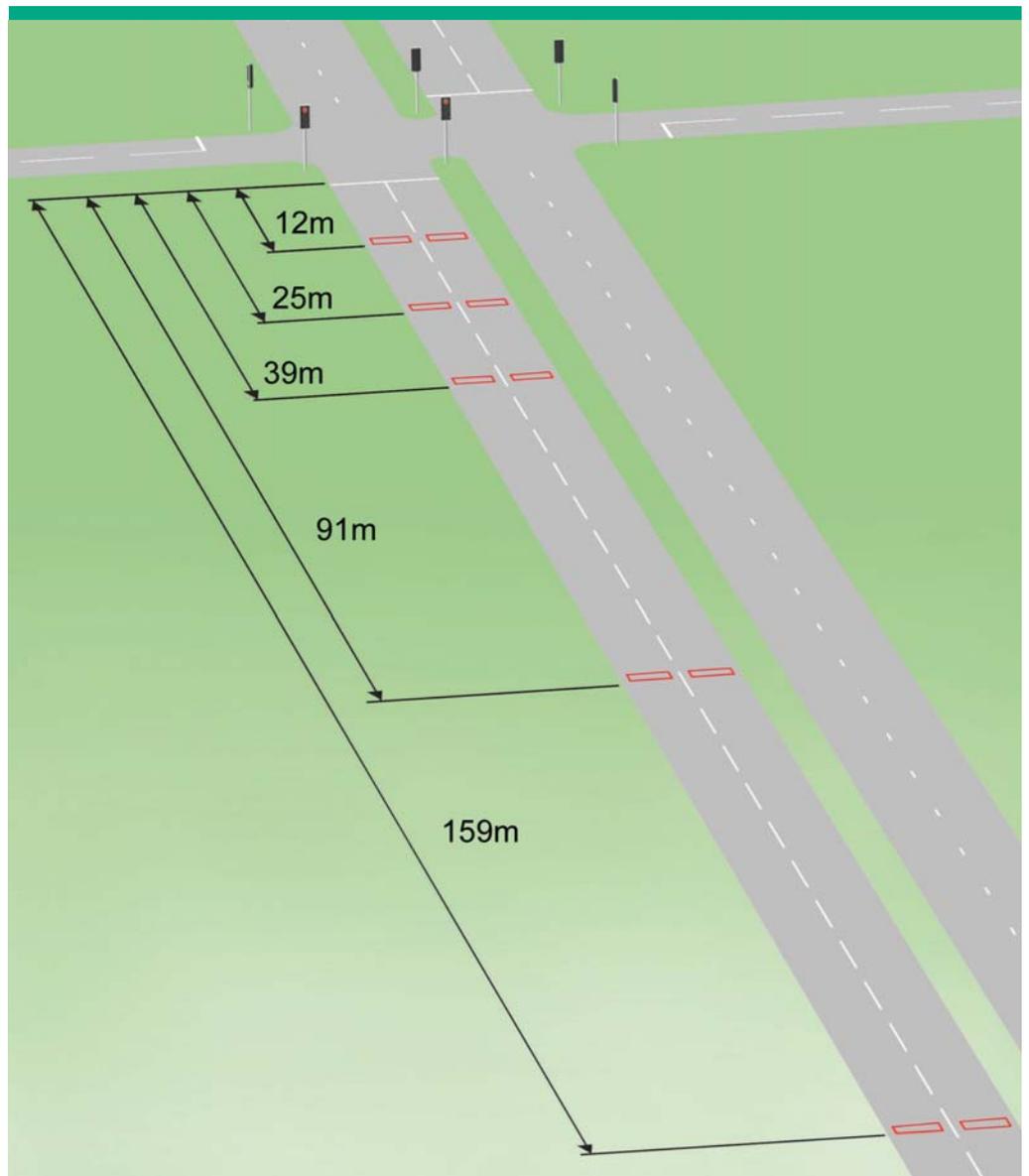
SD is a simpler approach, giving a fixed extension if a vehicle is travelling above a minimum speed. There are two types – “double” for 85th percentile speeds between 35 and 45 mph, giving a 3 second extension, and “triple” for 85th percentile speeds over 45 mph, giving a 3.5 second extension at both additional detection points. Again, once the vehicle reaches the system “D” area the extensions run in parallel.

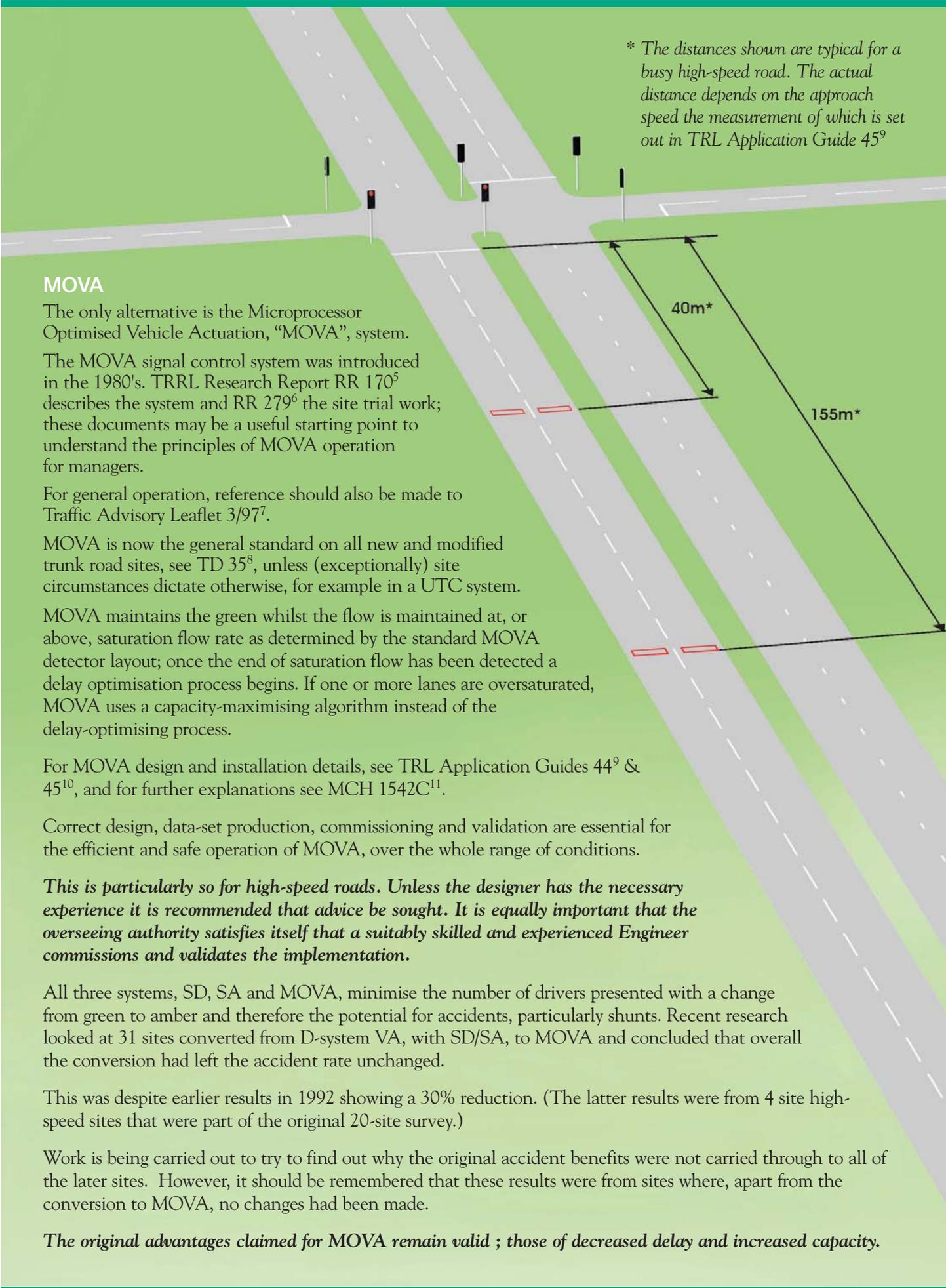
The green can terminate:

- at the end of the minimum green, or
- after the last extension period, a “gap change”, or
- at the maximum green, a “max. change”.

On a max. change, the controller will give two seconds extra all red. Both systems can tend towards maximum green changes in both heavy and medium vehicular flows. This not only gives an arbitrary change from green but an increased intergreen which drivers begin to take as the norm.

It must be stressed that if a junction, or stand-alone crossing, is within the high-speed category it must incorporate either system “D” detection with SA or SD, as specified in MCE0108C³, or the “MOVA” system described next. Designers for sites in Scotland should seek advice from the Scottish Executive.





* The distances shown are typical for a busy high-speed road. The actual distance depends on the approach speed the measurement of which is set out in TRL Application Guide 45⁹

MOVA

The only alternative is the Microprocessor Optimised Vehicle Actuation, "MOVA", system.

The MOVA signal control system was introduced in the 1980's. TRRL Research Report RR 170⁵ describes the system and RR 279⁶ the site trial work; these documents may be a useful starting point to understand the principles of MOVA operation for managers.

For general operation, reference should also be made to Traffic Advisory Leaflet 3/97⁷.

MOVA is now the general standard on all new and modified trunk road sites, see TD 35⁸, unless (exceptionally) site circumstances dictate otherwise, for example in a UTC system.

MOVA maintains the green whilst the flow is maintained at, or above, saturation flow rate as determined by the standard MOVA detector layout; once the end of saturation flow has been detected a delay optimisation process begins. If one or more lanes are oversaturated, MOVA uses a capacity-maximising algorithm instead of the delay-optimising process.

For MOVA design and installation details, see TRL Application Guides 44⁹ & 45¹⁰, and for further explanations see MCH 1542C¹¹.

Correct design, data-set production, commissioning and validation are essential for the efficient and safe operation of MOVA, over the whole range of conditions.

This is particularly so for high-speed roads. Unless the designer has the necessary experience it is recommended that advice be sought. It is equally important that the overseeing authority satisfies itself that a suitably skilled and experienced Engineer commissions and validates the implementation.

All three systems, SD, SA and MOVA, minimise the number of drivers presented with a change from green to amber and therefore the potential for accidents, particularly shunts. Recent research looked at 31 sites converted from D-system VA, with SD/SA, to MOVA and concluded that overall the conversion had left the accident rate unchanged.

This was despite earlier results in 1992 showing a 30% reduction. (The latter results were from 4 site high-speed sites that were part of the original 20-site survey.)

Work is being carried out to try to find out why the original accident benefits were not carried through to all of the later sites. However, it should be remembered that these results were from sites where, apart from the conversion to MOVA, no changes had been made.

The original advantages claimed for MOVA remain valid ; those of decreased delay and increased capacity.

MOVA may make possible the addition of, say, a pedestrian stage or separately signalled right turns, without the otherwise expected increase in delay. This type of revision in the stage sequence may directly tackle existing frequent and severe accident problems, with a predicted overall advantage.

A number of points were made in the research report that should maximise the probability of accident savings at MOVA sites. Unlike SD/SA, MOVA does not automatically increase the intergreen period at a max. change. It is recommended that an increased intergreen period be built in when specifying the timings, say, 1 second extra for 85th percentile speeds up to 45mph and 2 seconds for speeds above that.

Excessive increases in intergreen times, especially at sites just in the high-speed category, can increase risk.

As stated above, it is important to set up MOVA data correctly for safe operation. Of particular importance is the “cruise speed” which needs to be set realistically. (The cruise speed used in MOVA is measured and approximately the 15th percentile, i.e. the speed exceeded by 85 percent of vehicles.) The cruise speed is measured in free flow traffic conditions but checked at validation for other times of day for its suitability.

An overestimate, or an underestimate, could result in a greater number of vehicles being caught in the dilemma zone, with the resultant increase in accident potential.

HIGH SPEED SITES WITHIN URBAN TRAFFIC CONTROL (UTC)

At most isolated junctions, the use of any of the systems mentioned is straightforward. However, if the junction is linked to other signal-controlled installations, whether locally or through UTC, it is difficult to allow the flexibility of vehicle- actuation within basically fixed time systems. Many authorities increase the all red, on a permanent basis, at linked high-speed sites but do not provide equipment to minimise the chance of vehicles being presented with a change to amber. During peak hours this may be no different to those with SD/SA, as most changes will effectively be on maximum green.

However, during the off-peak period there is a greater accident potential without special speed measuring equipment. This can be minimised by having “time of day” maximum green times but, as again these are fixed, this method is less effective.

There are currently two basic types of UTC in the UK, fixed-time and SCOOT. An introduction to SCOOT can be found in Traffic Advisory Leaflet 7/99¹².

SCOOT will continually look at the appropriateness of the green times and adjust accordingly. This would certainly be

an advantage over strict fixed-time operation. However, it is looking at trends rather than individual arrivals.

One option may be to use a system, triggered by a “Gap Out” (GO) bit, which gives a VA component to a UTC stage. This has already been used to give a VA component at the end of what otherwise is a fixed UTC green. It is hoped to gain experience on its use with SD/SA.

GEOMETRIC DESIGN FEATURES

The design and implementation process should follow TA 84¹³. Reference should be made to TD50¹⁴ for all general layout features, including the design speed and to Local Transport Note 1/98¹⁵ for installation. The latter includes guidance on signal head alignment.

Duplicate primary signals are recommended on all high-speed approaches.

At some sites, signal visibility may be improved by installing additional heads on tall posts, above the standard signal head, or on mast arm brackets above the carriageway. If intending to use mast arm signals the designer should check whether the route is designated as a “high load route”. If it is, arrangements will be needed to swing the mast arm away from the carriageway.



The designer will need to apply for authorisation for any signal head mounted outside the limits given in the Traffic Signs Regulations and General Directions¹⁶. When drawing up the signal head arrangement, two issues should be addressed:

- possible maintenance problems
- signal visibility as drivers travel towards the stop line.

With a signal head mounted at a height of, say, 6 metres and aligned as recommended, the optical performance will begin to reduce rapidly at approximately 75 metres from the stop line, which could well be within the dilemma zone.

It is therefore essential that standard height signals are also visible to all drivers on the approach.

Two types of collision are common at high-speed sites:

- a rear-end shunt, where one driver stops and a following one does not.
- a side impact, where a driver enters the junction after the start of red and collides with conflicting traffic.

Both are minimised by the use of one of the systems described in the previous section on “Detection Systems for High Speed Sites”.

Side-impact collisions are also a potential risk for drivers making a right turn at the junction, who may misjudge the lengths of gaps in the opposing vehicular flow.

If the opposing vehicles are travelling at even moderately high speed, this judgement becomes more difficult.

It is strongly recommended that where the 85th percentile approach speed is greater than 45 mph on any approach, opposing right turns should be separately signalled and show only when the through traffic has been halted.

An alternative solution is to ban the right turns, if local circumstances permit.

Reference should be made to the section on high friction surfacing, (HFS), in TD50¹⁴. On high-speed approaches the length of HFS will be greater and particular attention should be paid to the approach geometry, the dilemma zone and queue length.

Because of the increased braking distances required at high speeds, drivers need adequate warning that they are approaching a signal-controlled junction. Advance warning signs are necessary on each approach in accordance with the requirements given in Chapter 4 of the Traffic Signs Manual¹⁷.

PEDESTRIANS, CYCLISTS, EQUESTRIANS

See TA15¹⁸ “Pedestrian Facilities at Traffic Signal Installations”. Injuries to pedestrians are greater as the speed of vehicles increase. Serious consideration should be given to reducing the 85th percentile speed of vehicles, especially where vulnerable road users are expected to cross.



RED RUNNING CAMERAS

At high speed sites there should be a delay before the camera is activated of at least 1 second of red, being increased to at least 1.5 seconds as the 85th percentile speeds increase.

OPERATION AND MAINTENANCE

With all additional specialist equipment, SD, SA and MOVA, it is important that it is set up correctly and maintained throughout its life.

On SD and SA the maximum green period setting is important.

Both systems can be terminated unnecessarily by a short maximum, relying on the increased intergreen, rather than the avoidance of decisions for drivers in the dilemma zone.

If the maximum is artificially high, the vehicular flow fairly low but with an 85th percentile over 35mph, the green signal will be held to the detriment of junction efficiency. Both low and high maximum greens could potentially affect the safety of the junction.

It is important that all signal-controlled equipment on high-speed roads should have red-lamp and remote monitoring.

Reference should be made to TD24¹⁹ for general inspection and maintenance items, particularly any relevant to high-speed sites.

The failure of signal-controlled junctions/crossings, including lamp failures, on high-speed roads can cause considerable uncertainty and confusion with consequent accident risk.

It is of the utmost importance that such signal installations are well maintained.

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