GENERAL NOTE

The Transport Planning and Design Manual (the TPDM) consists of eleven volumes and is published primarily as a working document for Transport Department staff. It also provides information and guidance to others involved in the planning and design of transport infrastructures in Hong Kong.

It is intended that the information contained herein will be periodically revised to take account of the most up-to-date knowledge and experience. The inevitable time-lag however, means that certain sections may at a particular time be unavoidably not up-to-date. For this and other reasons, the standards contained in this manual should not be followed rigidly but rather treated as a framework within which professional judgment should be exercised to reach an optimum solution.

Generally speaking, the standards contained in the TPDM generally apply to new traffic and transport facilities and should not be considered as exhaustive. Situation may arise for which considerations and requirements are not fully covered by the TPDM. Practitioners are particularly required to exercise professional judgement when dealing with existing facilities that are subject to site constraints, and to endeavour to take into account the views from stakeholders. Practitioners are also advised to make reference to other publications relevant to their designs such as the latest legislations, code of practices, guidelines, datasets, etc. before applying the TPDM.

Transport Planning & Design Manual

VOLUME 4 - Road Traffic Signals

1.1 References

(1) U.K. Road Research Technical Paper No. 56 – 'Traffic Signals' by Webster and Cobbe.

(2) Roads in Urban Areas – U.K. HMSO 1966

(3) Laws of Hong Kong Chapter 374' Road Traffic Ordinance and Subsidiary Legislation.

(4) Advisory Memorandum on Urban Traffic Engineering Techniques – U.K. HMSO 1966.

(5) U.K. Traffic Signs Regulations and General Directions 1981/859 HMSO.

(6) C.E. Manual Vol. 3, Chapter 2 – P.W.D. H.K. 1972.

(7) Code of Practice for the Lighting, Signing and Guarding of Roadworks, Highways Department, Hong Kong.

1.2 Introduction

1.2.1 Purpose of Volume

1.2.1.1 This Volume is in essence a revision to previous guidance on Signal Controlled Junctions.

The content has however been expanded to cover other areas of traffic signal design, and a more comprehensive approach is also adopted.

1.2.1.2 The Volume is intended to provide criteria and design guidelines for road traffic signals at junctions and mid-block pedestrian crossings.

1.2.1.3 An opportunity is also taken in this volume to include other topics such as Traffic Control Systems, Signal Equipments and Signal Co-ordination etc. However because the knowledge and development in these fields is so vast and is changing so rapidly, these subjects are therefore only touched upon briefly on the essential features. Users who would like to pursue further details are requested to refer to either the recommended references or literature provided by the equipment suppliers.

1.2.1.4 Criteria and design guidelines appearing in this Volume should not, unless otherwise stated, be regarded as standards to be rigidly adhered to. A flexible approach should be adopted for producing effective design commensurate with safety and practical considerations.

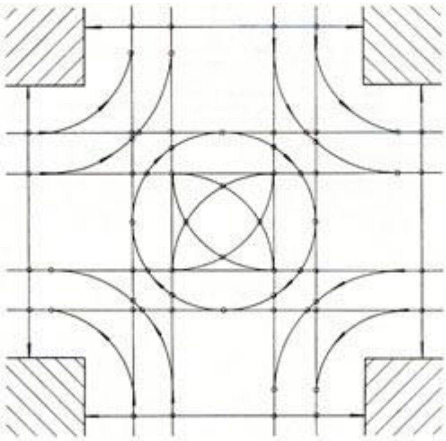
1.2.2 General

1.2.2.1 A Traffic signal installation is a power-operated device which informs motorists or pedestrians when they have the right of way at a particular intersection.

1.2.2.2 Traffic signals are used at intersections to reduce conflicts to a minimum by time sharing of right of way. This actually reduces the capacity of the intersection, but greatly enhances safety.

Conflicts at intersections may be illustrated in Diagram 1.2.2.1 which shows the potential conflict points at a theoretical 4 by 4 lanes wide intersection, at which all crossing and merging movements are permitted. With the provision of traffic signal control the number of potential conflicts can be reduced from 64 to zero.

DIAGRAM 1.2.2.1: CONFLICTS POINTS AT INTERSECTION



1.2.3 Criteria for Signals

1.2.3.1 General criteria for the use of traffic signals may be summarized as follows :-

(i) Use of traffic signals would enhance junction capacity as traffic would be discharged under control at saturation flow, thus maximizing the use of the traffic lanes available

(ii) Use of traffic signals would reduce accidents as the conflicts could be suitably dealt with

(iii) Use of signals would economize on police time necessary for the manual control of traffic

(iv) Use of traffic signals would reduce delay at intersections under heavy flows, especially to those traffic on the minor roads.

1.2.4 Signals and Roundabouts

1.2.4.1 Consideration can be given to the provision of a small roundabout under the following circumstances :-

(1) High proportion of turning traffic at the junction

(2) The existence of more than four approaches to the junction

(3) Approach widths so restricted that it would be impracticable to provide separate lanes for through and turning traffic

(4) A Y junction layout lending itself to roundabout design

(5) Where traffic flow is light a small roundabout may be less restrictive and impose less delay to drivers.

It should be noted however that roundabouts generally provide poor facilities for pedestrians. Their use must be carefully considered therefore where pedestrian flows are heavy.

1.2.4.2 Circumstances which may favour provision of traffic signals instead of small roundabout are :-

(1) Where there is requirement for better pedestrian crossing facilities which could not be easily accommodated in roundabouts.

(2) New roundabouts should usually not be contemplated within ATC areas or linked systems as it is likely to interfere with the platoon arrangement.

(3) Where flows are heavy that roundabout is likely to lock up if exit roads are congested.

(4) Where there is requirement to control the throughput at an intersection and there is adequate space for queues to form.

1.2.4.3 In choosing the most appropriate form of traffic control, intersections have to be considered on individual merits such as capacity and levels of service, safety aspects and vehicles delay etc.

1.2.4.4 Vehicle-actuated signals could be installed on approaches to roundabouts which are prone to locking in peak periods. Consideration may also be given to the use of part-time signals which are switched off during off-peak hours. It must be noted that as the the use of signals in roundabout is very new in Hong Kong that its use should be regarded as a last resort in situations where no other alternatives are available.

1.2.4.5 Reference should be made to T.P.D.M. Vol. 2 Chapter 4 for details of roundabouts.

1.3 Legal Aspects of Road Traffic Signals

1.3.1 Legislation

1.3.1.1 The legislation concerning Road Traffic Signals and associated Traffic Signs and Road Markings in Hong Kong are as follows :-

(i) Road Traffic Ordinance

(ii) Road Traffic (Traffic Control) Regulations particularly :-

(a) Part III and Third Schedule for Light Signals

(b) Fourth Schedule for zebra crossing and light signal crossings

(c) Part II and the First and Second Schedule for Traffic Signs and Road Markings

(d) Part VI - for pedestrian light signal crossing

1.3.2 Miscellaneous

1.3.2.1 The use of portable traffic signals and associated signs and carriageway markings in conjunction with roadworks should be in accordance with the "Code of Practice for Lighting, Signing & Guarding of Roadworks" prescribed by Highways Department.

1.3.2.2 The Commissioner of Transport is vested with the authority for traffic signals and associated traffic signs and road markings and he has also delegated his powers to certain officers. Advice on delegated powers may be obtained from Transport Department headquarters.

1.3.2.3 All road traffic signal equipment, including portable signals has to be type approved by Transport Department before use. The Chief Engineer, Traffic Control Division is the Commissioner's Representative in this respect.

1.4 Definitions

A short glossary of terms used in this volume in alphabetical order is included in this Chapter.

1.4.1 All red period (See 2.3.2.6)

1.4.1.1 Period when red signals are shown to all approaches simultaneously, usually of short duration to allow vehicles to clear the intersection.

1.4.2 Audible signals (See 3.2.4.3)

1.4.2.1 Signals in the form of pulsed tones provided for the benefit of visually handicapped pedestrians.

1.4.3 Area Traffic Control (ATC) (See 6.3)

1.4.3.1 Also called Urban Traffic Control, is the centralized control of traffic signals on an area wide basis by means of computer.

1.4.4 Backing board (See 3.2.1.5)

1.4.4.1 Background board coloured black with a white border which is placed behind signal lanterns to make them more visible.

1.4.5 Cycle time (See 2.4.6)

1.4.5.1 A cycle is a complete series of stages during which all traffic movements are served in turn. The cycle time is the sum of the stage times.

1.4.6 Degree of saturation (See 2.4.8)

1.4.6.1 The degree of saturation at an approach is the ratio of the design flow to the actual capacity of a particular approach.

1.4.7 Delay (See 2.5)

1.4.7.1 Traffic delay is the lost time by vehicles due to traffic friction or control devices.

1.4.8 Demand (See 2.3.4.2)

1.4.8.1 A request for right of way for traffic on a phase which has no right of way when the request is made. The demands normally being stored in the controller and served in a pre-arranged order.

1.4.9 Demand - dependent stage/phase (See 2.3.4.5 (ii))

1.4.9.1 A demand-dependent stage or phase is one whose appearance is dependent on a demand from a vehicle detector or pedestrian push-button i.e.f it is skippable.

1.4.10 Detector (See 7.3.6)

1.4.10.1 It is a device to detect the presence or passage of a vehicle in the roadway.

1.4.11 Early cut-off Overlap (See 2.3.3.2 (ii)a)

1.4.11.1 Condition in which one or more traffic streams are permitted to move after the stoppage of one or more traffic streams which during the preceeding stage had been permitted to run with them.

1.4.12 Effective green period (See 2.4.1.4)

1.4.12.1 It is the period in the green and amber periods throughout which flow could take place at saturation flow levels.

1.4.13 Extension (See 2.3.4.3)

1.4.13.1 A request for the continuation of the green signal to a pre-determined maximum, made by a vehicle which when the request is made has the right of way.

1.4.14 Fixed-time traffic signals (See 5.3.1)

1.4.14.1 Traffic signaling equipment in which the stages in each cycle are pre-set to suit predictable traffic conditions.

1.4.15 Flow factor (See 2.4.5)

1.4.15.1 The flow factor of 'y' value of an approach is the ratio of the design flow to the saturation flow of the particular approach.

1.4.16 Green filter arrow (See 2.3.1.4 (ii) and 2.3.3.2 (ii)a)

1.4.16.1 It is an additional green arrow mounted by the side of the three light display to indicate early movement in the direction of the arrow and is terminated by a full green light signal. It is normally used for early discharge of left turners ahead of other movements at the same approach.

1.4.17 Green split (See 2.4.2.8 and 5.6.2)

1.4.17.1 It is the ratio of green time allocated to each of the conflicting phases in a signal sequence.

1.4.18 Indicative green arrow (See 2.3.1.4 (ii) and 2.3.3.2 (ii)a)

1.4.18.1 It is an additional green arrow mounted on the right of the three light display of the secondary signal only, to indicate the early cut-off of an opposing flow.

1.4.19 Intergreen period (See 2.3.2.6)

1.4.19.1 The period between the end of the green display on one stage and the start of the green display on the next stage is known as the intergreen period.

1.4.20 Late start overlap (See 2.3.3.2 (ii)b)

1.4.20.1 Condition in which one or more traffic streams are permitted to move before the start of one or more of the traffic streams which, during the subsequent stage are permitted to all run together.

1.4.21 Lost time (See 2.4.1.4 and 2.4.4)

1.4.21.1 Lost time in the green and amber periods is the wastage time during which no flow takes place. Total lost time per cycle is the summation of these lost times for the critical phases plus other lost times due to red-amber periods, all red periods and pedestrian green and flashing green times.

1.4.22 Maximum green running period (See 2.3.4.4)

1.4.22.1 The maximum time that a green signal can run after a demand has been made by traffic on another phase.

1.4.23 Minimum cycle time (See 2.4.6)

1.4.23.1 The minimum cycle time which is just sufficient to pass the traffic.

1.4.24 Minimum green running period (See 2.3.2.7)

1.4.24.1 The duration of the green signal following the extinction of a red/amber signal during which no change of signal lights can occur.

1.4.25 Offset (See 2.4.28 and 5.6.2)

1.4.25.1 The time difference or interval in seconds between the start of the green indication at one intersection as related to the start of the green interval at another intersection from a synchronized system time base.

1.4.26 Optimum cycle time (See 2.4.6)

1.4.26.1 The theoretical cycle time for attaining minimum vehicle delay.

1.4.27 Passenger car units (See 2.4.2.3)

1.4.27.1 Passenger car units for a given type of vehicle is expressed in terms of the number of moving passenger cars it is equivalent to, based on headway and delay characteristics.

1.4.28 P.C.U. factor (See 2.4.10.3)

1.4.28.1 An average p.c.u. value assumed for the convenience of signal calculation to convert unclassified vehicle counts from vehicles per hour units to p.c.u. per hour units.

1.4.29 Phase (See 2.3.2.4)

1.4.29.1 The sequence of conditions applied to one or more streams of traffic which during the cycle, receive identical signal light conditions. Two or more phases may overlap in time. A series of phases is usually arranged in a pre-determined order but some phases can be omitted if required by the situation.

1.4.30 Portable signals (See 7.3.5)

1.4.30.1 Post-mounted or tripod-mounted temporary signals used for 2 phase shuttle working at roadworks on roads other than limited access roads.

1.4.31 Practical cycle time (See 2.4.6)

1.4.31.1 It is the cycle time at which the traffic signal installation will be loaded to 90 per cent of its capacity.

1.4.32 Reserve Capacity (See 2.4.9)

1.4.32.1 A measure of the spare capacity of a signal controlled junction, expressed in terms of the percentage of the current total flow factor value (Y) which will be available for further increase of traffic flows.

1.4.33 Right of way (See 1.2.21)

1.4.33.1 The condition which applies when a green signal is displayed to traffic at the approach thereby permitting that traffic to proceed in its direction if the way is clear.

1.4.34 Saturation flow (See 2.4.1)

1.4.34.1 The maximum flow which could be obtained if 100 percent green time was awarded to a particular approach.

1.4.35 Semi-vehicle-actuated signals (See 2.3.4.5)

1.4.35.1 Modified vehicle-actuated signals whereby detectors are installed on the side roads only. Some semi-vehicle-actuated signals also operate one or more demand-dependent stages within a fixed cycle time.

1.4.36 Split movement control (See 2.3.3.2 (ii)c and 3.2.7)

1.4.36.1 A condition in which one or more of the vehicle movements at the same approach are separately controlled by different signal displays.

1.4.37 Stage (See 2.3.2.3)

1.4.37.1 A condition of the signal lights which permits a particular movement of traffic. Stages usually, but not always contain a green period. They are arranged to follow each other in a pre-determined order but stages can be skipped, if not demanded, to reduce delay.

1.4.38 Traffic signals (See 7.3.4)

1.4.38.1 A system of different coloured lights, including arrow-shaped lights, for controlling conflicting streams of traffic.

1.4.39 Traffic signal controller (See 7.3.2)

1.4.39.1 The electronic control equipment which activates the signal phases at an intersection.

1.4.40 Vehicle-actuated (V.A.) signals (See 2.3.4)

1.4.40.1 Traffic signaling equipment in which the duration of the green time and cycle length varies in relation to the traffic flow on its approaches.

1.4.41 Vehicle extension period (See 2.3.4.3)

1.4.41.1 A vehicle extension period is the additional duration of the green signal which is secured by the actuation of a detector.

1.4.42 Transyt (See 5.6)

1.4.42.1 It is the short form for 'Traffic Network Study Tool', a program developed by the U.K. Transport and Road Research Laboratory for optimizing signal timings.

2.1 References

(1) U.K. Road Research Technical Paper No. 56 - 'Traffic Signals' by Webster & Cobb

(2) Roads in Urban Areas - HMSO 1966, U.K.

(3) Papers of 'International Conference on Road Traffic Signalling 1982' - Institution of Electrical Engineers

(4) C.E. Manual Vol. 3, Chapter 2 - P.W.D., H.K. 1972

(5) Laws of Hong Kong Chapter 374 'Road Traffic Ordinance and Subsidiary Legislation'

(6) British Standard 505 'Specification for Road Traffic Signals', 1971

(7) The Traffic Signs Regulations and General Directions 1981/859 (HMSO)

(8) Road Note 34 'A Method of Measuring Saturation Flows at Traffic Signals'- RRL 1963

(9) Transport Planning & Design Manual Vol. 2 'Highway Design Characteristics'

(10) Transport Planning & Design Manual Vol. 3 'Traffic Signs and Road Markings'

(11) 'Critical Movement Analysis' - Interim Materials on Highway Capacity, Transportation Research Circular No. 212, T.R.B., Washington, D.C., U.S.A.

(12) Departmental Advice Note TA/16/81 'General Principles of Control by Traffic Signals' - DTp, U.K.

(13) Departmental Advice Note TA/18/81 'Junction Layout for Control by Traffic Signals' - DTp, U.K.

(14) U.K. Departmental Specification MCE108 'Siting of Inductive Loops for Vehicle Detecting Equipments at Permanent Road Traffic Signal Installation'

(15) TSC-005 'Specification for Traffic Signal Controller for Use in Hong Kong' - TCSD/TD

(16) TCS-021 'Specification for Road Traffic Signals' - TCSD, PWD

(17) Advisory Memorandum on Urban Traffic Engineering Techniques - HMSO 1966

(18) 'Saturation flows at traffic signal junctions : studies on test track and public roads' by R.M. Kimber, M.C. Semmens and P.J.H. Shewey - Proceedings of IEE Conference on Road Traffic Signalling IEE 1982

(19) New approximate expressions for delay, stop rate and queue length at isolated signals' - by R. Akcelik - Proceedings of IEE Conference on Road Traffic Signalling IEE 1982

(20) Research Report 67 'The Prediction of Saturation Flows for Road Junctions Controlled by Traffic Signals', TRRL, 1986

2.2 Junction Layout

2.2.1 General

2.2.1.1 The aim of any junction layout is to provide for the safe movement of traffic, both vehicular and pedestrian, without undue delay or congestion. Various alternative layouts may be adopted and the ultimate choice will be governed by such factors as the nature and volume of traffic using the junction, the availability of land and the overall cost.

2.2.1.2 The overall capacity of a road network is limited by the capacity of individual junctions in the road network. Failure to provide the correct type of layout at one particular junction may result in accidents, congestion and delay to an extent which may impair the efficiency of the road system over a wide area.

2.2.2 Basic Requirements

2.2.2.1 It is essential that approaching drivers are made fully conversant with the nature of the layout by adequate signing.

2.2.2.2 Supplementary carriageway markings or channelised island should be used to guide drivers to their desired paths.

2.2.2.3 Drivers should have sufficient advance warning to know exactly what direction to take at junction by the provision of appropriate traffic signs.

2.2.2.4 Driver should have a clear and unimpaired view of the traffic signals at the junction

2.2.3 Typical Layout (Diagram 2.2.3.1)

2.2.3.1 Setting of Signal Equipment

(i) The minimum requirement is one traffic signal installed 1 m from the stopline, on the nearside of the carriageway. If at all possible a second primary signal is installed if there is a central island or central divider, at the other end of and 1 m beyond the stopline. Minimum visibility distances from the primary signals as given in Table 2.2.3.1 should be satisfied for achieving a safe layout.

Table 2.2.3.1

Design Speed	Visibility Distances
50 km/h	70 m
60 km/h	90 m
70 km/h	120 m
80 km/h	145 m
85 km/h	160 m
100 km/h	215 m

(ii) A secondary signal is normally installed diagonally opposite the first primary signal. The secondary signal may be opposite the outer approach lane or within an arc of 30 degrees towards the offside of the centre lane extended into the junction from the stop line and should be as close as possible (illustrated by Diagram 2.2.3.2).

If long distances of the order of 60m or more are unavoidable, then additional signals may be necessary. For wide approaches exceeding four lanes additional secondary signals should also be considered. When the signal method of control contains a right turn overlap, extreme care should be used in the siting of secondary signals for the direction of flow which loses right of way first - the secondary signal in this case should not be places beyond the junction. (See 2.3.3.2 (ii)a)

(iii) The best available sight line needs to be provided when locating a signal controller, to assist an operator when signals are under manual control or being tested. In siting the controller due consideration should also be given to minimize visual intrusion and impediment to pedestrians which the controller could give rise to.

(iv) Footpaths in Hong Kong are narrow and lots of street furniture (including traffic signal post) are needed to be installed. It is therefore considered that in narrow footpaths or congested areas cranked post or cantilever installation would be more appropriate. In addition, the designer should also visit the site and determine the pole arrangement before commencement of civil works by either Highways Department, Territory Development Department, Civil Engineering Department, Developers and so on.

DIAGRAM 2.2.3.1: TYPICAL LAYOUT OF A SIGNAL - CONTROLLED JUNCTION

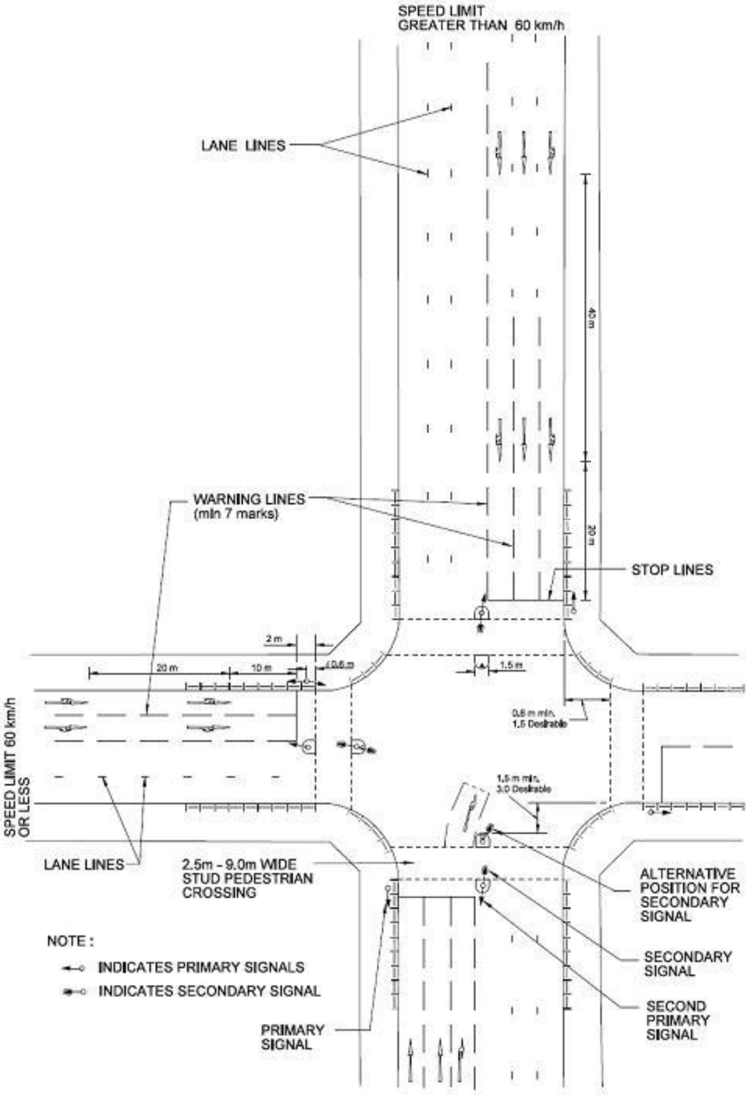
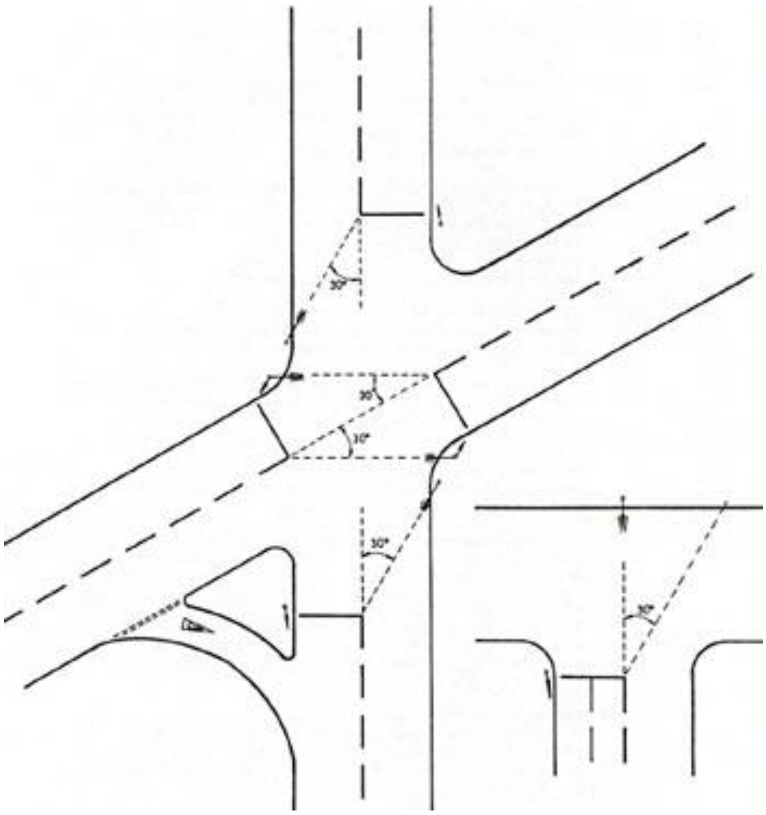


DIAGRAM 2.2.3.2: POSSIBLE LAYOUTS SHOWING POSITIONING OF SECONDARY SIGNALS



2.2.3.2 Carriageway Markings

(i) Typical carriageway markings are as shown on Diagram 2.2.3.1.

(ii) Carriageway markings within the intersection can assist driver in taking the correct path through a complicated intersection e.g. right turning boxes in junctions where there are opposing right-turners using the same phase and passing each other on their nearsides.

(iii) Arrows together with abbreviated destination marks painted on the carriageway well before the intersection can often by useful in advising drivers of the position on the road which they should adopt. In the queuing lanes arrows should be used to denote the lanes allocated exclusively to a particular movement of traffic.
It should be noted that lane markings are mandatory and care should therefore be taken in selecting the appropriate lane markings at a signalized junction.

(iv) Reference should be made to Transport Planning and Design Manual Vol. 3 for further details of Road Markings.

2.2.3.3 Traffic Signs

(i) Regulatory signs may be used in conjunction with signal displays to indicate movements which are the subject of a Traffic Regulation Order.

(ii) The following are the general signs used in the First Schedule of the Road Traffic (Traffic Control) Regulations :-

(a) Fig. 106 - Ahead Only

(b) Fig. 107 - Turn Left or Turn Right

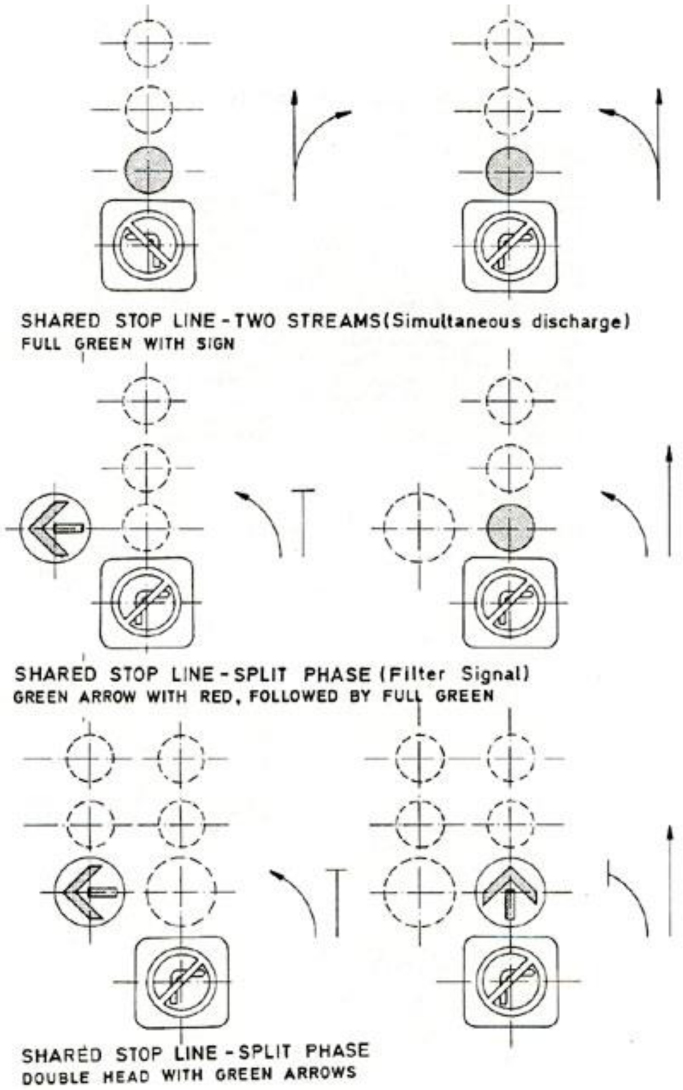
(c) Fig. 109 - Turn Left Ahead or Turn Right Ahead

(d) Fig. 112 - No Left Turn or No Right Turn

(e) Fig. 123 - No U Turns

(iii) These regulatory signs should be generally of light reflective material attached to signal posts. Care boxes in junctions where there are opposing right-turners using the same phase and passing each other on their nearsides.
Alternatively internally illuminated signs may be used in conjunction with the signal lantern set up as shown in Diagram 2.2.3.3. It is recommended that the use of internally illuminated signs with signals should be restricted to 'No left turn' and 'No right turn' and 'No U turn' only.

DIAGRAM 2.2.3.3.: TYPICAL SIGNAL DISPLAYS WITH INTERNALLY ILLUMINATED SIGNS



(iv) Reference should be made to Transport Planning and Design Manual Vol. 3 for further details of Traffic Signs.

2.2.3.4 Traffic Islands Islands of 1.5m minimum width placed at or near the center of the carriageway are mainly for the benefit of pedestrians. They enable pedestrians to cross the road in two halves and pedestrians may take refuge there while they are waiting for gaps to cross the road. Islands conveniently provide space for housing traffic signals posts and signals and may also be used for channelising traffic.

When islands are used the width remaining to traffic on either side of them must be checked for minimum provision allowance. Islands should contain bollards (illuminated at night) with arrows indicating 'keep left' or 'pass either side' as appropriate. Reference should be made to Transport Planning and Design Manual Vol. 2 Section 3.4.7 for further details of traffic islands.

2.2.3.5 Approach and Lanes

(i) Because signal control permits movement from any approach for only a proportion of the time it is sometimes necessary for the intersection approaches (where queuing takes place) to be wider than the roads which feed these approaches, in order to pass the required flows (illustrated by Diagram 2.2.3.4).

A preliminary assessment of the minimum approach widths needed for new or improved four leg junctions with two-phase control may be made by means of the following formula :-

$$\frac{W1}{W2} = \frac{g1}{g2} = \frac{D1}{D2} = \sqrt{\frac{q1}{q2}}$$

Where q1 and q2 are the larger flows in pcu's (see 2.4.2.3) during phases 1 and 2 respectively; g1 and g 2 are the effective green times; W1 and W2 are the corresponding widths; D1 and D2 are the corresponding lengths.

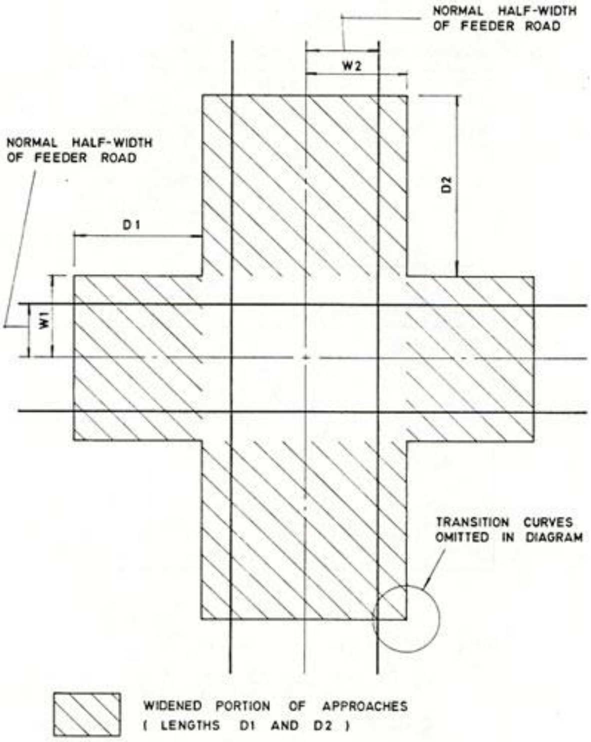
Similarly the rule can be extended to cover forks and other intersections controlled by 3-phase signals by making the ratio of the widths

$$W1: W2: W3 = \sqrt{q1}: \sqrt{q2: \sqrt{q3}}$$

and the green times and lengths widened have the same ratios.

DIAGRAM 2.2.3.4: SIMPLIFIED DIAGRAM OF WIDENED APPROACHES AT SIGNAL - CONTROLLED INTERSECTION

(NOT TO SCALE)



(ii) Approaches should be marked out in lanes. Lane widths at signaled junctions should normally be between 3 and 3.6m although 2.7m is acceptable in some instances where speeds are not high and the reduced width would enable an extra lane to be provided on multi-lane approaches. Table 2.2.3.2 gives the commonly used lane widths for various approaches.

Table 2.2.3.2
Lane Width

Approach Width in Metres	Width in Metres			
	Lane 1	Lane 2	Lane 3	Lane 4
3-5	3.50			
5.50	5.50 (2.75)	(2.75)		
6.00	3.00	3.00		
6.75	3.38	3.37		
7.00	3.65	3.35		
7.30	3.65	3.65		
8.00	4.00	4.00		
8.50	4.50 (3.00)	4.00 (2.75)	(2.75)	
9.00	3.00	3.00	3.00	
9.50	3.50	3.00	3.00	
10.00	3.40	3.30	3.30	
10.30	3.50	3.40	3.40	
11.00	3.70	3.65	3.65	
11.50	3.90 (3.10)	3.80 (2.80)	3.80 (2.80)	(2.80)
12.00	3.00	3.00	3.00	3.00

NOTES:
(1)Lane 1 is nearest the kerb.
(2)The figures in brackets may be used where the capacity of the approach may be appreciably increased by providing another lane for turning traffic. They may not, however, be suitable for areas where kerbside inter-ference, e.g. handcarts, is frequent.

(iii) On roads where land is available the saturation flow and capacity of an approach of a junction can be increased by widening out the road in the vicinity of the junction to provide more ahead lanes.

(iv) It is generally recommended to have the same number of lanes on the exit side of the intersection as there are straight ahead lanes (exclusively or partly used by straight-ahead) traffic on the approach side. It, however site conditions render it necessary to have fewer lanes on the exit side of the intersection, a distance of about 100m should be allowed for merging to take place (illustrated in Diagram 2.2.3.5).

2.2.3.6 Layout for Right-turning Vehicles

(i) The usual practice is for opposing right-turners to turn on the nearside of each other. With this arrangement locking of turning movement cannot occur but visibility is likely to be restricted. There can also be advantages in offsetting the center line or the central reserve so that more space is available to traffic approaching the intersection than to traffic leaving it in order to create a shielded right turn movement (See Diagram 2.2.3.6).

(ii) Diagram 2.2.3.7 shows the right turning lane separately signaled and segregated by a traffic island from the adjacent ahead-only traffic. This feature is strongly recommended on high speed roads and may be considered in places where right-turning movements on opposing arms are heavy i.e. exceeding 300 pcu/hr.

2.2.3.7 Pedestrian Crossings

(i) Pedestrian facilities should be provided wherever possible, to assist pedestrians to cross in safety, whilst exercising due care and attention, with minimum delay to traffic.

(ii) The layout shown in Diagram 2.2.3.1 includes pedestrian crossings marked out in studs. A pedestrian refuge is usually placed at or near the center of a single carriageway if the widths remaining to traffic in the two directions are sufficient.

(iii) Wherever possible, pedestrians signals should be used to give positive indications to pedestrians. (See Chapter 3 for further details)

(iv) At sites where pedestrian signals are not provided it is generally desirable that the vehicle signal indications should be visible to pedestrians as an aid in judging when to cross.

(v) It is sometimes desirable to restrict the crossing of pedestrians to certain approaches at an intersection and use guardrails to deter pedestrians from crossing at unmarked or unsuitable places (e.g. where filter movements or split movements may be moving unexpected by pedestrians).

DIAGRAM 2.2.3.5 : JUNCTION WITH FLARED APPROACHES

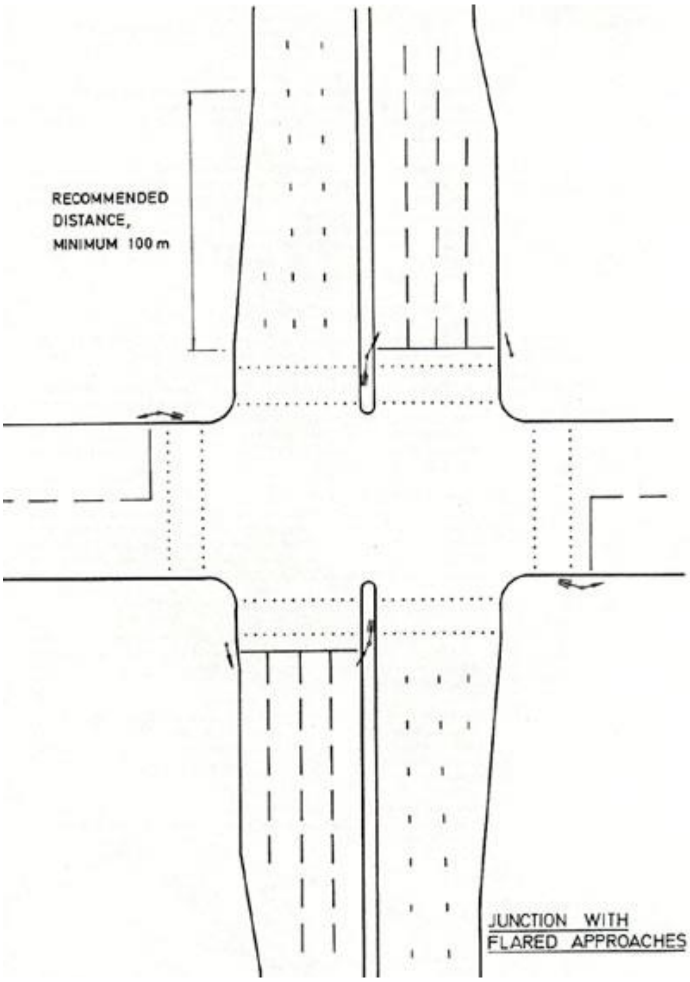


DIAGRAM 2.2.3.6: TYPICAL LAYOUT FOR RIGHT TURNING VEHICLES

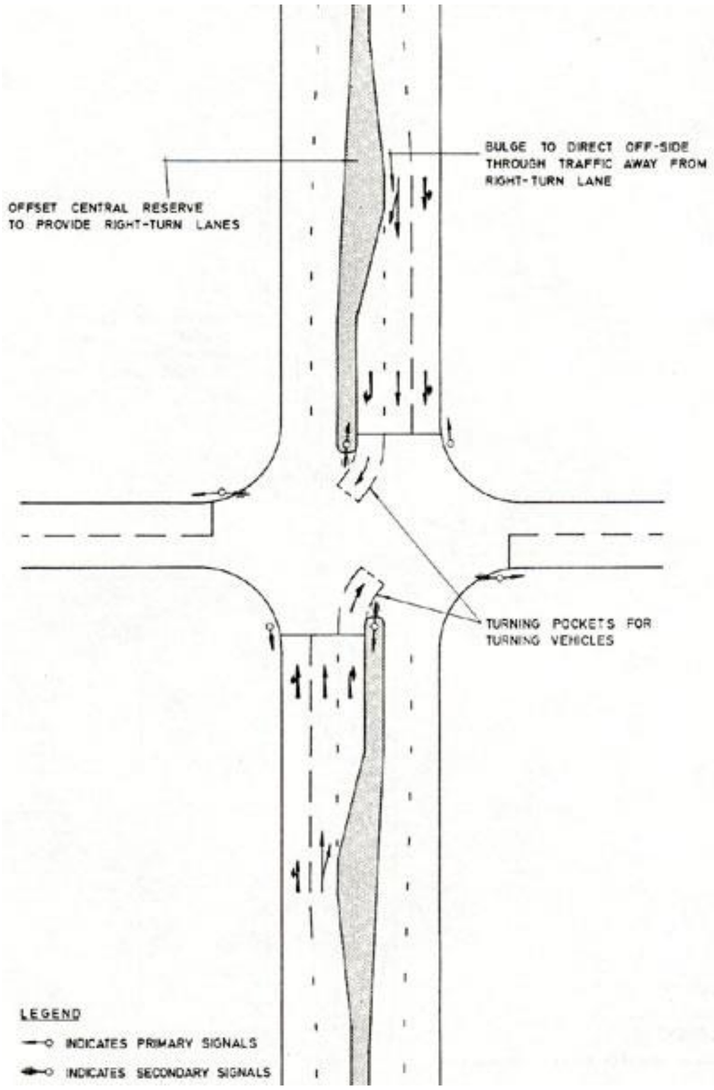
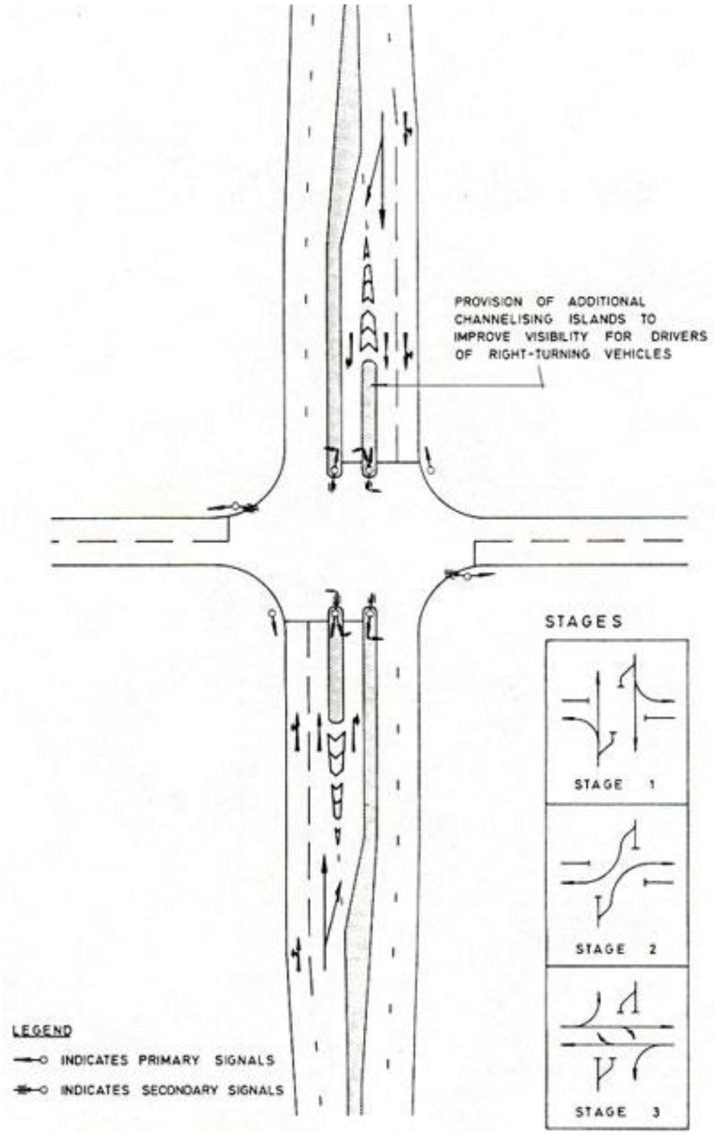


DIAGRAM 2.2.3.7 : ARRANGEMENTS FOR DEALING WITH HEAVY RIGHT-TURNING MOVEMENTS ON OPPOSING ARMS



2.3 Method of Signal Control

2.3.1 Signal Displays (See diagram 2.3.1.1 for typical Signal Display Arrangement)

2.3.1.1 Vehicular light signal displays shall comply with Road Traffic (Traffic Control) Regulations Part III and the Third Schedule. Each signal face shall unless otherwise specified contain three optical systems arranged vertically each having a nominal diameter of 200 mm. Where green arrow optical system is used as either green arrow or substitute green arrow, it should preferably be of 300 mm nominal diameter, although an alternative 200 mm one may also be used. The 200 mm green arrow should only be used when it is impossible to use the 300 mm lens. The height of the center of the green lens from the surface of the carriageway in its immediate vicinity shall be, where light signals are placed at the side of the carriageway, not less than 2.1 metres nor more than 3.5 metres and where light signals are placed over the carriageway not less than 5.3 metres nor more than 9 metres.

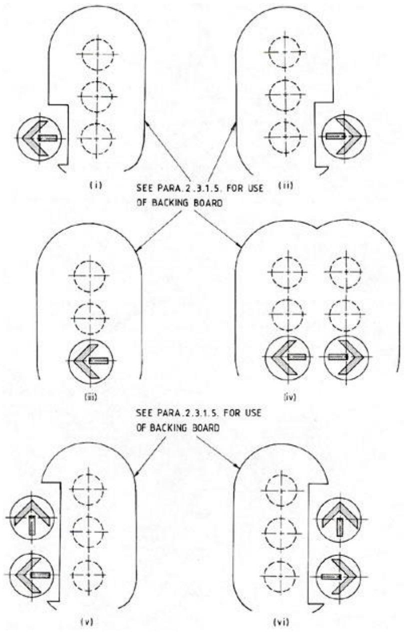
2.3.1.2 Traffic control is by means of red, amber and green signals, supplemented by additional green arrow light signals, tram signals, etc road markings and regulatory signs as necessary.

2.3.1.3 The instruction conveyed by each coloured light signal may be summarized as follows; -

(i) red light signal - indicates the prohibition that vehicular traffic shall not proceed beyond the stop line on the carriageway provided in conjunction with the light signals, or if the stop line is not for the time being visible or there is no stop line, beyond the light signals.

(ii) amber light signal - when shown alone, indicates the prohibition that vehicular traffic shall not proceed beyond the stop line, or if the stop line is not being visible at the time being or there is no stop line, beyond the signals, except in the case of any vehicle which when the light signal first appears is so close to the stop line or light signals that it cannot be safely stopped before passing the stop line or light signals.

DIAGRAM 2.3.1.1: TYPICAL SIGNAL DISPLAY ARRANGEMENT



(iii) amber and red light signals together - indicates an imminent change from red to green or from red to a green arrow but shall not alter the prohibition conveyed by the red light signal.

(iv) green light signal - indicates that vehicular traffic may pass the light signals and proceed straight on or to the left or to the right if it is safe to do so.

(v) green arrow signal - indicates that vehicular traffic may pass the light signals and may, subject to complying with any prescribed traffic sign or prescribed road marking, proceed only in the direction indicated by the arrow notwithstanding any other indication given by the light signals.

(vi) Tram signal light - A lens tram signal light which shows an amber "T" characteristic when illuminated is used in tram signals. The signal may be used in the form of a single signal aspect affixed to ordinary vehicular signals or may be substituted for the green lens in a standard 3-head vehicular signals which is the preferred arrangement. In the latter arrangement the illumination of the "T" will be preceded by a red and amber light signal.

(vii) LRT signal - this will be separately covered in a future chapter on LRT signals.

2.3.1.4 Green arrow light signal

(i) Substitute Green Arrow Signal
A green arrow light signal may be fixed in place of the full green light in a three light signal head. It may indicate a movement o the left, to the right or straight ahead only. An arrow indication in this position must always be preceded by a red and amber light signal. The direction of any green arrow may be varied to suit the particular circumstances providing that no arrow points below the horizontal position and that no adjacent arrows point within 45 degrees of one another.

(ii) Additional green arrows
on the left of the three light display indicating a movement to the left or straight ahead only

(a) on the left of the three light display indicating a movement to the left or straight ahead only

(b) on the right of the three light display to indicate a movement to the right or straight ahead only

(c) on the right of the these display, on the secondary signal only, to indicate the early cut-off of an opposing flow. (i.e. indicative green arrow see 2.3.3.2 (ii) a) These additional arrows may or may not be preceded by a red and amber display.

(iii) The green arrow signals should be terminated by a full green light signal or an amber light signal.

(iv) Typical arrangements of arrow signals are shown at Diagram 2.3.1.1.

(v) When green arrows are used drivers have come to expect an exclusive right of way and conflicting movements should therefore be avoided.

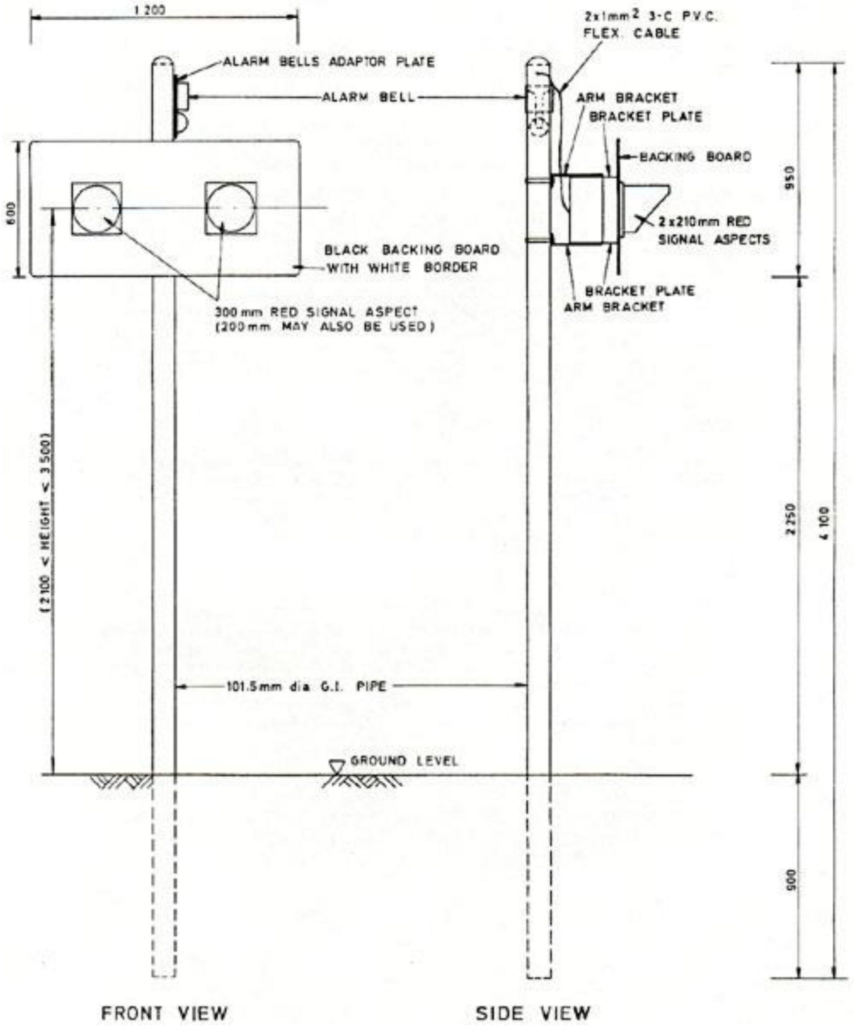
2.3.1.5 To enhance the visibility of signals, high intensity type of signals should be used and backing boards should also be used wherever space permits, especially where external illuminations such as advertising signs would undermine the conspicuity of the signal aspects, or where signals are facing in the east west direction and there is visibility problem caused by the low sun.

2.3.1.6 The lamp intensities shall be capable of an automatic reduction during the hours of darkness to suit the environment (Normally a dimming voltage of about 80% of normal voltage is used during period 7 pm to 5:30 am).

2.3.1.7 Wig-wag Signals

A wig-wag signal is a special type of signal used to facilitate fire appliances and ambulance vehicles exiting from Fire Stations and ambulance stations. As shown in Diagram 2.3.1.2 the typical installation consists of two 300 mm nominal diameter red signal aspects mounted horizontally with alarm bells on a signal post. Operated from the Fire Stations, the red signal aspects will be lit up in an alternate and intermittent manner, simultaneously with the alarm bells, to indicate the prohibition that other vehicular traffic shall not proceed beyond the signals. The signal set up is provided in pairs, one in the near side of the carriageway and the other in the central divider on the opposite side. An electrically operated lift-barrier at the emergency crossing in the central divider is also a common feature used together with wig-wag to allow emergency vehicles to gain access to the other carriageway.

DIGRAM 2.3.1.2: TYPICAL MOUNTING OF WIG-WAG SINGAL



2.3.2 **Signal Sequences (See Diagram 2.3.2.1**)

2.3.2.1 The signal sequence at junction traffic signals is red, red + amber and green, amber and red. The standard period during which an amber signal is displayed is fixed at three seconds and the red + amber signal at two seconds. The green signal and the red signal are shown for periods which are reasonably variable between a minimum and a preset maximum, but they can remain unchanged in one state during low traffic periods in vehicle-actuated signals.

2.3.2.2 There are two alternative concepts used in describing the control of traffic by means of light signals. One, known as stage control, is concerned with sequential steps in which the junction control is varied. The other, phase control, refers to the periods of time allocated to each traffic stream. Diagram 2.3.2.2 shows for a hypothetical junction the traffic movements permitted in each step of stage control. Superimposed on this figure is the designations of each phase if the junction is considered to be under phase control. Diagram 2.3.2.3 shows a time diagram for the same junction in which the period for which each phase has a green signal is indicated.

2.3.2.3 <u>Stage</u>
A stage is usually determined from the start of an amber period and always ends at the start of the following stage. Stages usually, but not always, contain a green period. They are arranged to follow each other in a predetermined order but stages can be omitted, if not demanded, to reduce needless delay.

2.3.2.4 Phase

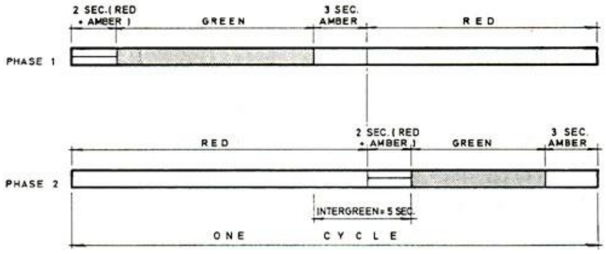
Where two or more streams are always signaled to proceed simultaneously then they may share the same phase. Two or more phases may overlap in time. A phase is usually considered as commencing at the start of the green display and ending at the start of the amber display to the traffic streams on the phase in question. A series of phases is usually arranged in a predetermined order but some phases may be omitted if not demanded and if it is safe to do so.

2.3.2.5 Cycle

A complete series of stages during which all traffic movements are served in turn is known as a cycle. The cycle time is the sum of each of the stage times.

DIAGRAM 2.3.2.1: TYPICAL SIGNAL SEQUENCE

SIGNAL SEQUENCE WITH SEQUENT AMBERS



SIGNAL SEQUENCE WITH ALL RED PERIOD

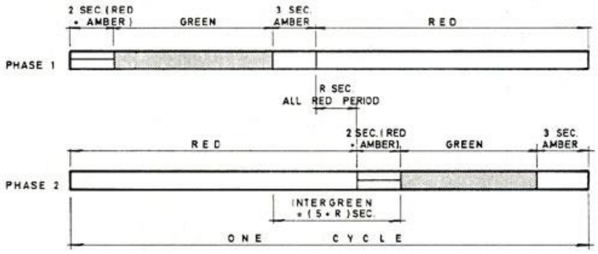


DIAGRAM 2.3.2.2

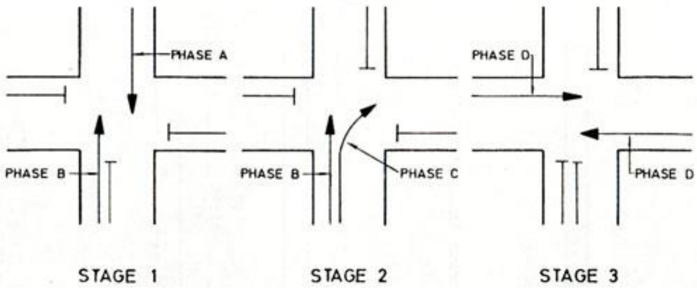
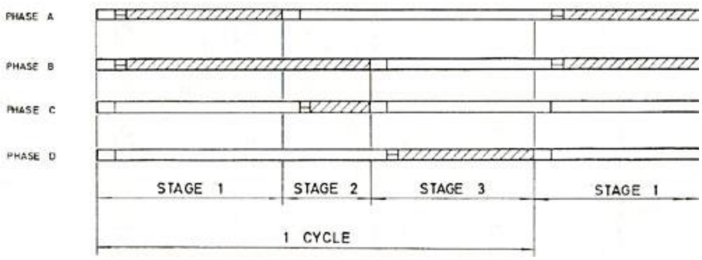


DIAGRAM 2.3.2.3



2.3.2.6 Intergreen Period

The period between the end of the green display on one stage and the start of the green display on the next stage is known as the intergreen period. It comprises an amber display, red + amber display and may also contain a period when the red signals are shown to all approaches simultaneously. With a five second intergreen the amber and red + amber periods occur consecutively. Any period over five seconds will include a period where red signals are shown to all approaches simultaneously. (i.e. an all red period) Safety requirements may dictate a longer period to be given in the following circumstances :-

(i) To allow vehicles to clear the intersection when the distance across the junction is excessive.

(ii) To improve safety on high speed roads.

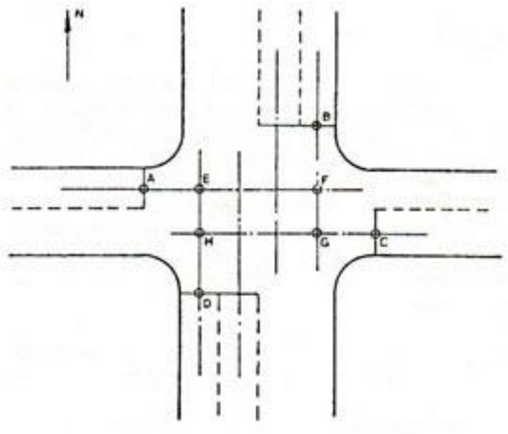
(iii) On roads where there are insufficient numbers of right-turning traffic to justify provision of a separate stage.

It should be noted that an intergreen period which is too short will be potentially dangerous but a period which is too long is equally unsatisfactory since it may lead to delay, frustration and disobedience. A guide to determining the length of the intergreen period is illustrated in Diagram 2.3.2.4. The vehicle which passes over the stop line at the start of the amber display must be clear of the potential collision point in relation to a vehicle starting at the onset of green of the following stage, when traveling at the normal speed for the intersection. The distances AF and BF should be determined and those distances which give the highest difference used. The recommended intergreen period can be determined from the table I. Where appreciable right turning traffic is the determining factor in choosing the intergreen period, the figures given in Table II should be used and attention is drawn to the note regarding pedestrians. On high speed roads, some controllers have the facility to extend the intergren period on a maximum green termination.

2.3.2.7 Minimum Green Periods

When a green signal is displayed to traffic it is desirable for that signal to be shown for an initial fixed period which cannot be overridden by any demands, whether emanating from vehicles, manual control devices or received remotely from central computers or linked controllers. Such a period is built into signal controllers and is known as the minimum green period. With the exception of the cases mentioned below, the shortest minimum green period normally used is five seconds but site conditions may require a longer period. Typically this will be where large numbers of heavy vehicles have difficulty in starting away from the stop line or the approach is on a steep gradient. Where pedestrians and traffic share the same stage the minimum green period may be governed by the time required by pedestrians to clear the crossing. On early cut off and late start stages the minimum may be as low as three seconds.

DIAGRAM 2.3.2.4: DETERMINATION OF INTERGREEN TIMES



Potential collision points

When East-West arms are losing right of way, if AF-BF is greater than CH-DH, then ‘x’ = AF-BF (or vice versa)

When North-South arms are losing right of way, if DE-AE is greater than BG-CG, then ‘x’ = DE-AE (or vice versa)

TABLE I AHEAD TRAFFIC

Distance ‘x’(metres)	9	10-18	19-27	28-36	37-46	47-54	55-64	65-74
Intergreen (seconds)	5	6	7	8	9	10	11	12

TABLE II TURNING TRAFFIC

Distance ‘x’(metres)	9	10-13	14-20	21-27	28-34	35-40	41-45	46-50
Intergreen (seconds)	5	6	7	8	9	10	11	12

Note : Where the following stage is a pedestrian stage, the distance “x” should be determined from the position of the pedestrian crossing. Where pedestrians are losing right of way, the start of the following stage should be delayed until the crossing area is clear.

2.3.3 Traffic Engineering at Signalled Junctions

2.3.3.1 Principles of Signal Control

(i) Conflicts are reduced at signal controlled junctions by holding certain traffic streams stationary while others are allowed to pass. To hold all streams and release each in turn will remove all conflicts but will not be satisfactory since delays to all traffic will be high and effective capacity of the junction will be low.

(ii) The art of designing an installation is in reducing the delay and increasing the capacity while still maintaining a high degree of safety.

(iii) Reduction in total delay and improvement in capacity can achieved by: -

(a) Utilising the lowest practicable number of stages in any signal cycle.

(b) Ensuring that each traffic approach is capable of carrying the maximum predicted traffic flow for that approach.

(c) Ensuring that the time allotted to each stage is appropriate to actual traffic flow.

(d) Matching if possible, ‘y’ values for flows operating within the same phrase. (See 2.4.5)

(e) If appropriate, co-ordinating the control of adjacent junctions to maintain traffic platoons. The aim is always to keep as much traffic moving as practicable at the same time.

(iv) The techniques which may be employed, singly or in combination, can be summarized as:-

(a) Where the degree of conflict is acceptable and movements can be executed safely with the exercise of due care, a conflicting move may be accepted (e.g. a right turn on full green).

(b) Restriction of movements, e.g. banned right turns, where conflicting manoeuvres are forbidden.

(c) Separation of traffic streams which conflict, assigning them to different stages.

2.3.3.2 The following are examples chosen to illustrate the above principles.

(i) Four Arms Junction With Two Stages

(a) With all movements permitted

This is a very common junction and two-stage operation forms the basis of signalling techniques. Traffic on opposite arms flow simultaneously while those on the other two arms are stopped.

Each arm may have one or more lanes approach but the right turning traffic may impede vehicles wishing to proceed over the junction if the road width is restricted.

This is an example of a shared stop line with simultaneous discharge and the three light display with a full green light signal is used.

(b) With Right turn traffic prohibited

Where there is a relatively minor right turn flow the capacity of the junction is reduced by the road space occupied by such traffic waiting to turn right and by the time which has to be provided to this movement in the cycle. If the right turn manoeuvre is removed then reduced delay and improved capacity can be expected. Where one exists, an alternative route can be indicated to traffic before the junction is reached. Usually motorists can turn left before the junction, make two right turns to appear at the junction on the left hand arm (known as a ‘g’ turn).

Alternatively motorists can pass through the junction, turn left and make two further left turns to appear at the junction on the left arm (known as a ‘q’ turn). In the latter case the diverted traffic will pass through the junction twice and may adversely affect the expected improvements.

The staging can be applied to a single lane approach and the signal display is a three light with a full green light signal and a ‘No Right Turn’ sign mounted on the signal head.

(ii) Four Arms Junction With Three Stages

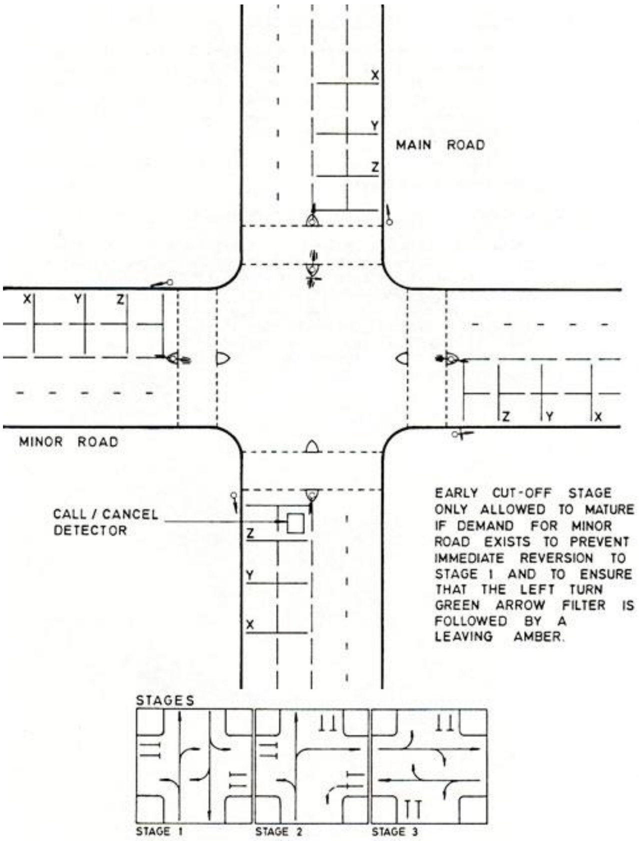
(a) Early Cut Off For Right Turn Movements(See Diagram 2.3.1.1)

Where heavy right turn traffic exists on one approach the stage sequence can permit opposing flows to proceed together on the first stage and only one flow to proceed on the next. This will permit the right turn queue to discharge without conflict and to allow any traffic passing over the junction, which has been delayed by the right turn traffic, to clear the approach.

The signal display on the arm which loses right of way at the end of the first stage should be sited with care and in particular the secondary signal should not be placed beyond the junction. The arm which is permitted to flow over to stages will have a three light primary and the secondary, which is always placed beyond the junctions, and should have a right turn arrow in addition to the full green signal illuminated on the second stage when the opposing traffic has been signaled to stop. Normally this right turn green arrow is provided on the secondary signal only, on the right of the signal display. This arrangement is known as an indicative green arrow.

If traffic demand is sufficient, it is possible to show an additional left turn green arrow (i.e. green filter arrow) to the side road traffic on stage 2. Care must be taken to avoid danger to pedestrians from the left turn traffic. Such traffic must be provided with at least one independent lane. The display will have a three light head with the additional green arrow on the primary. During the second stage a red signal will be displayed together with the green arrow. The green arrow will be extinguished when the full green signal appears at the start of the third stage.

DIAGRAM 2.3.3.1: EARLY CUT-OFF STAGE



(b) Late Start For Right Turn Movements

An alternative way of dealing with right turning traffic is to delay the start of the opposing traffic by a few seconds. This method causes difficulty at the start of the following stage if the right turn flow is heavy and the opposing traffic cannot establish precedence. For this reason a late start stage is not recommended.

The signal arrangement is the three light display without any additional green arrows.

(c) Separate Stages For Right Turn Movements(Exclusive Stages)

Where both right turn movements are heavy a better solution can be to hold both right turn flows against a red signal while the ahead and left turn traffics flow unhindered. All traffic is then stopped before the right turn traffic on both approaches is released simultaneously on the same state. It is usual to separate the right turn traffic into exclusive lanes by traffic islands and use separate signal displays for each approach. This method should be employed on high speed roads. (See Diagram 2.2.3.7)

2.3.4 Vehicle-actuated (V.A.) Traffic Signals

2.3.4.1 With vehicle – actuated (VA) signals the duration of the green periods and the cycle time will vary in relation to the traffic flow into and through the controlled area. A vehicle-actuated signal responds to demands recorded for the various directions of flow on street. Once a green has been given to a particular direction of flow, the length of green for that direction will be extended until all the traffic has passed through the junction, or the maximum green times for that direction has timed out. Vehicle actuated signals will be most appropriate for isolated junctions where co-ordination with other signals is not important and for locations with fluctuating light or medium traffic flows. The various facts of vehicle actuated operation are discussed below.

2.3.4.2 Stage Demands

On the approach to a red signal, a green signal will be demanded on the arrival of a vehicle on that approach. This demand is stored in the controller which will serve stages in cyclic order omitting any stages for which no demand has been received. Where it is essential that one stage must always follow another, the appearance of the first stage will automatically insert a demand for the second stage. When a stage loses right of way on a maximum change, then a demand is inserted for a reversion to that stage after other demands have been met.

2.3.4.3 Stage Extension

When a green signal is displayed, the period for which it is displayed may be extended by vehicles detected moving towards the signal. On expiry of the last extension and no more vehicles are detected, the signal controller will answer a demand of another stage at the end of the minimum green period (See 2.3.2.7) or immediately if the present minimum period has expired. If vehicles continue to extend the green period and a demand exists for another stage, the green signal will be terminated on expiry of a preset maximum period after the demand has been received.

The purpose of the extension, or the sum of several extensions, is to permit vehicle to pass the stop line before expiry of the green period.

The extension period required for each of the three vehicle detector loops is usually 1.5 seconds based on a minimum approach speed of 20 mph. A steep approach will require a longer extension. However if the extensions are set too long, the response of the vehicle actuation will be sluggish under normal traffic conditions and thus results in loss of capacity.

2.3.4.4 Pre-set Maximum Period

To prevent vehicles on a halted phase from waiting indefinitely because of a continuous stream of traffic on the running phase a maximum period is timed off, after which the signals change right-of-way irrespective of the state of the vehicle extension period. Usually the maximum period starts at the beginning of the green period if vehicles are waiting on any halted phase, or at the time the first vehicle passes over the detector on any halted phase, whichever is the later. Thus the period may be regarded as a maximum waiting period rather than a maximum green period. With a change of right of way owing to the expiry of the maximum period, provision is made for the right-of-way to return to the original road as soon as traffic conditions on the other roads permit (i.e. maximum reversion).

If the traffic is fairly heavy on all phases the green periods may run successively to maximum, giving in effect fixed-time operation. Many signals in large cities operate in this manner during peak hours. The sum of the maximum green periods for each stage, plus the sum of the intergreen periods between each stage in cyclic order will given the maximum cycle time for the signal. It is usually not recommended that cycle times in excess of 120 seconds are used.

Some modern microprocessor controllers incorporate complex algorithms which attempt to reconcile heavy and continuing demand on the main route with smaller demands on the side roads. In these controllers the maximum green period varies in accordance with the traffic conditions.

2.3.4.5 Semi-vehicle-actuated signals

(i) With some semi-vehicle-actuated signals, detectors are installed on the sides roads only i.e. not all approaches and the right-of-way normally rests with the main road, being transferred immediately or at the end of a pre-set period to the side road when a vehicle passes over the side road detector. The green period on the side road can be extended in the normal way by successive demands up to a pre-set maximum. After right-of-way has been returned to the main road, it cannot be taken away from the main road until the pre-set period has expired.

(ii) Another modified form of V.A. signals is to operate one or more demand-dependent stages within a fixed cycle time. These demand dependent stages which may consist of vehicle phases (such as right turn traffic, minor flows) or pedestrian phases may be skipped or extended in accordance with the prevailing situation detected. The advantage of this type of signals is that a fixed cycle time can be maintained for linking with surrounding controllers and some limited V.A. facilities are also available to cope with traffic conditions.

2.3.4.6 Vehicle Detection for V.A. Signals

(i) Primitive pneumatic detectors have been superseded by the more popular inductive loop detectors. Micro-wave detectors are also used but because of problems inherent with the method of detection such as long detection distances, inability to detect stationary vehicles, shielding of detection by other vehicles etc., its use is largely on an experimental basis and usually limited to portable signals and semi-VA signals.

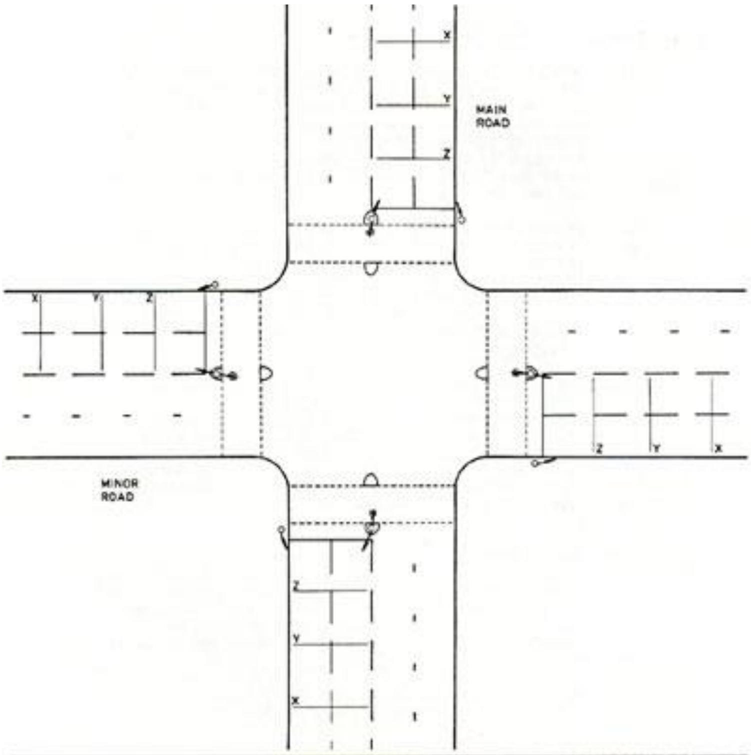
(ii) In inductive loop detectors, wire loops carrying a small electric current are buried in the carriageway. Vehicles passing over the loop cause a change in the inductance of the loop and a count is registered in a detector unit. Provided that the loops detectors are properly installed and maintained they will work reliably and offer very efficient vehicle detection because of their more precise indication of vehicle presence.

(iii) The normal standard method of detection at signals is the ‘system D’ arrangement in which buried loops in the road surface are provided at either two or there points on each approach to the signals. They are located as shown in Table 2.3.4.1. The loops are designated X, Y, and Z, the X loops being that farthest from the intersection and the Z loop the nearest to the intersection. Demands will normally originate from the X detector whereas extensions are from the Y and Z detectors.

(iv) Detection of turning traffic is normally by means of a loop provided within the junction in such a position that only vehicles entering the junction from one approach to make a right turning movement shall normally cross the loop. The output from the detector unit may be arranged to demand/hold/extend and early cut-off stage for the turning movement.

(v) Reference should be made to DTP Specification MCE 018E for full details of sitting of Inductive loops.

TABLE 2.3.4.1
SITING OF LOOPS FOR SYSTEM 'D' DETECTION



DISTANCE FROM STOP-LINE TO X LOOP	EFFECTIVE EXTENSION DISTANCE	NUMBER OF LOOPS	DISTANCE FROM STOP-LINE TO Y LOOP	DISTANCE FROM STOP-LINE TO Z LOOP
39m	42m	3	25m	12m
30m	33m	3	18m	7m
18m	21m	2	-	6m

2.4 Signal Calculations

2.4.1 Signal Calculation Concepts

2.4.1.1 The amount of traffic that can be pass through a signal-controlled intersection from a given approach i.e. the capacity, will depend on the green time available to the traffic and the maximum flow of vehicles pass the stopline during the green period.

2.4.1.2 The discharge of vehicles from a queue may be illustrated by Diagram 2.4.1.1. When the green period commences, vehicles take some time to start and to accelerate to normal running speed, but after a few seconds, the queue discharges at a more or less constant rate which is termed the 'saturation flow'.

2.4.1.3 The saturation flow may be defined as the maximum flow which can be obtained if there is a continuous queue of vehicles and they were given 100 percent green time.

2.4.1.4 For the convenience of signal calculation, the green and amber periods are replaced by an 'effective green' period (g), throughout which flow is assumed to take place at the saturation rate, and a 'lost' time (*l*) during which no flow takes place.

If

k = combined green and amber period
g = effective green period
G = actual green time
l = lost time for a single phase
S = Saturation flow
C = Cycle time

Then capacity Q from an approach may be expressed as

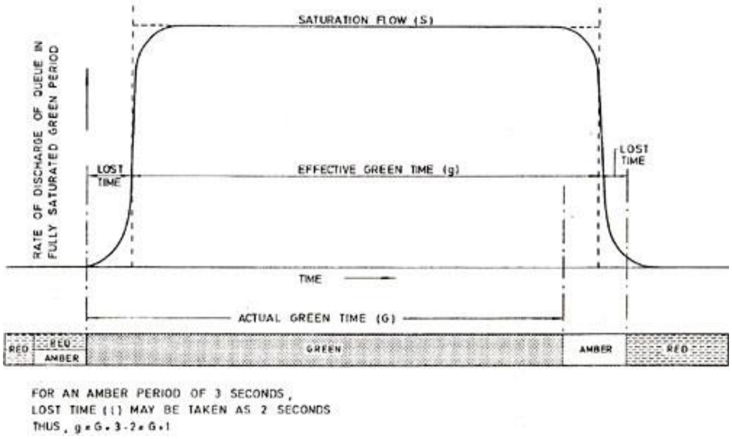
$Q = \frac{gS}{C}$ where $g = k - l$

2.4.1.5 With amber period of 3 sec, *l* may be taken as 2 sec

Thus

$$k = G + 3$$
$$g = G + 3 - 2$$
$$g = G + 1$$

<u>DIAGRAM 2.4.1.1: VARIATION WITH TIME OF DISCHARGE RATE OF QUEUE IN A FULLY SATURATED GREEN PERIOD</u>



2.4.2 Estimation of Saturation Flow

2.4.2.1 Exclusive Straight-ahead Lanes

TRRL RR 67 (Ref. 20) suggested that :-

(i) The saturation flow per lane (S) expressed in terms of passenger car units per hour (pcu/h), with no turning traffic may be given by

(ii) S = 1940+100(W-3.25) for nearside lane or single lane entries
S = 2080+100(W-3.25) for non-nearside lanes
Where W is the lane width at entry in metres.

(iii) Signal approaches are sometimes locally widened to provide an additional lane near the junction.
When the additional lane at the stopline is available for a distance back from the stopline at least sufficient to contain one full cycle capacity of traffic, the above methods of estimation of saturation flow apply. If the signal approach is only widened very close to the stopline, then the above formulae may be a considerable overestimate capacity. A more realistic approach capacity should be deduced from entry lanes before widening plus an allowance for extra vehicles stored every cycle in the additional lane provided near the intersection. In these circumstances, on sit estimation of saturation flow will be necessary.
Reference may be made to Table 2.2.3.2 in Section 2.2.3.5 for general guidance on marking of lanes at approaches.

2.4.2.2 Effect of Gradients

(i) For each 1 per cent of uphill gradient the saturation flow (S) should be decreased by 42 pcu/h. The gradient should be taken on the average slope between the stopline and a point on the approach 60m before it.

(ii) Downhill gradients have no effect on the saturation flow.

2.4.2.3 Effect of Composition

The effect of different types of vehicle on the saturation flow at traffic signals is given by the following p.c.u. equivalents :-
(Also in T.P.D.M. Vol. 2 section 2.3)

Private Car, Taxi, Light Goods Vehicle	1.0
Motor Cycle and Motor Scooter	0.4
Medium or Heavy Goods Vehicles	1.75
Through Bus (see 2.4.2.6 (iii)) or coach	2.0
Pedal Cycle	0.2
Tram	3.5 – 5.0
Public Light Bus	1.5

2.4.2.4 Exclusive Turning Lane

$$S_R = \frac{S}{\left(1 + \frac{1.5}{r}\right)}$$ for unopposing turning traffic

$$S_R = \frac{(S-230)}{\left(1 + \frac{1.5}{r}\right)}$$ for opposed turning traffic

where r = radius of curvature of vehicle paths (m)

2.4.2.5 Lanes with Mixed Traffic

$$S_M = \frac{S}{\left(1 + \frac{1.5f}{r}\right)}$$ for unopposing turning traffic

$$S_M = \frac{(S-230)}{\left(1 + \frac{1.5f}{r}\right)}$$ for opposed turning traffic

where f = proportion of turning vehicles in a lane.

2.4.2.6 Effect of Waiting Vehicles & Bus Stops

(i) Reduction in saturation flow caused by parked vehicles in the vicinity of the approach is equivalent to a loss of carriageway width at the stopline as follows :-loss in c/w width $= 1.68 - \frac{0.9(z-7.62)}{G}$ (metres)
where z (≥7.62) is the clear distance of the nearest parked vehicle from the stopline in metres. G is green time in seconds.
If the whole expression becomes negative the effective loss should be taken to be zero. The effective loss may be increased by 50 per cent for a parked medium or heavy goods vehicle.

(ii) No stopping restriction before and beyond a junction may be considered where junction capacity is tight or where the parking/stopping activities are adversely affecting the effective operation of the junction signals.

(iii) The actual effects of a stopping bus are complex and will vary considerably depending on bus stop location, bus dwell time, parking activity, lane configuration and traffic volume. Until further research is accomplished, it is recommended that a p.c.u. value of 5.0 may be taken for stopping buses that operate and stop within 200 m of the signals.

Designers should also refer to Section 2.4 of T.P.D.M. Vol. 9 for detailed guidelines on siting of bus tops.

2.4.3 Measurement of Saturation Flows

2.4.3.1 It is not always practicable to conduct direct measurements of saturation flows e.g. because of resources constraints or when designing new intersections. Direct measurements are however definitely worthwhile for critical intersections working near saturation as the direct measurements will provide more accurate flows for detailed signal plan preparation or junction capacity analysis.

2.4.3.2 Formal measurements of saturation flow shall be conducted in accordance with U.K. Road Note No. 34.

2.4.3.3 Less formal measurements may be made for approaches where there are existing signals or where the junction is police controlled. It is usually satisfactory to carry out such counts commencing, say, 5 seconds after the traffic has started so as to eliminate starting delays and continuing the count until traffic begins to “tail off”. A reasonably consistent value of saturation flow could usually be obtained after several counts.

2.4.4 Total Lost Time per Cycle (L)

2.4.4.1 With 2 sec red/amber (starting amber)
3 sec amber (leaving amber)
I = 5 + R (see diag. 2.3.2.1)
where R = all red period
I = intergreen perod
If lost time for a single phase in the green and amber period (Z) = 2 sec
loss time per phase change = (I – 3) + z

Total lost time per cycle
L = (I – 1)
or = (R + 4)

2.4.4.2 For a full pedestrian stage during which all traffic is stopped, the pedestrian green and flashing green periods should be considered as additional all red periods (i.e. additional lost times) in signal calculations.

2.4.5 Flow Factors

2.4.5.1 Flow factor 'y' for each phase is given by

$$y = \frac{design\ flow\ for\ an\ approach\ (q)}{saturation\ flow\ for\ an\ approach\ (S)}$$

2.4.5.2 Where more than one approach is operating during a phase the maximum 'y' should be used. Where an early cut-off or late start is to be used in connection with a right turn the 'y' values for the right turn and for the approach with shortened time should be added together to represent one phase unless the straight on traffic on the same approach as the right turn has a higher value, when this latter figure should be taken.

2.4.5.3 The summation of these higher y values for the phases is the 'Y' value which is in fact a measure of the congestion and which will be used for calculating the optimum signal setting.

$$Y = \sum y$$

2.4.6 Cycle Times (C_o, C_m and C_p)

2.4.6.1 For an isolated signal installation, where the mean traffic level is constant and where vehicle arrivals are at random, the U.K. Transport and Road Research Laboratory (TRRL) has shown that the optimum cycle time for minimum delay is given by :-

$$C_O = \frac{1.5L+5}{1-Y} \text{ secs}$$

2.4.6.2 Also and the cycle time which is just sufficient to pass the traffic is given by :-

$$C_m = \frac{L}{1-Y}$$

2.4.6.3 This is the minimum possible cycle time which may be associated with excessively long delays. In designing linked signals a cycle time should be chosen which provides a margin over this minimum possible cycle time for the key intersection. In practice it will be generally appropriate to choose a practical cycle time, such that the installation is then loaded to 90 per cent of its capacity

$$C_p = \frac{0.9L}{0.9-Y}$$

2.4.6.4 In locations where pedestrian crossing volumes are high it will be desirable to use as short a cycle time as practicable to minimize delays imposed on pedestrians. It will be of good practice to limit cycle times to below 90 seconds and where this is not intended due to capacity reasons, careful checking of site conditions should be made to ensure that pedestrians are not being endangered. In designing for new junctions the maximum operating cycle time should be limited to 90 seconds.

2.4.7 Green Times

2.4.7.1 Signal setting for the effective green periods(g) should be in proportion to the y values on each approach, with an allowance for lost time

$\frac{g1}{g2} = \frac{y1}{y2}$ etc.

and $g = \frac{y(c-L)}{Y}$

$G = g - 1$

i.e. $g_1 = \frac{y_1(c-L)}{Y}$

$g_2 = \frac{y_2(c-L)}{Y}$ etc.

where

g = effective green period
y = flow facto
G = actual green period
c = cycle time
L = total lost time
Y = summation of flow factors
c- L = total effective green time

2.4.7.2 Care should be taken in performing the calculation if parallel pedestrian facilities are included in the junction method of control. If they are included, the minimum green times for the minor movements could well be dictated by parallel pedestrian crossing green times. This could well considerably distort the green split calculation.

2.4.8 Degree of Saturation

2.4.8.1 Degree of saturation (X) for individual approaches may also be expressed as :-

$$X = \frac{q}{Q}$$

where

q = design flow
Q = capacity of approach
c = cycle time
S = saturation flow

2.4.8.2 The degree of saturation should be the same for all the predominant arms of an intersection when the signal timings are optimum and is given by

$$X_o = \frac{2Y}{1 + Y}$$

2.4.9 Junction capacity Analysis

2.4.9.1 The ultimate capacity of an intersection may be defined as the maximum flow which can pass through the intersection with the same relative flows on the various approaches and with the existing proportions of turning traffic.

2.4.9.2 Generally capacity will increase as the cycle time increases, since the ratio of lost time to useful time decreases (the effect becomes negligible when the cycle is very long). In practice, for maximum reserve capacity assessment, a maximum cycle time of 120 seconds should be adopted. However it should be noted that for new installations, the maximum operating cycle time should be limited to 90 seconds (See 2.4.6)

2.4.9.3 If the capacity were taken as the flow which could just be accommodated by such a cycle the delays would normally be excessively high. A practical capacity of 90 per center of this maximum possible flow, which produces generally acceptable delays, is recommended.

2.4.9.4 To calculate reserve capacity at 120 sec cycle time

The cycle time which is just long enough to pass all the traffic, is given by

$$C_m = \frac{L}{1-Y}$$

Similarly the maximum Y which could be accommodated by a fixed cycle time c is given by

$$Y_{max} = 1 - \frac{L}{c}$$

For $C_m = 120$ sec

$$Y_{max} = 1 - \frac{L}{120}$$

For practical purposes, the ultimate Y value, Yult, is taken as 90 per cent of Ymax.

$$Yult = 0.9 - 0.0075L$$

The percentage of ultimate reserve capacity is then given by

R.C.(ult) = $\frac{Yult-Y}{Y} * 100\%$

2.4.9.5 To calculate Reserve Capacity at any cycle time c, R.C.(c)

(i) Sometimes it may be of interest to know the reserve capacity of a junction operating in the current cycle time i.e. R.C.(c)

if c = current cycle time

$$Y_{max} = 1 - \frac{L}{c}$$

and assuming a practical Y value of 0.9 Ymax

R.C.(c) = $\frac{0.9Y_{max}Y}{Y} * 100\%$

(ii) Care should be taken in performing this calculation if parallel pedestrian facilities are included in the method of control. For minor movements particularly, the minimum green time for the approach can well be dictated by the parallel pedestrian crossing green times. This could well considerably distort the R.C. calculation.

2.4.10 Traffic Signal Calculation Sheet (Diagram 2.4.10.1)

2.4.10.1 A 'Traffic Signal Calculation sheet' has been devised for the convenience of performing signal computation. Most of the useful formula have been incorporated so that a designer may perform signal calculations without referring back to the Manual. The designer may also use his own discretion in using the worksheet in part only, or modifying it to suit his particular purpose.

2.4.10.2 Brief notes on the columns and rows :-

Col 1	width of approach or lane width applicable for movement
Col 2	corresponding saturation flow
Col 3	site factors for making adjustment for site factors
Col 4	revised saturation flow after adjusting for site factors
Col 5	design flow
Col 6	revised design flow after adjusting for left turners/turners/right turners
Col 7	flow factors
Col 8	greater y value
Col 9	Summation of the greater y-value
Col 10	cycle lost time
Row 11	optimum cycle time
Row 12	minimum cycle time
Row 13	practical Y value for the ultimate situation i.e. 120 sec cycle time
Row 14	reserve junction capacity for the ultimate situation i.e. 120 sec cycle time
Row 15	practical cycle time
Row/Col 16	selected cycle time
Row 17	maximum Y value for the selected cycle time
Row 18	reserve capacity of junction operating at the selected cycle time
Row 19	effective green time
Row 20	degree of saturation for movement

2.4.10.3 <u>Stage/Phase Sequence Diagram</u>
The method of signal control should be fully illustrated by the Stage/Phase Sequence diagram, complete with the following details :-

(i) Diagramatic junction layout

(ii) Signals operation sequence

(iii) Design flows in p.c.u./hr.

(iv) P.c.u. factor, if necessary, for converting unclassified counts from veh/hr to p.c.u./hr.

(v) Intergreen periods required

(vi) Actual green times (G = g - 1)

2.4.10.4 Traffic signal design calculation should be treated as a starting point only. In practice further improvements can often be made after installation by incremental adjustments following on-site observations.

Location :
Time of day :
Sheet No. :
Date :

TRAFFIC SIGNAL CALCULATION SHEET
DIAGRAM 2.4.10.1 (T.P.D.M. V. 4.2)

Division :	
Designed by:	
Checked by :	

Movement/Phase	(1) Width m	(2) Sat Flow pcu/h	(3) Site factors	(4) Rev Sat Flow pcu/h	(5) Flow pcu/h	(6) Rev Flow pcu/h	(7) $y=\frac{(6)}{(4)}$	(8) greater y	(9) $Y=\Sigma y$	(10) $L = \Sigma(I-1)$ sec	(16) for c sec	(19) g $\frac{y}{Y}(c-L)$	(20) Deg. sat. $\frac{(6)}{(4)}\times\frac{(16)}{(19)}$

P.C.U. factor =	
(11) $c_o = \frac{1.5L + 5}{1 - Y}$	
(12) $c_m = \frac{L}{1 - Y}$	
(13) $Y_{ult} = 0.9 - 0.0075L$	
(14) R.C.(ult) $= \frac{Y_{ult} - Y}{Y} \times 100\%$	
(15) $c_p = \frac{0.9L}{0.9-Y}$	
(16) assigned c	
(17) $Y_{max} = 1 - \frac{L}{c}$	
(18) R.C.(c) $= \frac{0.9Y_{max} - Y}{Y} \times 100\%$	

STAGE/PHASE SEQUENCE DIAGRAM (with flows in p.c.u.)

I= G=	I= G=	I= G=	I= G=	I= G=

SATURATION FLOW (p.c.u./h) : (i) When width $W < 5.45$m

WIDTH(W) METRES	3.03	3.33	3.63	3.94	4.24	4.54	4.85	5.15
SATURATION FLOW p.c.u./h	1850	1875	1900	1950	2075	2250	2475	2700

(ii) When width $W > 5.45$m
SAT FLOW = 525W or S_i, whichever the greater,
(p.c.u./h) where S_i = 1790 p.c.u. or 1690 p.c.u. (kerb-side lane)

Site Factors : adjust 3% for each 1% gradient
adjust : 85% (poor) - 120% (good)

(iii) SAT FLOWS (p.c.u./h) for exclusive turning lane(s) and no opposing flow

1 lane $= \frac{1800}{1 + \frac{1515}{r}}$ 2 lane $= \frac{3000}{1 + \frac{1515}{r}}$

where r = radius of turn

Turning vehicles (shared lane)
left turn : adjust 125%
right turn : adjust 175%
(assumes opposing flow)

Pedestrian crossing minimum green & flashing green times checked ☐ Y ☐ N

2.5 Delays and Queues at Signalised Junctions

2.5.1 General

2.5.1.1 Average delay per vehicle on a single approach to an intersection, (d) may be defined as the difference between the average journey time through the intersection and the time for a run which is not stopped or slowed down by the signals.

In designing a signal controlled junction it may be of interest to know the average delay for vehicle and what extensions of delay are likely to occur, especially when there are other intersection nearby.

2.5.2 TRRL Method (Transport Road Research Laboratory)

2.5.2.1 Webster and Cobber recommended that :-

$$d = \frac{c(1-\lambda)^2}{2(1-\lambda X)} + \frac{X^2}{2q(1-X)} - 0.65\left(\frac{c}{q^2}\right)^{\frac{1}{3}} X^{(2+5\lambda)}$$

where

d = average delay per vehicle on the particular arm

λ = proportion of the cycle which is effectively green for the phase under consideration i.e.f g/c

X = the degree of saturation. This is the ratio of actual flow to the maximum possible flow under the given setting of signals and equals 3600q/λs where S = saturation flow in veh/hour

c = Cycle time in seconds

g = Effective green time in seconds

q should be the flow in vehicles per second to give delay in seconds For tabulation purpose, rewrite as

$$d = cA + \frac{B}{q} - C$$

where

$A = \frac{(1-\lambda)^2}{2(1-\lambda X)}$ (see table 2.5.2.1)

$B = \frac{X^2}{2(1-X)}$ (see table 2.5.2.2)

C has been calculated as a percentage of the first two terms of the equation and tabulated in terms of X, and M (M = qc) in table 2.5.2.3

As C has a value in the range of 5 to 15 per center of d in most cases, a rough approximation of the delay formulae may therefore be given by

$$d = \frac{9}{10}\left(\frac{c(1-\lambda)^2}{2(1-X)} + \frac{X^2}{2q(1-X)}\right)$$

2.5.2.2 The average queue (N) at the beginning of the green period is also given approximately by :-

$N = q\left(\frac{r}{2} + d\right)$ whichever the grater

or qr

where

r = effective red time

q = flow (in same units as r and d)

d = average delay per vehicle

Table 2.5.2.1

Tabulation of $A = \frac{(1-\lambda)^2}{2(1-\lambda X)}$

$x\backslash\lambda$	0.1	0.2	0.3	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.80	0.90
0.1	0.409	0.327	0.253	0.219	0.188	0.158	0.132	0.107	0.085	0.066	0.048	0.022	0.005
0.2	0.413	0.333	0.261	0.227	0.196	0.166	0.139	0.114	0.091	0.070	0.052	0.024	0.006
0.3	0.418	0.340	0.269	0.236	0.105	0.175	0.147	0.121	0.098	0.076	0.057	0.026	0.007
0.4	0.422	0.348	0.278	0.246	0.214	0.184	0.156	0.130	0.105	0.083	0.063	0.029	0.008
0.5	0.426	0.356	0.288	0.256	0.225	0.195	0.167	0.140	0.114	0.091	0.069	0.033	0.009
0.55	0.429	0.360	0.293	0.262	0.231	0.201	0.172	0.145	0.119	0.095	0.073	0.036	0.010
0.60	0.431	0.364	0.299	0.267	0.237	0.207	0.179	0.151	0.125	0.100	0.078	0.038	0.011
0.65	0.433	0.368	0.304	0.273	0.243	0.214	0.185	0.158	0.131	0.106	0.083	0.042	0.012
0.70	0.435	0.372	0.310	0.280	0.250	0.221	0.192	0.165	0.138	0.112	0.088	0.045	0.014
0.75	0.438	0.376	0.316	0.286	0.257	0.228	0.200	0.172	0.145	0.120	0.095	0.050	0.015
0.80	0.440	0.381	0.322	0.293	0.265	0.236	0.208	0.181	0.154	0.128	0.102	0.056	0.018
0.85	0.443	0.386	0.329	0.301	0.273	0.245	0.217	0.190	0.163	0.137	0.111	0.063	0.021
0.90	0.445	0.390	0.336	0.308	0.281	0.254	0.227	0.200	0.174	0.148	0.122	0.071	0.026
0.92	0.446	0.392	0.338	0.312	0.285	0.258	0.231	0.205	0.179	0.152	0.127	0.076	0.029
0.94	0.447	0.394	0.341	0.315	0.288	0.262	0.236	0.210	0.183	0.157	0.132	0.081	0.032
0.96	0.448	0.396	0.344	0.318	0.292	0.266	0.240	0.215	0.189	0.163	0.137	0.086	0.037
0.98	0.449	0.398	0.347	0.322	0.296	0.271	0.245	0.220	0.194	0.169	0.143	0.093	0.042

Table 2.5.2.2

Tabulation of $B = \frac{X^2}{2(1-X)}$

X	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.1	0.006	0.007	0.008	0.010	0.011	0.013	0.015	0.017	0.020	0.022
0.2	0.025	0.028	0.031	0.034	0.033	0.042	0.046	0.050	0.054	0.059
0.3	0.064	0.070	0.075	0.081	0.088	0.094	0.101	0.109	0.116	0.125
0.4	0.133	0.142	0.152	0.162	0.173	0.184	0.196	0.208	0.222	0.235
0.5	0.250	0.265	0.282	0.299	0.317	0.336	0.356	0.378	0.400	0.425
0.6	0.450	0.477	0.506	0.536	0.569	0.604	0.641	0.680	0.723	0.768
0.7	0.817	0.869	0.926	0.987	1.05	1.13	1.20	1.29	1.38	1.49
0.8	1.60	1.73	1.87	2.03	2.21	2.41	2.64	2.91	3.23	3.60
0.9	4.05	4.60	5.28	6.18	7.36	9.03	11.5	15.7	24.0	49.0

Table 2.5.2.3

Correction term C as a Percentage of the first two terms

x	M=q x c / λ =q/c	2.5	5	10	20	40
0.3	0.2	2	2	1	1	0
	0.4	2	1	1	0	0
	0.6	0	0	0	0	0
	0.8	0	0	0	0	0
0.4	0.2	6	4	3	2	1
	0.4	3	2	2	1	1
	0.6	2	2	1	1	0
	0.8	2	1	1	1	1
0.5	0.2	10	7	5	3	2
	0.4	6	5	4	2	1
	0.6	6	4	3	2	2
	0.8	3	4	3	3	2
0.6	0.2	14	11	8	5	3
	0.4	11	9	7	4	3
	0.6	9	8	6	5	3
	0.8	7	8	8	7	5
0.7	0.2	18	14	11	7	5
	0.4	15	13	10	7	5
	0.6	13	12	10	8	6
	0.8	11	12	13	12	10
0.8	0.2	18	17	13	10	7
	0.4	16	15	13	10	8
	0.6	15	15	14	12	9
	0.8	14	15	17	17	15
0.9	0.2	13	14	13	11	8
	0.4	12	13	13	11	9
	0.6	12	13	14	14	12
	0.8	13	13	16	17	17
0.95	0.2	8	9	9	9	8
	0.4	7	9	9	10	9
	0.6	7	9	10	11	10
	0.8	7	9	10	12	13
0.975	0.2	8	9	10	9	8
	0.4	8	9	10	10	9
	0.6	8	9	11	12	11
	0.8	8	10	12	13	14

2.5.2.3 Values of queues likely to be exceeded once in 20 cycles and once in 100 cycles have also been computed and given in Table 2.5.2.4 and Table 2.5.2.5.

2.5.2.4 The above estimation on delays and queues holds good for equilibrium conditions which are achieved when the demand flow is on average less than the capacity available i.e. undersaturated. It will be seen that when the flow reaches about 90 per cent of the capacity the delay rises steeply and theoretically the delay increases to infinity as the flow tends to the ultimate capacity, thus yielding excessively high results. In practice oversaturation can happen with less serious results. When flow exceeds capacity, queues will build up at a steady rate and the resulting delay and queue length may also be estimated as a function of time.

2.5.2.5 Once the anticipated values for the queue have been calculated, the queue length may be determined simply from the number of queuing lanes available and the average length occupied by a queuing vehicle. For estimation purposes, a queuing length per vehicle of 6.0 metres is adequate.

2.5.2.6 It should be noted that as additional vehicles may arrive between the start of the green period and the time when the last vehicle in the original queue starts to move, the actual back of the queue may be slightly longer than the estimated queue length. Site observations and signal offset timing adjustments are usually helpful when backing back problems occur.

Table 2.5.2.4

Critical maximum queues (1 in 20)

Probability of the maximum queue in any cycle exceeding the critical value given in this table is 5 per cent

Degree of saturation	M=q x c / λ =q/c	2.5	5.0	10.0	20.0	40.0
0.3						
	0.4	5	7	12	20	34
	0.6	4	5	9	15	24
	0.8	3	4	6	9	15
0.5	0.2	6	7	15	26	47
	0.4	5	7	12	20	35
	0.6	4	5	9	15	24
	0.8	3	4	6	9	15
0.7	0.2	7	9	15	25	44
	0.4	6	8	12	20	34
	0.6	5	7	9	15	25
	0.8	5	5	7	9	15
0.8	0.2	9	12	16	25	46
	0.4	8	11	14	21	35
	0.6	8	9	11	16	25
	0.8	7	8	9	11	16
0.9	0.2	19	18	22	30	49
	0.4	19	17	20	23	39
	0.6	19	16	17	21	34
	0.8	18	15	15	18	22
0.95	0.2	36	28	33	40	55
	0.4	35	27	30	35	47
	0.6	34	26	25	34	39
	0.8	34	25	27	27	32
0.975	0.2	74	63	65	62	84
	0.4	74	57	65	59	75
	0.6	69	61	62	54	65
	0.8	65	56	61	52	64

Table 2.5.2.5

Critical maximum queues (1 in 100)

Probability of the maximum queue in any cycle exceeding the critical value given in this table is 1 per cent

Degree of saturation	M=q x c / λ =q/c	2.5	5.0	10.0	20.0	40.0
0.3						
	0.4	6	9	14	23	38
	0.6	5	6	11	17	28
	0.8	3	5	7	12	17
0.5	0.2	7	9	17	29	53
	0.4	6	9	14	23	38
	0.6	5	7	11	17	28
	0.8	4	5	7	12	18
0.7	0.2	9	12	17	28	50
	0.4	9	9	15	23	38
	0.6	8	9	12	18	28
	0.8	7	7	8	12	18
0.8	0.2	13	15	19	28	50
	0.4	12	13	17	24	39
	0.6	12	13	14	20	28
	0.8	11	12	12	15	18
0.9	0.2	29	25	29	38	55
	0.4	28	24	27	33	46
	0.6	27	24	26	28	42
	0.8	27	23	24	25	29
0.95	0.2	40	36	38	47	65
	0.4	40	34	37	44	55
	0.6	40	32	30	42	48
	0.8	39	32	34	36	40
0.975	0.2	82	70	79	69	93
	0.4	83	66	75	65	82
	0.6	82	70	69	58	79
	0.8	79	65	66	56	79

2.5.3 Time-Dependent Expressions by Akcelik

2.5.3.1 For conditions where the flow is near or even exceeds the capacity, delays and queues may be estimated as suggested by R. Akcelik below :-

$$No = \begin{cases} \frac{Qt}{4}\left(Z + \sqrt{Z^2 + \frac{12(x - x^1)}{Qt}}\right) & \text{for } x > x^1 \\ \text{zero} & \text{otherwise} \end{cases}$$

where
- No = average overflow queue
- Q = capacity of approach, i.e. λ S in veh/hr.
- Qt = throughput, i.e. the maximum number of vehicles which can be discharged during the flow period t hours
- Z = X – 1 (may be negative when X<1)
- X = degree of saturation i.e. $\frac{q}{Q}$
- λ = g/c i.e. green time ratio
- g = effective green time
- c = cycle time
- q = Average arrival flow rate
- X' = $0.67 + \frac{Sg}{600}$ the degree of saturation below

which the average overflow queue is approximately zero

2.5.3.2 Average delay is given by

$$d = \frac{C(1-\lambda)^2}{2(1-y)} + \frac{N_o X}{q}$$

where
- d = average delay
- c = cycle time in sec.
- λ = green time ratio
- X = degree of saturation
- y = flow factor i.e. q/s

2.5.3.3 Average stop-line line queue at the start of the green period in vehs is given by

$N = qr + N_o$

when r = effective red time

qr = total no of vehicles which arrive during the red period

2.6 Procedure for Signal Design

2.6.1 Typical Procedure

Typical procedure for signal design may be outlined below. Diagram 2.6.1.1 contains an illustration of the following steps :-

2.6.1.1 Step 1 - Identify Traffic flow Volumes
The assumed or known traffic flow volumes are identified, including turning movements.

2.6.1.2 Step 2 - Identify Junction Layout, Lane Geometry and Site characteristics
The assumed or known junction layout, including lane geometry and site characteristics are identified. It may be necessary, if revealed in Step 4 or Step 7, to modify the layout to cater for turning movements, pedestrians or to enhance capacity.

2.6.1.3 Step 3 - Identify Signal Phasing and Method of Control
The method of control to be used for analysis is identified.

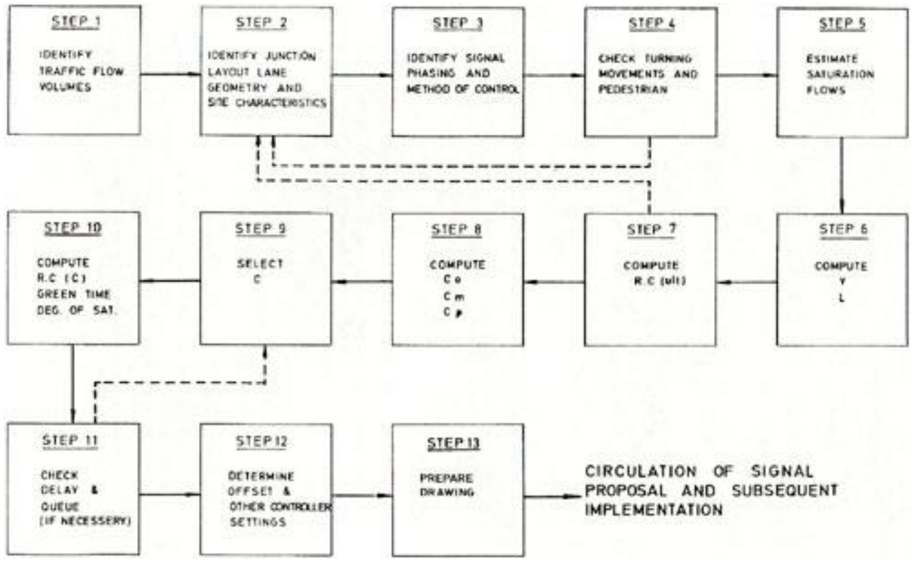
2.6.1.4 Step 4 - Check turning movements and Pedestrians
Adequate provision for turning movements and pedestrians should be roughly checked. It may be identified at this stage that the assumed method of control would need adjustment before carrying on. Make adequate allowance in calculations for parallel pedestrian minimum green crossing times. See 2.4.7.2

2.6.1.5 Step 5 - Estimate Saturation flows
The saturation flows for various approaches/movements are identified. In critical cases the saturation flows for important movements may have to be measured on site.

2.6.1.6 Step 6 - Compute Y, L
The lost times, flow factors and summation of the critical flow factors are computed.

2.6.1.7 Step 7 - Compute R.C. (ult)
The maximum reserve capacity of the intersection (see 2.4.9) is then calculated as a measure of operating performance. If this is note satisfactory, then it may be necessary to go back to Step 2, modify data and layouts and recalculate. A minimum provision of 25% reserve capacity should be provided wherever possible for new junctions. A lower standard may be adopted for existing junctions where further improvement is restricted by space limitations.

<u>DIAGRAM 2.6.1.1 PROCEDURE FOR SIGNAL DESIGN</u>



2.6.1.8 <u>Step 8 - Compute C_o, C_m and C_p</u>

The optimum, minimum and practical cycle time for operating the junction are then computed for further analysis, if necessary.

2.6.1.9 <u>Step - Select c</u>

It is then necessary to select a cycle time for operating the intersection. Sometimes, for reason for linking, the selected cycle time may be different from C_o, C_m and C_p

2.6.1.10 <u>Step 10 - Compute green time, Degree of Saturation and R.C.(c)</u>

The green times of various phases are then computed. Degree of saturation and Reserve Capacity may be computed as well if detailed analysis of signal operation is required.

If to provide good linking the cycle chosen results in a very low degree of saturation and a very high reserve capacity, consideration should be given to double - or triple - cycling this junction within the linking group i.e. running it at half or two-third of the linking cycle time.

2.6.1.11 <u>Step 11 - Check Delay and Queue</u>

Delay and Queue length may be checked when required. It may be necessary to try other cycle time if the results are not satisfactory.

2.6.1.12 <u>Step 12 - Determine offset and other controller setting</u>

Offset and other controller settings such as minimum green, maximum green etc are then finalized. Offsets for linking signals may be prepared with the aid of time-distance diagrams. (Refer to section 5.3.3 for time-distance diagrams)

2.6.1.13 <u>Step 13 - Prepare drawing</u>

For documentation purpose, proper drawings showing junction layout, method of control, stage/phase diagram, traffic flow etc need to be prepared and maintained. Standard symbols to drg. No. KT 1699 and B.S. 505 should be used wherever applicable.

2.6.2 Preliminary Planning Applications

2.6.2.1 Very often in preliminary planning purpose it would suffice to know roughly whether the junction capacity would cope with the expected flows.

2.6.2.2 In this case the typical procedure as outlined in 2.6.1 could still be used with the following simplification :-

(1) Steps 8 to 12 may be omitted.

(2) For ease and speed of computation saturation flows may be taken as 1790 pcu per lane.

(3) $L = \sum(R + 4)$
where R may be taken as 1 for ordinary inter-sections and 3 for very large intersections.

(4) If parallel pedestrian facilities are included, allowance should be made. See section 2.4.7.2.

2.6.2.3 Alternatively, the approximate method recommended in U.K. M.O.T.'s ®Urban Traffic Engineering Techniques' may be used. The maximum flow per metre width for each phase is determined and summed up for comparison with a standard practical capacity the crossing streams could be in various proportions 215/215, 280/150, 330/100 etc. so as to add up to 430. No allowance is made above for right turning traffic and appropriate reductions to carriageway widths should be made where required.

3.1 References

(1) U.K. Road Research Technical Paper No. 56 – 'Traffic Signals' by Webster & Cobbe

(2) C.E. Manual Vol. 3, Chapter 2 – P.W.D., H.K. 1972

(3) Laws of Hong Kong Chapter 374 ‘Road Traffic Ordinance and Subsidiary Legislation'

(4) British Standard 505 'Specification for Road Traffic Signals', 1971

(5) The Traffic Signs Regulations and General Directions 1981/859 (HMSO)

(6) Transport Planning & Design Manual Vol. 2 ‘Highway Design Characteristics'

(7) Transport Planning & Design Manual Vol. 3 ‘Traffic Signs and Road Markings’

(8) Departmental Advice Note TA/16/81 ‘General Principles of Control by Traffic Signals’ – DTp, UK

(9) Departmental Advice Note TA/15/81 ‘Pedestrian Facilities at Traffic Signal Intersections’ – DTp, UK

(10) Departmental Advice Note TA/10/80 ‘Design Considerations for Pelican and Zebra Crossings’ – DTp, UK

(11) ‘Pedestrian’ – Interim Materials on Highway Capacity, Transportation Research Circular No. 212 T.R.B., Washington, D.C., U.S.A.

3.2 Pedestrian Facilities at Signalized Junctions

3.2.1 Introduction

3.2.1.1 When a traffic signal installation is being designed or modified the nature and extent of pedestrian traffic flow has to be taken into account as well as that of vehicular traffic.

3.2.1.2 The object of providing pedestrian facilities is to assist pedestrians to cross in safety, whilst exercising due care and attention, with the minimum delay to traffic.

3.2.1.3 There are a number of alternative methods of achieving this aim and the Engineer has to consider which of these methods can be best applied to individual sites, knowing the pedestrian flow pattern, degree of saturation and the topographical layout.

3.2.1.4 It should be noted that segregation of pedestrian and vehicles by means of under-passes or overpasses, can provide the safest means of achieving these objectives.

3.2.2 Justification

3.2.2.1 Each junction should be considered on its own merits, taking into account of all factors such as pedestrian flows, infirm or handicapped pedestrians, junction capacity and any available accident statistics. Normally pedestrian phases should be provided wherever practicable. Reference should be made to section 3.7 of TPDM Vol. 2 for further details.

3.2.3 Types of Facility

3.2.3.1 General

At location where it is intended to provide a pedestrian facility, consideration should be given to the installation of a full pedestrian stage if the capacity of the junction permits. Alternatively, one of the techniques given in paragraphs 3.2.3.4 to 3.2.3.6 should be used.

3.2.3.2 No pedestrian Signal

(i) In some cases it is not possible to provide pedestrian phases because of capacity or equipment constraints. The presence of traffic signals at an intersection, even without the provision of red and green man displays, does provide assistance to pedestrians in crossing the arms of a junction. This is particularly so where refuges are available and in many cases no further facility is necessary.

(ii) An extended all red period between two traffic stages to assist pedestrians is not recommended. This practice leads to increased delays to traffic and to driver disobedience since the extended period will always be present even when there are no pedestrians.

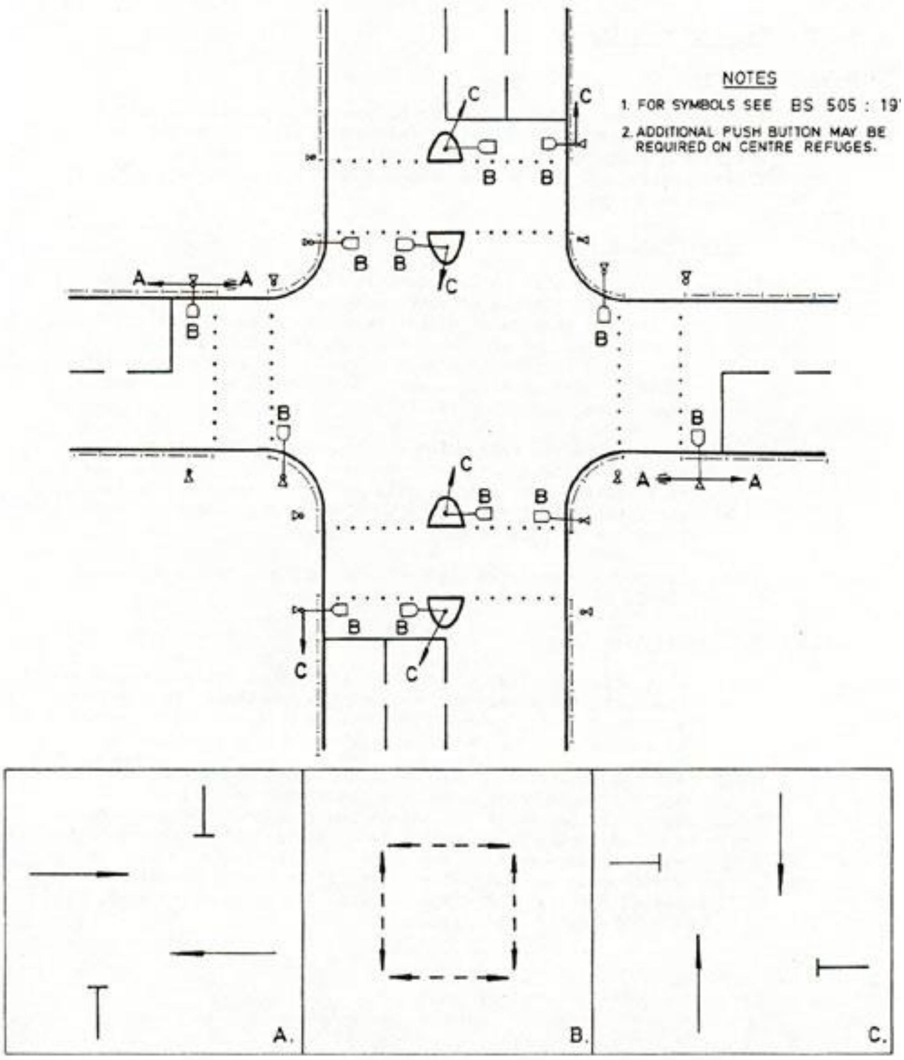
(iii) It should however be noted that normally pedestrian phases should be provided wherever possible.

3.2.3.3 Full Pedestrian Stage

(i) With this facility, all traffic is stopped whilst pedestrians are signaled across all arms of the junction. This method will cause delay to traffic. The facility should be called by demand from push buttons which should be provided at all points where pedestrians may cross. Where the crossing is across a dual carriageway, additional push buttons at the central reserve should also be considered. Diagram 3.2.3.1. shows the typical arrangement and stage diagram.

(ii) Although pedestrians may be allowed to cross any of the approaches to an intersection there will usually be one approach upon which the pedestrian problem is most acute. The pedestrian stage should immediately follow the end of the vehicle stage on this approach. The controller should be arranged to ensure that on termination of the pedestrian period the right of way will revert to a nominated stage in the absence of other demands.

DIAGRAM 3.2.3.1:FULL PEDESTRIAN STAGE



(iii) In special circumstances such as excessive pedestrian volumes, extraordinary junction configurations etc., where the usual arrangement to delineate a signal controlled pedestrian crossing as shown on Fig. 803 of Road (Traffic Control) Regulations is inadequate, consideration may be given to the use of white cross hatching road markings as shown on Fig. 613 of the Road (traffic Control) Regulations. Pedestrians may then cross the road diagonally as well as at right angles within the area. Should the area cover a junction of roads, a separate pedestrian phase will, have to be provided and the pedestrian green and flashing green times should be so designed as to cater for those pedestrians crossing diagonally. This may affect the efficiency of the signal control method and adversely affect the throughput capacity at the junction. Reference should be made to the Transport Planning and Design manual Vol.3 for further details of the road markings.

3.2.3.4 Parallel Pedestrians

Where it is possible to permanently prohibit some turning movements a combination of pedestrian and vehicle stages can be installed, see Diagram 3.2.3.2. By virtue of banned turns pedestrian facilities can be provided across appropriate arms. In order to reduce the possibility of vehicles turning illegally kerb radii should be squared off as in diagram. This facility can be usefully employed at a "T" junction with a one way street where road widths permit, by installing a triangular island in the mouth of the side road. The left and right turning movements from the side road pass either side of the main road between the segregated flows when the side road traffic has the right of way. Diagrams 3.2.3.2. and 3.2.3.3 illustrate this facility.

3.2.3.5 Staggered Pedestrian Facility (Diagrams 3.2.3.4, 3.2.3.5, 3.2.3.7)

Where carriageway widths permit, it is possible to economize on cycle time by provision of a large island in place of the normal refuge. Pedestrians can negotiate one half of the carriageway at the normal stop line when traffic on that approach is held on red. Normal pedestrian signals are shown during this period. The other half of the carriageway is controlled by separate signals which are located at the opposite end of the island. Normally, the stagger should be at least one crossing width in order to alert pedestrians that the crossing is in two halves. A right-hand stagger (Diagram 3.2.3.4) may reduce junction intergreen times by placing approach stop lines closer to junction. A left-handed stagger (Diagram 3.2.3.5) is however normally preferred, as pedestrians stepping onto the central refuge will turn towards the approaching traffic stream.

In case synchronzied pedestrian green can be arranged in at least one stage of traffic signal cycle of a staggered crossing with left-handed stagger, provision of 800mm overlapping for pedestrian crossing, i.e. stagger with less than one crossing width (Diagram 3.2.3.7), may be considered for enhancing walkability at junction, as well as alleviating the crowded pedestrian situation at central refuge together with the widening of the pedestrian crossing if necessary.

Under the latest transport policy, we have pledged to provide better facilities for the pedestrian. In this regard, staggered pedestrian crossing is considered a less desirable facility as pedestrians will have to wait and cannot cross the road in one go. The central refuge island is often not large enough when the pedestrian flows are heavy. Therefore, the use of staggered crossing for new crossings should be restrained as far as possible. It should only be used as a last resort to solve the capacity problem and its use should be brought to the attention of the Chief Traffic Engineer of respective Traffic Engineering Divisions for approval.

DIAGRAM 3.2.3.2:PARALLEL PEDESTRIAN STAGE

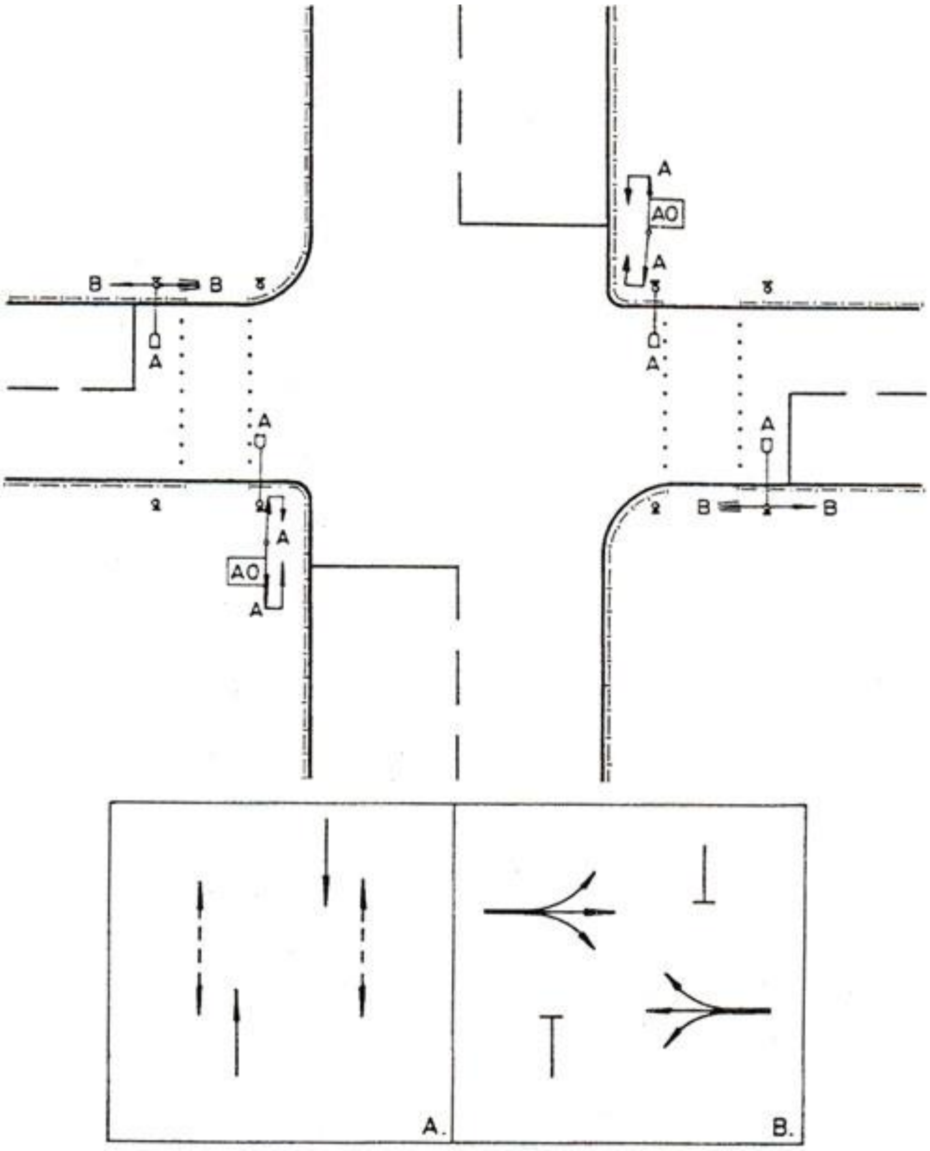


DIAGRAM 3.2.3.3 :PARALLEL PEDESTRIAN STAGE ONE WAY STREET ARRANGEMENT

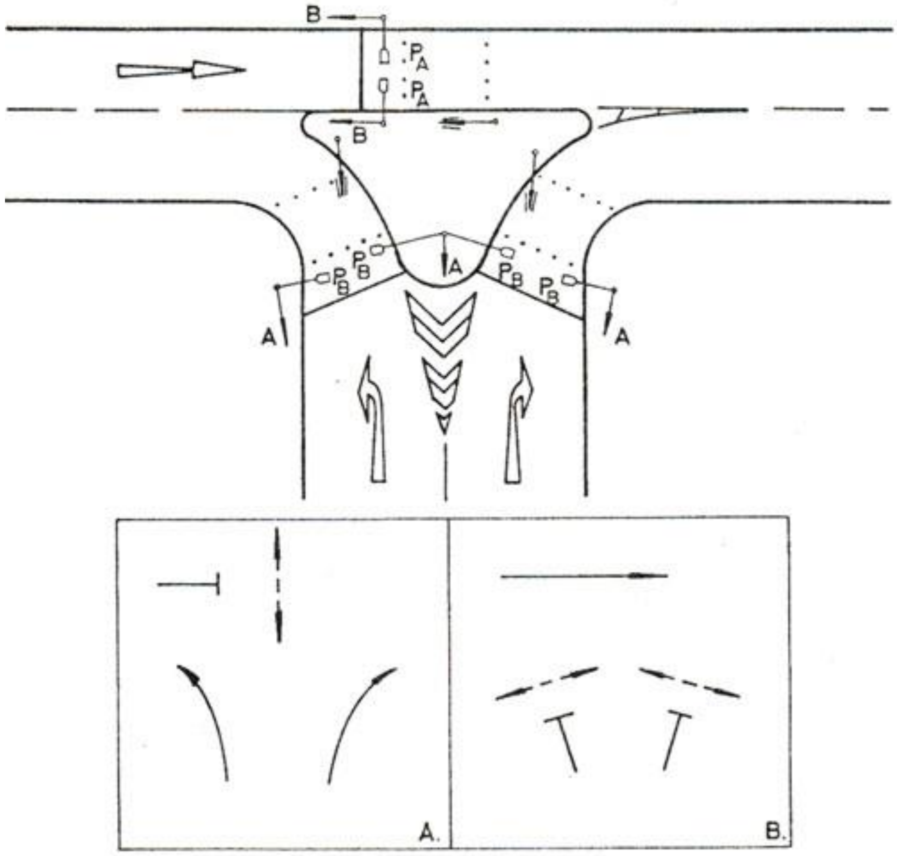


DIAGRAM 3.2.3.4 :STAGGERED PEDESTRIAN FACILITY (RIGHT – HANDED STAGGER)

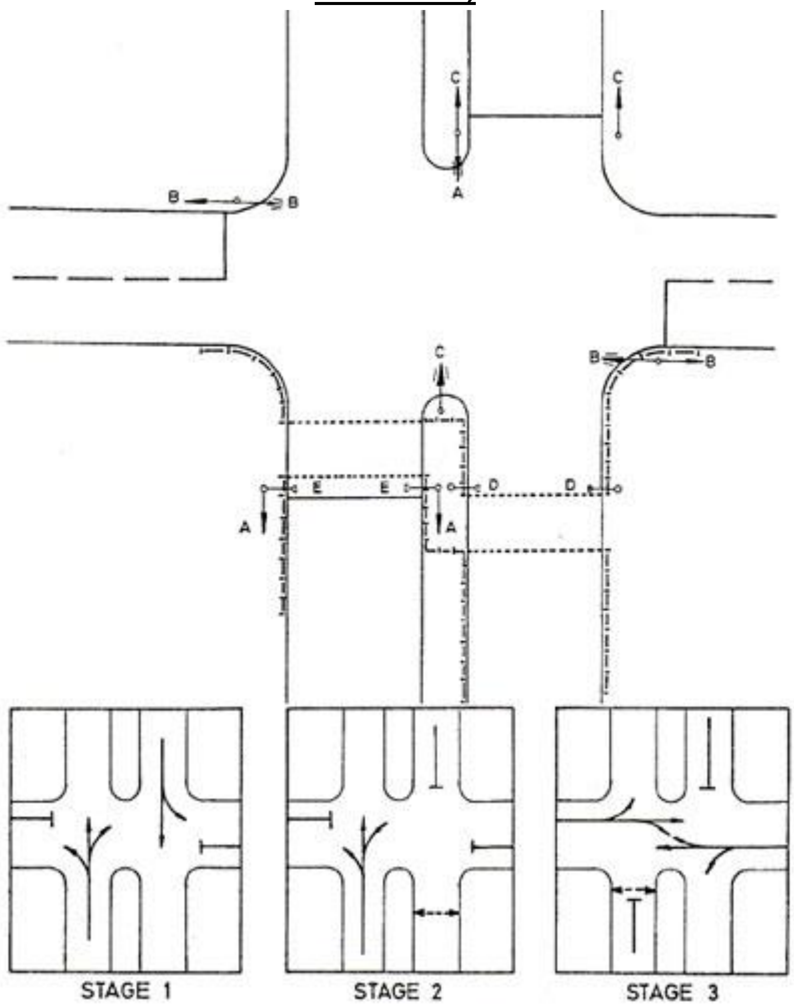
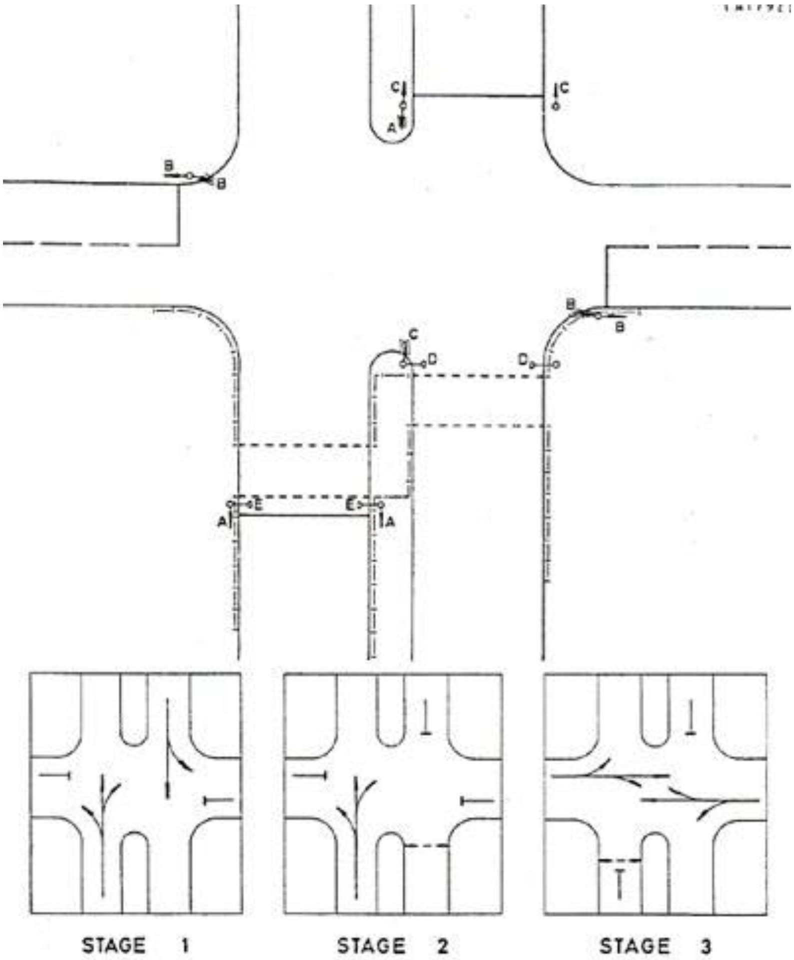


DIAGRAM 3.2.3.5 :STAGGERED PEDESTRIAN FACILITY (LEFT – HANDED STAGGER)



3.2.3.6 Displaced Pedestrian Facility

If the junction is operating close to capacity, a pedestrian facility should be considered away from the junction. The crossing may be provided across the full width of the carriageway and not more than 50m from the mouth of the junction. The stage is incorporated within the junction signal cycle and the stage position chosen to impede the minimum of traffic flow.

DIAGRAM 3.2.3.6 :DISPLACED PEDESTRIAN FACILITICY

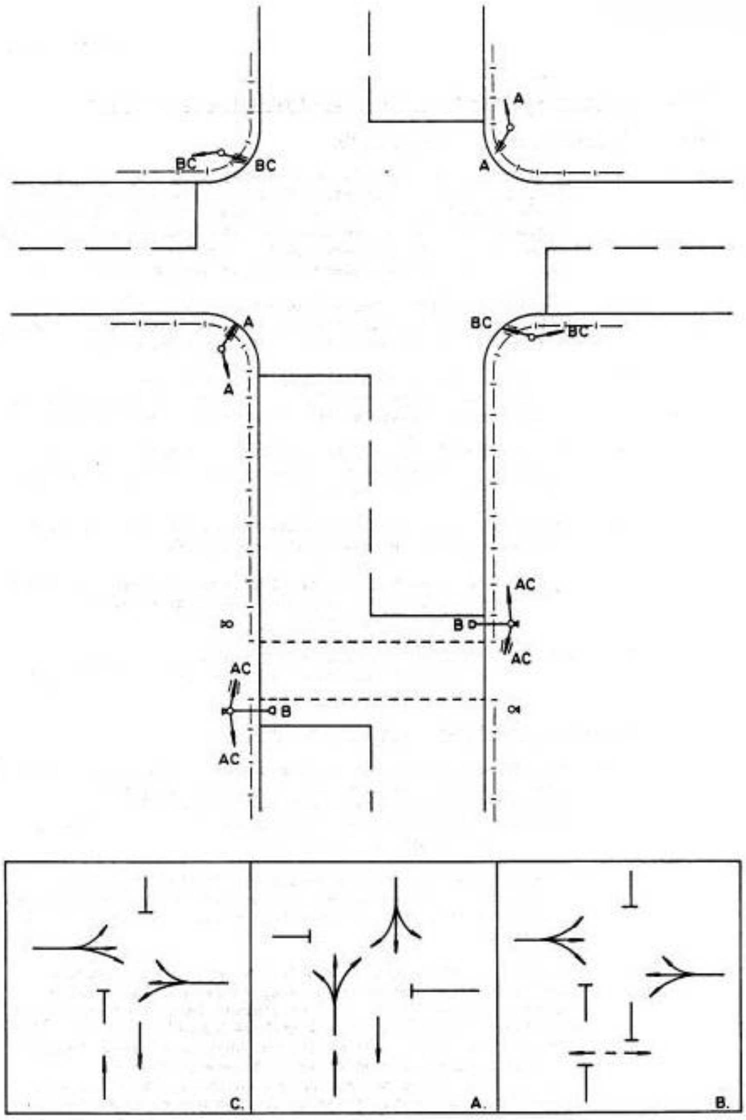
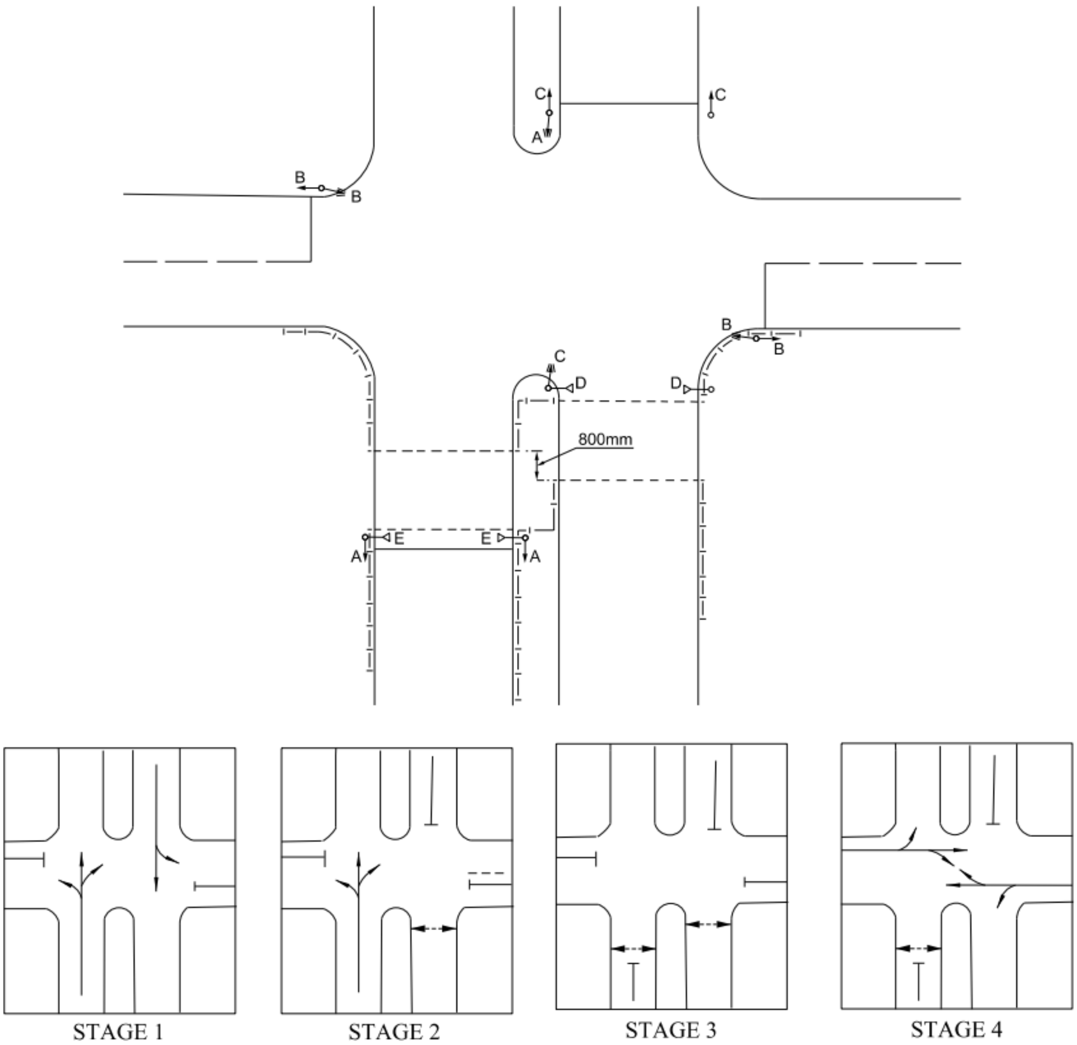


DIAGRAM 3.2.3.7: OVERLAPPING FOR PEDESTRIAN CROSSING AT STAGGERED CROSSING



3.2.4 Equipments Relevant to Pedestrians Facilities at Junctions

3.2.4.1 Pedestrian Light Signal Displays

(i) Pedestrian light signals shall comply with Road Traffic (Traffic Control) Regulation 33 and the Third Schedule. Normally each signal face shall contain two optical systems arranged vertically, the upper red standing man and the lower green walking man of 300mm nominal diameter. An alternative size of 200mm nominal diameter may be used when specified.

(ii) Pedestrian signal aspects should be positioned so that pedestrians looking at these aspects are also looking towards the direction from which the traffic is approaching.

(iii) The red signal when illuminated by a steady light shall indicate to a pedestrian that he shall not cross or start to cross the carriageway at the crossing. (Red stationary man).

(iv) The green signal when illuminated by a steady light shall indicate to a pedestrian that he may cross the carriageway at the crossing. (green walking man)

(v) The green signal when illuminated by an intermittent light (flashing green man) shall indicate that

(a) to a pedestrian who is already on the crossing that he shall proceed to pass over the crossing with reasonable speed; and

(b) to a pedestrian who is not already on the crossing that he shall not start to cross the carriageway at the crossing.

3.2.4.2 Pedestrian Push Buttons and Vehicle Actuation

(i) Pedestrian push button unit is a device that enables the calling up of pedestrian stage on demand. It is usually mounted on signal posts and may be used in conjunction with vehicle actuation signals for effective traffic management. Additional push button units should be considered in wide refuges to avoid prolonged waiting in case pedestrians are trapped at the end of the pedestrian stage.
It is advisable to have push buttons located at each side of the pedestrian crossing, so that pedestrians approaching from either direction of the crossing shall be able to call up pedestrian stage when needed.
Where the push button and electronic audible traffic signal (eATS) are installed at the same signal pole, the type of push button with integrated tactile unit should be used. Reference should be made to section 3.2.4.3 for more details on eATS installation.

(ii) Vehicle actuation coupled with push button devices can be expected to minimize delays to both pedestrians and motorists, principally because traffic flow will not be unnecessarily disrupted at pedestrian stages with no real demand.

3.2.4.3 Audible Traffic Signals

(i) Audible Traffic Signals (ATS), in the form of pulsed tones, are intended for the benefit of visually impaired pedestrians. The set up consists of a pole-mounted audible device which emits different pulse rate representing different pedestrian signal indications, e.g. a slower pulse rate during the red standing man period, and a quicker pulse rate for the green walking man period.

(ii) Electronic Audible Traffic Signals (eATS) are capable of automatically adjusting their output sound level in response to changes in ambient noise level and have two different sets of volume settings for daytime and nighttime operation. A tactile unit may also be included to supplement the eATS function. The tactile unit consists of a raised direction arrow and at the same time transmits vibrating movement synchronising with the pulse rate of the prevailing eATS signal. The arrow indicates the direction of the crossing and the pulsed signals transmitted from the tactile unit indicates the pedestrian modes to the visually impaired pedestrians. This unit is particularly useful to facilitate visually impaired pedestrians to differentiate audible signals emitted from different pedestrian crossings at junctions with a number of closely-spaced signalized pedestrian crossings.

(iii) eATS should be installed for all new signalized pedestrian crossings and new signalized junctions with pedestrian phases, and should operate 24-hour daily. The guidelines on eATS settings and the associated complaint handling procedure are described in Departmental Instructions section 2.1.5 (d).

(iv) The eATS installation requirements are summarized below:-

(a) The eATS unit should be mounted on the signal pole under the pedestrian signal aspects at a height between 1.85m and 2m above ground level (Diagram 3.2.4.1) and faced towards the middle of the other end of the crossing, where another set of eATS is installed (Diagram 3.2.4.2). To allow more headroom for pedestrians, mounting height at 2m is preferred. The eATS should be installed on the side of the crossing towards the approaching traffic. The installed eATS shall maintain a clearance of not less than 200mm from the carriageway. In addition, its sound propagation path should be free from major obstacles such as column structures or traffic signs.

(b) The tactile unit (or push button with integrated tactile unit) should be mounted at a height of about 1m above the pedestrian ground level or at a height ranging from 900mm to 1200mm (Diagram 3.2.4.1). In no circumstances should it be lower than 0.9m or higher than 1.2m above pedestrian ground level. The lateral distance between the tactile unit and the edge of the crossing shall not be more than 600mm (Diagram 3.2.4.3) and the access to the tactile unit should not be obstructed, e.g. by guard rails, street lamp post, planters, surface drainage channels etc. For signal poles on the footpath, the tactile unit should be mounted on the side facing towards the footpath. For signal poles on the refuge island, the tactile unit should be mounted on the side facing towards the refuge island. The orientation of the direction arrow should indicate the direction of the pedestrian crossing (Diagram 3.2.4.4).

(c) Where the eATS cannot be installed at the pedestrian aspect signal pole due to site constraints, the eATS may be installed on a separate mini-pole. The eATS mounting arrangement at this auxillary-pole is illustrated at Diagram 3.2.4.5.

(d) The eATS should be connected to the corresponding pedestrian aspect signal cable to obtain its operating power and pedestrian signal phase information. eATS normally relies on the voltage difference between brightening and dimming of pedestrian signal to differentiate whether day mode or night mode should be in operation. Therefore, the traffic controller at junctions where eATS are to be installed should have dimming function.

(e) In addition to the dimming signal, the eATS have the provision of a dedicated input to accept signal from the traffic signal controller to control its operation mode. When ductings and cables are planned for new pedestrian signal installations, allowance should be made for wiring requirements for possible conversion of eATS to operate by this control signal from the special facility output of the traffic signal controller in the future.

(f) eATS of different pedestrian phases should not be mounted on the same signal pole. Caution should be exercised where two eATS would be operating on different phases for two adjacent crossings, such that the eATS for one crossing would not be confused with the eATS of the other crossing, e.g. at small triangular refuge islands. The visually impaired organizations should be consulted and, if necessary, the signal phasing and/or the junction layout should be altered to avoid this confusion.

3.2.4.4 Other On-Street Furniture at Signalised Junction

(i) Crossing Studs

The crossing place shall be indicated by two rows of studs each of the dimension given in the Fourth Schedule. The footway at the crossing position shall be provided with a drop kerb to assist pedestrians, except for at the corner radius where there is a danger that the back wheel of left turning vehicles may run over the kerb.

(ii) Central Refuges

These refuges, with illuminated bollards, are normally installed to channelise road traffic and to offer some assistance to pedestrians. They are an effective and popular aid to pedestrians.

(iii) Guard Rails

It is desirable in some cases to restrict the crossing of pedestrians to certain approaches at an intersection and guard rails can be used to prevent pedestrians crossing at dangerous places (for example where filtering traffic may be moving at times unexpected by pedestrians). Guard rails should always be provided on large islands where staggered pedestrian movements are allowed. Normally minimum length of guard rails provided at each side of a crossing should be 15 m.

DIAGRAM 3.2.4.1:TYPICAL eATS INSTALLATION ARRANGEMENT (SIDE VIEW)

ALL DIMENSION IN MILLIMETRES

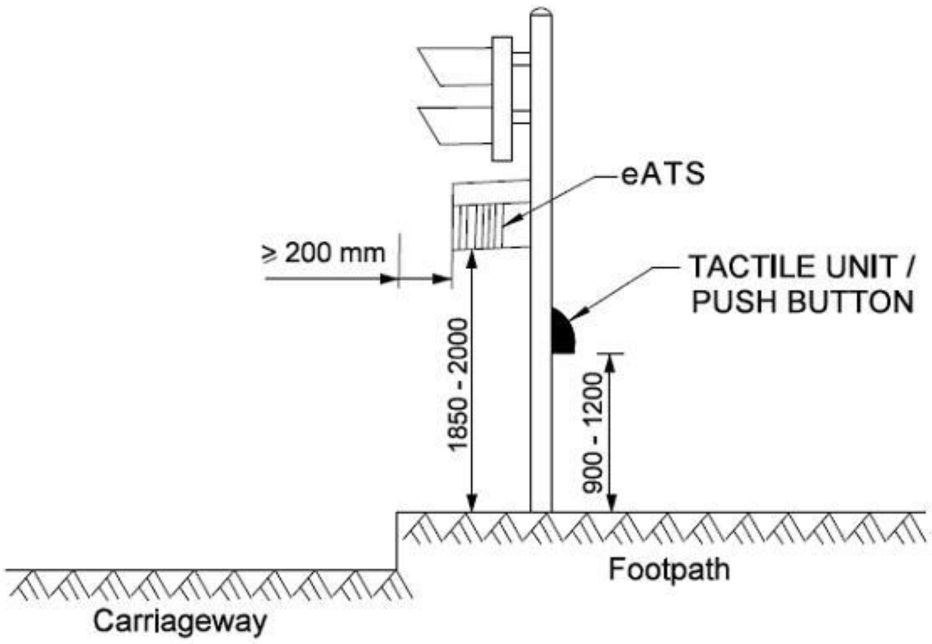


DIAGRAM 3.2.4.2:TYPICAL eATS INSTALLATION ARRANGEMENT (TOP VIEW)

ALL DIMENSION IN MILLIMETRES

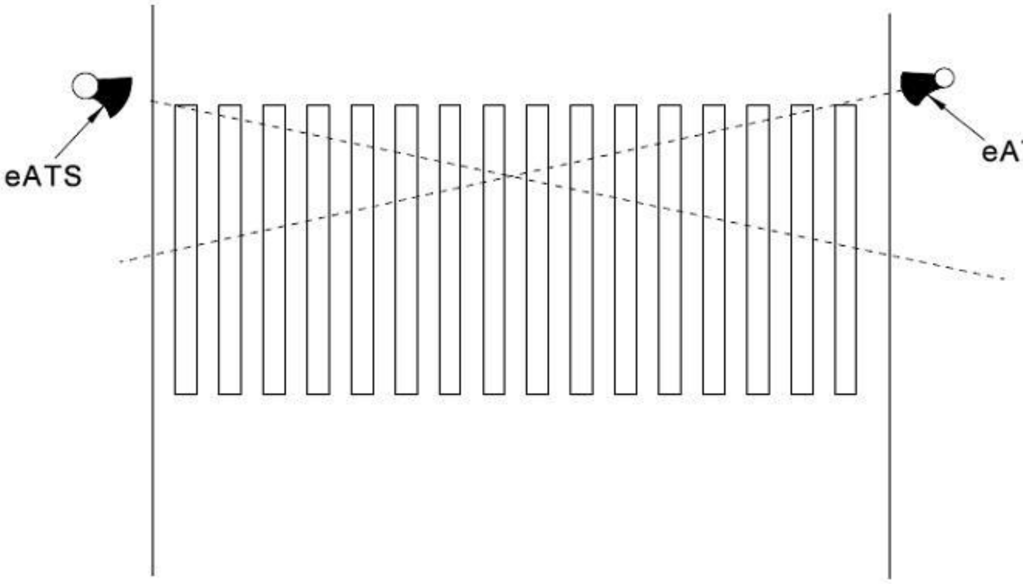
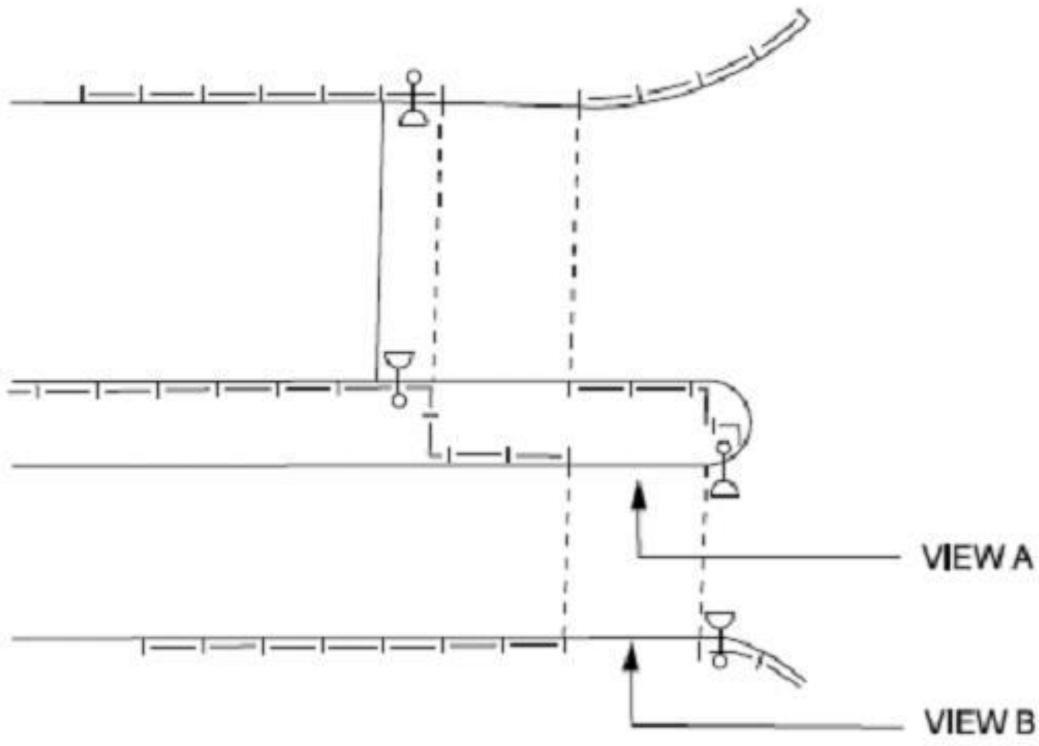
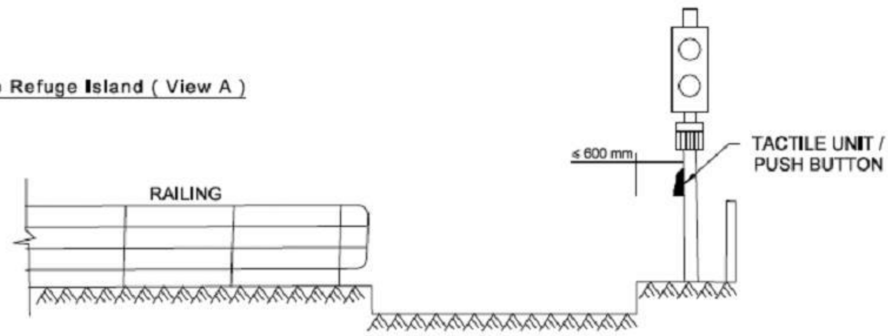


DIAGRAM 3.2.4.3:TYPICAL eATS INSTALLATION ARRANGEMENT IN A STAGGERED CROSSING



Front view to Refuge Island (View A)



Back view from footpath (View B)

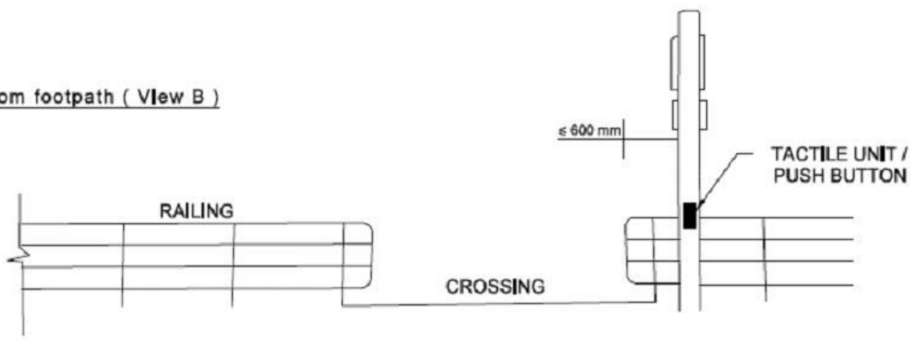


DIAGRAM 3.2.4.4:TYPE AND ORIENTATION OF THE DIRECTION ARROW OF TACTILE UNIT OF eATS AT DIFFERENT LOCATION OF PEDESTRIAN CROSSING

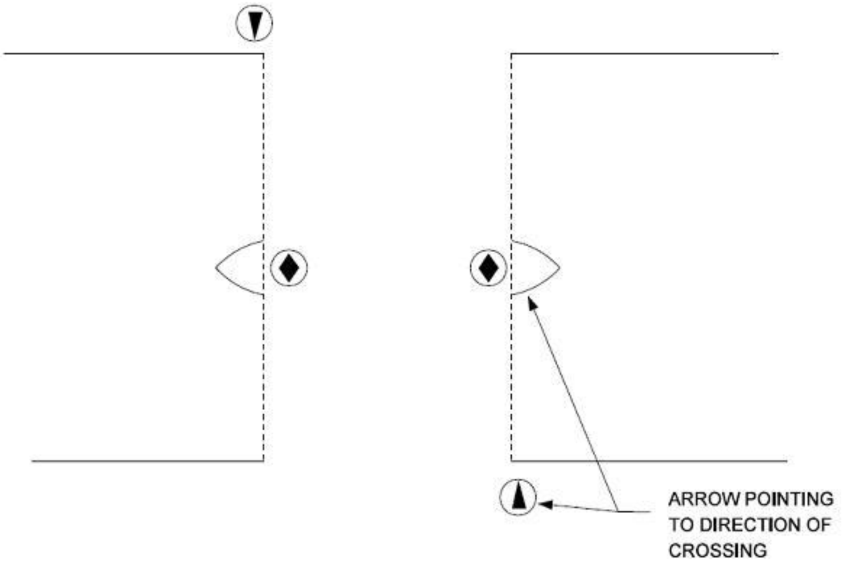
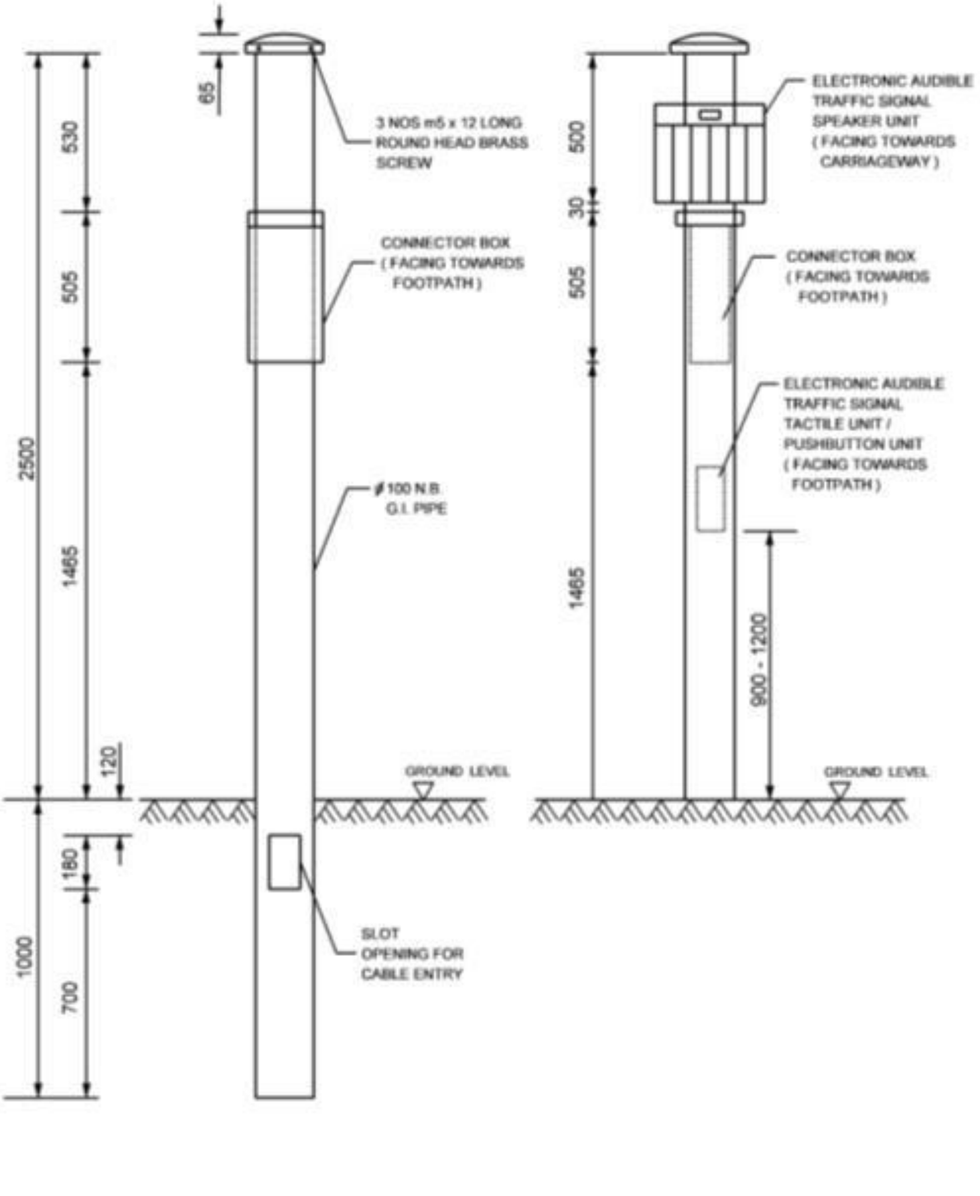


DIAGRAM 3.2.4.5:GENERAL ARRANGEMENT OF AUXILIARY TRAFFIC LIGHT SIGNAL POLE FOR eATS

ALL DIMENSION IN MILLIMETRES



3.2.5 Pedestrian Signal Sequence and Timings

3.2.5.1 The sequence of pedestrian signals is red, green, flashing green and red.

3.2.5.2 In designing the pedestrian facility the first consideration must be to ensure that the pedestrian time (i.e. green plus flashing green time) is sufficient to enable pedestrians to cross the full width of the road with relative ease at normal walking speed. Since a road with pedestrian refuges or central reservation shall be treated as separate carriageway in accordance with the Road Traffic (Traffic control) Regulations 374G 33(5), both the minimum full green period and the minimum flashing green period shall allow pedestrian to cross the longest crossing measured between kerbs and pedestrian refuges. An assumed walking speed of 1.2 m/sec for the measured crossing distance can generally be adopted in determining the minimum times. However, to account for the elderly, people with disabilities, or exceptionally heavy pedestrian flow situation at crossings, a longer flashing green period assuming a walking speed of 0.9 m/sec could be considered. This is in line with TPDM Volume 6 Cl. 8.4.3.4 which recommends a walking speed of 0.9 m/sec to cater for the need of people with disabilities.

3.2.5.3 The length of the flashing green is obtained by determining the maximum distance from safe refuge to safe refuge e.g. from the footpath to the central divider of a dual carriageway so that when a pedestrian steps off the kerb in the last second of full green, the flashing green period is always sufficient to enable him to get to a safe refuge before the flashing green finishes.-

3.2.5.4 On a straight crossing with central refuge dividing two carriageways, the minimum length of the green period should allow pedestrians to clear a distance of the width of the greater width of the two carriageways plus the width of the central refuge so that it is feasible for pedestrians to cross the road in one attempt. Where there is no central refuge the minimum length of the green period should allow pedestrians to clear half of the road width. Normally minimum green periods less than 5 sec are considered too short and are not recommended.

3.2.5.5 Provided that the above minimum requirements are met, the green period of parallel pedestrian stage may be determined by the predominant traffic flow running in parallel.

3.2.5.6 Having determined the minimum pedestrian green times the following empirical formula may be used for checking whether the light signal crossing facilities provided are adequate for the pedestrian volumes wishing to cross :

$$PC = K \times GTP \times W$$

where PC = Pedestrian crossing capacity in pedestrians per hour

GTP = Green time proportion

i.e. $\frac{\text{Pedestrian green + flashing green time}}{\text{Cycle time}}$

W = Lateral width of pedestrian crossing

K = A constant equivalent to saturation flow for pedestrians, may be taken as 1900 ped/metre/hours.

3.2.5.7 Where the following is a pedestrian stage, the intergreen time should be checked in accordance with diagram 2.3.2.4 where the distance ‘X’ should be determined from the position of the pedestrian crossing. This is to ensure that the last vehicle should clear the crossing by the time the pedestrian green signal is lit.

3.2.5.8 On-site checking should be carried out for new signals after implementation whenever possible, to ensure that the minimum pedestrian timings and clearance periods provided are adequate. Vehicle green times should also be checked, as excessive vehicle green can lead to traffic speeding through the junction and can also lead to non-observance of the signals by pedestrians.

3.2.6 Widths of Crossings

3.2.6.1 Table 3.2.6.1 serves as a general guide for the appropriate crossing widths in relation to the expected flows. Its adequacy should however be checked against the green/flashing green time as in 3.2.5.6. Adjustments may be made to the width or green time proportion where appropriate. However the width of the crossing should not normally exceed 9 m.On-site checking should be carried out for new signals after implementation whenever possible, to ensure that the minimum pedestrian timings and clearance periods provided are adequate. Vehicle green times should also be checked, as excessive vehicle green can lead to traffic speeding through the junction and can also lead to non-observance of the signals by pedestrians.

Table 3.2.6.1
Crossing Widths
According to Approximate Pedestrian Flows

	Crossing Width (m)	Pedestrians Per Hour Both Directions
1.	2.5	1500 - 3000
2.	4	2400 - 4800
3.	5	3000 - 6000
4.	6	3600 - 7200
5.	7	4200 - 8400
6.	8	4800 - 9600
7.	9	5400 - 10800

3.2.6.2 It is essential that there is adequate reservoir space at the side of the road and within any refuge island provided for pedestrians to wait without encroaching onto the carriageway and without obstructing the movements of other passing pedestrians. Care is particularly required with regard to this in respect of the central refuge where crossings are staggered. It is recommended that a minimum average pedestrian area occupancy of 0.2 sq.m./person should be provided wherever possible.

3.2.7 Split Vehicular Movements

3.2.7.1 Split movements at the same approach are generally viewed as confusing to both motorists and pedestrians. They are particularly dangerous to pedestrians in situations where one movement will start to move as soon as the adjacent split movement loses its right of way. In these circumstances channelishing islands should be constructed to separate the split movements and provide refuges for pedestrians to wait. If the islands cannot be provided consideration should be given to removing the crossing and relocating it elsewhere.

3.3 Signalized Mid-block Crossings

3.3.1 Introduction

3.3.1.1 At-grade mid-block crossings may be one of the following types :

(i) light signal controlled crossings

(ii) Zebra Crossings

(iii) Cautionary crossings.

3.3.1.2 Reference may be made to T.P.D.M. Volume 2 Section 3.7 for details and advice on the choice of zebra crossings and cautionary crossings.

3.3.2 Typical Layout

3.3.2.1 Signalized Straight Crossing (Diagram 3.3.2.1)

(i) Crossing studs – the crossing place should be indicated by two rows of crossing studs as specified in the Fourth Schedule.

(ii) Central Refuges – central refuges should be used wherever possible to offer assistance to pedestrians and provide space for housing other street furnitures such as second primary signal, secondary signals and bollards. The minimum width as indicated should be 1.5 metres.

(iii) Guard railing – guard railing is used to prevent pedestrians from stepping on to the road and to guide them on to the crossings. Minimum length of guard railing should be 15 m wherever possible at each side of the crossing.

(iv) Dropped kerb – Dropped kerb should be used for the full width of the crossing.

(v) Pedestrian push buttons – pedestrian push buttons, if provided, should be installed at both sides of the crossing on both sides of the road and at the central divider.

3.3.2.2 Signalized Staggered Crossing (Diagram 3.3.2.2)

(i) If pedestrian movement takes place in two stages the crossing should be staggered.

(ii) A straight crossing is normally preferred to a staggered crossing as pedestrians can cross the road in one attempt and consequently will experience les delay. This will tend to minimize jay-walking.

(iii) Use of a staggered crossing may however be given favourable consideration in the following circumstances :

(a) where one would like to slow down pedestrians intentionally for safety reasons e.g. high vehicle speeds, low visibility etc.

(b) where the road is very wide and one needs to economize on pedestrian green time for capacity reasons

(c) where one needs to provide flexibility in optimizing progression of opposite traffic streams.

(iv) Staggering should be left-handed so that pedestrians stepping on to the central refuge turns towards the next traffic stream.

(v) Care should be taken in the use of staggered crossing to ensure that adequate reservoir space is provided at the refuge and that pedestrian would not be asked to wait for unduly long periods to become impatient.

(vi) Crossing studs, refuges, guard railing, dropped kerbs and pedestrian push buttons etc are similar to those used in a straight crossing.

DIAGRAM 3.3.2.1:TYPICAL SIGNALISED STRAIGHT CROSSING

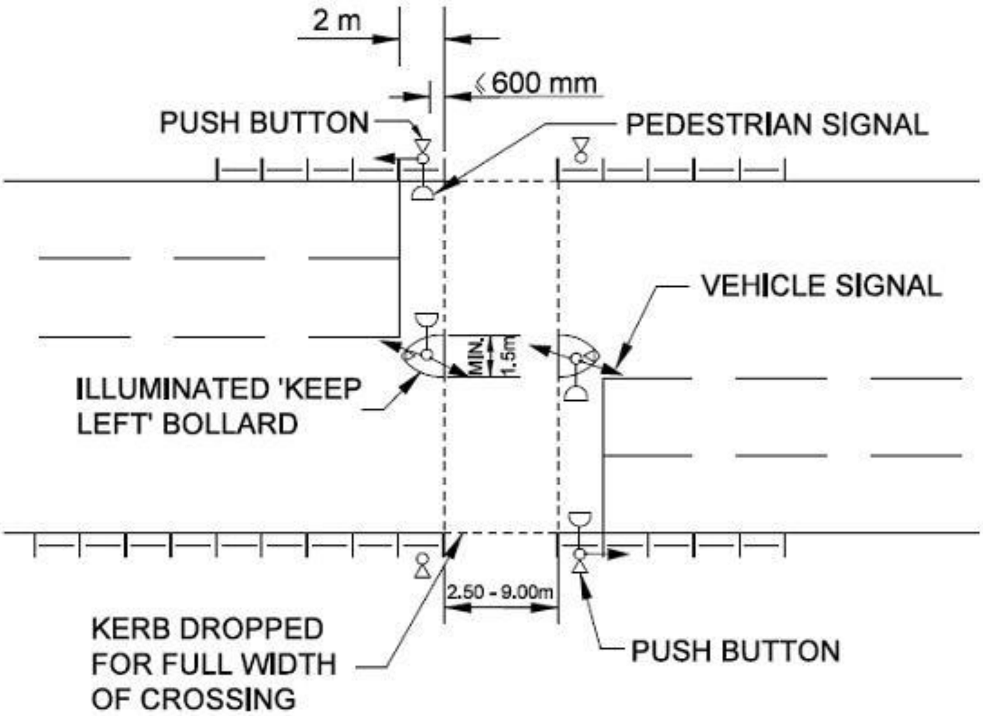
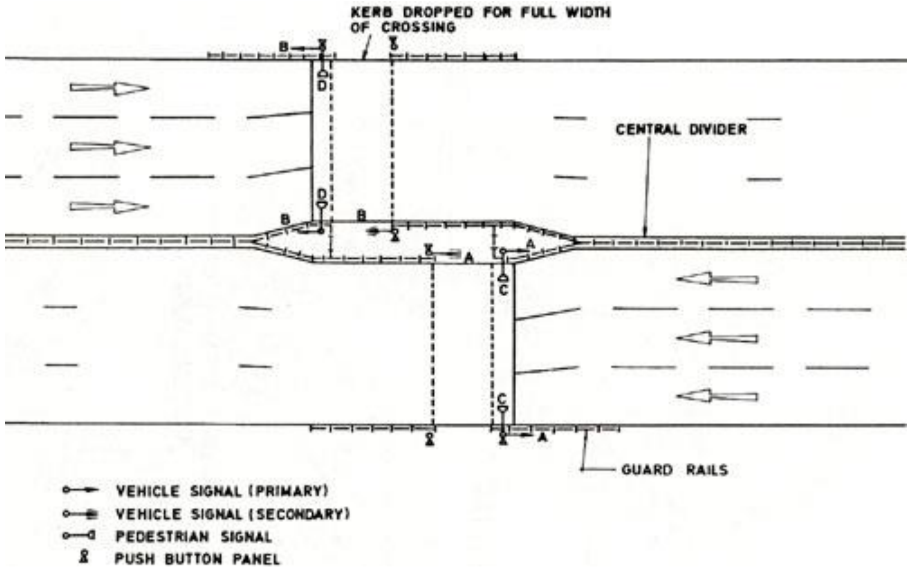


DIAGRAM 3.3.2.2:TYPICAL SIGNALISED STAGGERED CROSSING



3.3.3 Siting

3.3.3.1 Pedestrian crossings are provided to increase pedestrian safety and convenience without incurring excessive delays to traffic. These crossings should be so sited to attract the maximum number of pedestrians who would otherwise cross the road at random, and also to give drivers adequate opportunity to recognize them in time to stop safely.

3.3.3.2 Pedestrian crossings should be sited where there is adequate footway capacity at each end of the crossing for assembly and dispersal and should not be in competition with pedestrian subway or footbridges.

3.3.3.3 Signalized pedestrian crossings sited closer than 135 m to a signalized junction should be linked-controlled to ensure efficient operation.

3.3.3.4 Desirable Minimum sight distances in accordance with Table 3.3.3.1 should normally be available to motorists on the approach to a crossing, and should only in exceptional circumstances be less than the Absolute Minimum. Appropriate warning signs should be erected where visibility distances, are at or below Absolute Minimum.

Table 3.3.3.1. Sight Distance for Pedestrian Crossing

	85 percentile approach speed of light vehicles (km/h)	Equivalent approximate average speeds (km/h)	Desirable Minimum (m)	Absolute Minimum (m)
1.	50-59	40-49	70	50
2.	60-69	50-59	95	70
3.	70-84	60-69	125	85
4.	85-99	70-84	165	125
5.	100-120	85-99	225	165

3.3.4 Miscellaneous : Crossing widths, signal displays/timings, actuation and audible signals

3.3.4.1 The operation of a signalized mid-block crossing in respect of crossing width, signal displays/timings, vehicle actuation and audible signals is identical to that at a signalized junction as detailed in 3.2.4.4(iii).

4.1 References

(1) U.K. Road Research Technical Paper No. 56 – ‘Traffic Signals’ by Webster and Cobbe.

(2) C.E. Manual Vol. 3 Chapter 2 – P.W.D., H.K. 1972

(3) Laws of Hong Kong Chapter 374 ‘Road Traffic Ordinance and Subsidiary Legislation’

(4) British Standard 505 ‘Specification for Road Traffic Signals’, 1971

(5) The Traffic Signs Regulations and General Directions 1981/859 (HMSO)

(6) Transport Planning & Design Manual Vol. 2 ‘Highway Design Characteristics’

(7) Transport Planning & Design Manual Vol. 3 ‘Traffic Signs and Road Markings’

(8) Departmental Advice Note TA/16/81 ‘General Principles of Control by Traffic Signals’ – DTp, UK

(9) Departmental Advice Note TA/18/81 ‘Junction Layout for Control by Traffic Signals’ – DTp, UK

(10) Departmental Advice Note TA/12/81 ‘Traffic Signals on High Speed Roads’, DTp, UK

(11) UK Departmental Specification MCE018 ‘Siting of Inductive Loops for Vehicle Detecting Equipments at Permanent Road Traffic Signal Installation’ DTp

4.2 Introduction

4.2.1 General

4.2.1.1 This Chapter sets out the requirements to be met when traffic signals are installed on roads where the 85 percentile approach speeds at a junction are between 60Km/h and 105 Km/h on any arm.

4.2.1.2 Drivers traveling at even moderately high speeds on roads where traffic signals are installed can find themselves with a difficult decision to make when green changes to amber. They are often faced with a choice between attempting to brake to halt at the stop line, or continuing at the same speed through the junction and clearing it safely. They may fail to achieve either, thus putting themselves and others at risk.

4.2.1.3 Because of the increased braking distances required at high speeds, drivers need adequate warning that they are approaching a signaled junction. High approach speeds also result in drivers misjudging the lengths of gaps in opposing traffic when making a right turn at the junction which in turn increases the risk of accidents occurring.

4.2.1.4 On high speed roads, use of right turn clearance phases should be avoided. Right turning movement, across high speed flows should be channelised and controlled with a separate vehicle phase.

4.2.1.5 The methods employed to overcome these problems are given in the following sections.

4.3 Design Features

4.3.1 Speed-related Green Extensions

4.3.1.1 To assist drivers it is necessary to provide green extensions, the extensions being related to the 85 percentile approach speed.

4.3.1.2 Normal approved vehicle detection equipment is used within 40 m of the stop line on each approach and in addition approved speed discrimination or speed assessment equipment is used as detailed in UK DTp's Department Specification MCE 0108 'Siting of inductive loops for Vehicle Detection Equipment'

4.3.1.3 When the 85 percentile approach speed on any arm exceeds 105 Km/h it is recommended that traffic signals should not be installed.

4.3.2 Advance Warning Signs

4.3.2.1 Advance warning signs are necessary on each approach in accordance with the requirements given in TPDM Volume 3 'Traffic Signs and Road Markings'

4.3.3 Visibility Requirements

4.3.3.1 The minimum visibility distances to the primary signal(s) required by drivers are given in table 4.3.3.1

Table 4.3.3.1

85 percentile approach speed	Visibility distance
50 km/h	70 m
60 km/h	95 m
70 km/h	125 m
85 km/h	165 m
100 km/h	225 m
120 km/h	300 m

4.3.3.2 The use of duplicate primary signals is recommended on all high speed approaches where circumstances permit.

4.3.3.3 Wherever possible overhead traffic should be used to complement pole mounted signals on high speed roads. Current recommendations on use of overhead signals are as follows :-

(i) Overhead traffic signals generally give an outstanding indication to drivers and eliminate most of the visibility problems associated with pavement furnitures, shop signs and columns supporting balconies. They are of particular benefit on roads where spot speeds are high.

(ii) It should only be used to complement pole mounted signals rather than exclusively used in a traffic light installation.

(iii) 300mm high intensity signal aspects with backing boards should be used.

(iv) The lights should normally be arranged vertically as in ordinary pole mounted signals. The height of the center of the green lens from the surface of the carriageway is normally 5.5 metres.

(v) Because of large foundations required by the higher masts, these signals cannot be installed at all locations and its exact position have to be determined on site. Normally the signals are installed as additional primary signals near and to the right of the middle of the carriageways.

(vi) Overhead signals should not be used on approaches where the method of control involves separate control for split movements.

4.3.4 Right-turning Movements

4.3.4.1 Even at moderately high approach speeds it is evident that there is an accident risk if right-turning traffic is obliged to identify and use gaps in conflicting traffic streams.

4.3.4.2 It is strongly recommended that where the 85 percentile approach speed is greater than 70 km/h on any arm of the junction right turns across the through traffic from that arm should be separately signaled when the through traffic has been halted.

4.3.4.3 An alternative solution is to ban the right turns when local circumstances permit.

4.4 Maintenance

4.4.1 General

4.4.1.1 The failure of traffic signals, including lamp failure, on high speed roads can cause considerable uncertainty and confusion to drivers with consequent accident risk. It is of utmost importance to ensure that such signal installations are well maintained.

5.1 References

(1) U.K. Road Research Technical Paper No. 56 – 'Traffic Signals' by Webster and Cobbe.

(2) Roads in Urban Areas – U.K. HMSO 1966.

(3) C.E. Manual Vol. 3, Chapter 2 – P.W.D. H.K. 1972.

(4) Departmental Advice Note TA/16/81 'General Principles of Control by Traffic Signals' DTp, U.K.

(5) User Guide to 'TRANSYT' Version 6 – TRRL Supplementary Report 255 DTp, U.K.

(6) Advisory Memorandum on Urban Traffic Engineering Techniques – U.K., HMSO 1966.

5.2 Introduction

5.2.1 General

5.2.2.1 The effect of the stop aspect at a signalized junction is to marshall vehicles into a queue behind the stop line. When this queue is released as the green is given, it will discharge initially at its maximum rate i.e. satuation flow travels on its way in the form of a platoon. If, as this platoon approaches another signal controlled intersection, its arrival is made to coincide with the start of green, the vehicles will experience on delay. In dealing with heavy traffic movements in the urban area, it is obviously desirable that the operation of individual signals should be co-ordinated wherever possible so that maximum benefit is gained from the platooned flows.

5.2.2 Benefits of Co-ordination of Signals

5.2.2.1 It is generally viewed that proper co-ordination of signals will :

(i) Prevent the queue of vehicles at one intersection from extending back and interfering with an upstream junction.

(ii) Increase the capacity of the linked route.

(iii) Enhance driver comfort as well as road safety by offering less stops and smoother flows in a controlled manner.

(iv) Attain minimum overall delay for motorists

5.3 Fixed-time Co-ordinated signals

5.3.1 General

5.3.1.1 These systems are based on assumptions that traffic flows are repetitive over a weekly cycle and that the appropriate predetermined signal settings can be prepared to cope with these predictable traffic flows. The traffic plans, or signals setting can then be selected according to the day of week and time of day. A prerequisite to this kind of system is that the controllers should be synchronized and capable of multi-plan operation.

5.3.2 Simple Progressive System

5.3.2.1 This is the most commonly-used simple linking system. Working with a common cycle time, the signals are so timed that the 'go' periods are staggered in relation to each other according to the desired road speed to give a 'progression' of green periods along the road in both directions i.e. driver of a vehicle released by the green aspect at the first signal and proceeding along the major route at a predetermined speed will find that every signal changes from red to green on his approach, and he can pass through the signal without delay.

5.3.3 Time-Distance Diagrams

5.3.3.1 The phasing of the signals in a simple progressive system can be prepared with the aid of a time-distance diagram, examples of which are shown in Diagrams 5.3.3.1 and 5.3.3.2.

5.3.3.2 On these diagrams, distances between intersections along the route are plotted along the abscissa and the travel times are plotted along the ordinate axis. The slope of diagonal lines represent the chosen speed of progression and green phases of successive junctions are offset in time. Normally the problem is one of determining by trial and error, the optimum through-band speed and width for a fixed cycle time.

5.3.3.3 In Diagram 5.3.3.1 where the flow is one way only, vehicles traveling at the predetermined progressive speed, and having passed one intersection will then receive the right of way without impediment.

5.3.3.4 In Diagram 5.3.3.2 where the flow of traffic is two-directional and where the intersections are unevenly spaced, the situation is more complex and it may be necessary to come to a compromise on progression between the two directions. It may also be necessary to take into account other requirements such as demands from cross-street traffic.

5.3.3.5 The time-distance diagram method can be used to bias in favour of a particular direction of flow e.g. to favour a heavy inbound flow in the morning peak at the expense of increased delay to the fewer vehicles traveling in the opposite direction. The situation may be reversed in the evening peak.

5.3.3.6 Cycle time for a co-ordinated signal system is normally dictated by a key junction i.e. the junction i.e. the junction which is most heavily loaded and which requires, therefore the longest cycle time. Spare green time should be allocated as required to clear traffic turning into the main route from side roads in order not to delay the through platoons or to traffic in the opposite direction. To minimize congestion, opportunities for leaving the system should also be greater than for entering.

5.3.3.7 It should be noted that the progressions in light traffic situation should not be so good as to encourage speeding of vehicles.

DIAGRAM 5.3.3.1:CO-ORDINATED SIGNALS-ONE WAY TRAFFIC

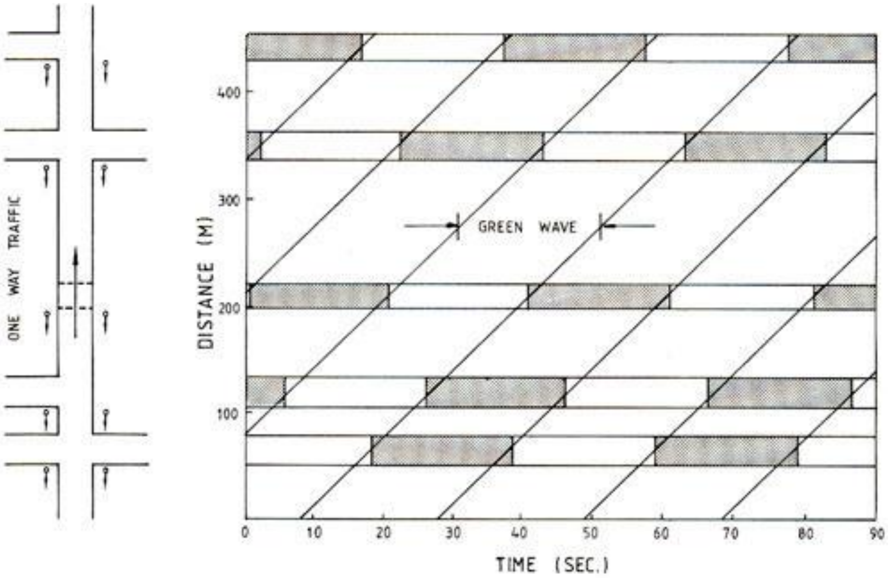
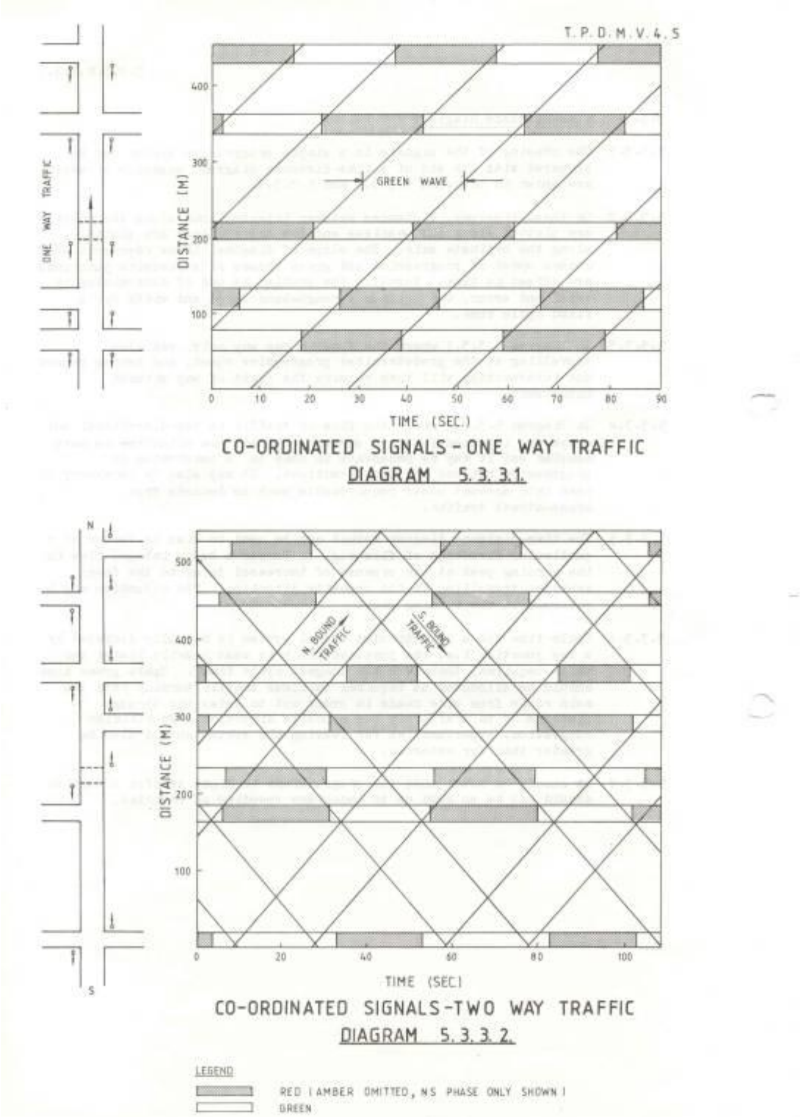


DIAGRAM 5.3.3.2:CO-ORDINATED SIGNALS-TWO WAY TRAFFIC



5.4 Vehicle-actuated Signals

5.4.1 Flexible Progressive System

5.4.1.1 Vehicle-actuated signals may be used for a flexible progressive system. Local controllers at each intersection in the system operate according to the overriding progressive plan whilst there are continuous demand from all detectors. If the flow reduces and there is no longer a continuous demand on the detectors at a particular installation in the system, it is free to operate as an isolated vehicle-actuated installation, changing right of way when necessary to suit the traffic at the intersection.

5.4.1.2 However there is a proviso that any change of right of way that takes place should not interfere with traffic passing through the system in accordance with the progressive plan. This means that there are certain periods in the cycle when a change of right-of way cannot take place. This is because there would be insufficient time in which to regain right-of way for the road which, according to the progressive plan, is entitled to it. There are also periods when a forced change of right of way can be made to facilitate the working of progressive plan. Working of this type of V.A. progressive system is more complex than the fixed time system and details are very much dependent on the equipment supplied.

5.4.2 Tailor-made Systems

5.4.2.1 Mutual co-ordination may be 'tailor-made' for particular intersection signals where they are reasonably close to each other and are not part of a larger system. Usually the signals at the key intersection are allowed to operate in a fully vehicle-actuated manner and allowed to control the times at which the right of way is changed at the neighbouring intersections. This 'tailor made' control may be to favour traffic leaving the key intersection (i.e. forward linking) or to prevent a queue back from the key intersection interfering with the previous intersection (i.e. backward linking).

5.5 Mechanisms for Linking Signals

5.5.1 Cable-linking

5.5.1.1 Local traffic signal controllers at intersections working in a linking group may be cable-linked to a master controller. The master controller generally ensures that the local controllers, or 'slave controllers' as they are termed, operate in synchronization by sending control signals or instructions down the link cable to every slave controllers. The slave controllers, on receipt of the control signal time off a pre-set period to effect phase/stage changes. In area traffic control systems, all controllers on the street are cable-linked to a control center where a central computer takes direct control of the signals on the street.

5.5.2 Cabless Linking

5.5.2.1 Linking of signals may also be achieved by cables means such as radio, mains synchronization etc. In the more popular mains synchronization method the controller will contain a real time clock for local plan selection and synchronization. This real time clock will be synchronized to the mains frequency within a specified accuracy. In the event of a mains power failure of a total or transitory nature, the real time clock will derive its power from a standby power source and the necessary timing signals to maintain the real time clock will be obtained from a standby crystal oscillators.

5.6 Optimization of Co-ordinated signal timings by Computer Program

5.6.1 General

5.6.1.1 For fixed time signals along a single corridor the signal settings prepared by using the graphical method i.e. time-distance diagrams are reasonably satisfactory. However, for traffic networks involving several routes criss-crossing one another this method becomes inadequate and unworkable as it does not take account of the relative flows of traffic as well as the overall delay in the network. The possible combinations of the signal settings are too numerous for manual investigations.

5.6.1.2 For complex networks, the use of computer-aided iterative methods for optimizing signals setting is therefore necessary. Among the various iterative methods, TRANSYT is one of the most widely used signal optimization computer program currently available in Hong Kong.

5.6.2 The Transyt Program

5.6.2.1 The Transyt program was developed by the U.K. Transport and Road Research Laboratory in a series of experimental applications in Glasgow, where an ATC System had been installed.

5.6.2.2 The program builds up a mathematical model of the traffic network based on a simple link and node diagram. A cycle time for the network is input and based upon the input flows, methods of control and saturation flows for the various approaches, green splits for the chosen cycle time for each junction (node) are calculated.

5.6.2.3 Using either initial offsets input or commencing at a start point calling all stage 1's for the network at time point zero, the program simulates traffic running through the network for one signal cycle and determines the overall impedence within the network.

5.6.2.4 A hillclimb technique is then carried out in which first offsets and later green splits at the various nodes are altered successively and the change in impedence is assessed. Finally, a point is reached where the impedence in the network is at a minimum and optimum green splits and offsets are found. A table of the final settings and degrees of saturation of the various links is printed out together

5.6.2.5 The program has inbuilt facilities to allow increased emphasis to be attached to key links in the network and the whole process can if desired be biased either towards minimum delay or minimizing stops to vehicles. A special routine is also available to separately model bus movements.

5.6.3 Using the Transyt Program

5.6.3.1 Subject to the availability of the off-line computer and prior arrangement authorized by CE/TC, officers from other TE Divisions with experience of using Transyt, may make use of the computer facilities at the Kowloon Area Traffic Control Centre for running Transyt. Arrangement for the use of these computer facilities would be handled by SE/K of TCD.

5.6.3.2 Manual checking of progression along major corridor by plotting time-distance diagrams and random checking of green times at critical junctions to safeguard against input errors are often rewarding prior to implementing the Transyt signal settings on the streets.

5.6.3.3 Users may refer to Appendix III for details of how the Transyt data is prepared, run and evaluated on the Kowloon ATC computer.

6.1 References

1 U.K. Road Research Technical Paper No. 56 – 'Traffic Signals' by Webster & Cobbe.

2 Papers of 'International Conference on Road Traffic Signalling 1982' – Institution of Electrical Engineers.

3 Departmental Advice Note TA/16/81 'General Principles of Control by Traffic Signals' – DTp, U.K.

4 'Recent Developments in Signal Technology' by A. Mowatt – Highways and Transportation No. 4 Volume 31 April 1984.

5 T.R.R.L. Laboratory Report 1014 'SCOOT – A Traffic responsive method of co-ordinating signals' U.K. D.O.E./D.Tp.

6 TCSD Report TC 03/84 'Report by B.J. Carter on SCAT, in operation in Sydney, N.S.W., Australia.

7 Transportation and Traffic Engineering Handbook – Institute of Traffic Engineers.

8 West Kowloon ATC Evaluation Study by A.J. Humphreys PWP 1978.

6.2 Introduction

6.2.1 Signals with permanent fixed cycle operation in where the timings and order of stages are not varied to meet changing conditions are rarely satisfactory. The delays experienced are usually unacceptable and the ensuing driver frustration can lead to disobedience.

6.2.1.2 In most urban traffic situations it is therefore desirable to change signal timings to allow for fluctuations in the traffic flow.
This is generally accomplished using one of the following methods:

(i) Area Traffic Control by means of computer

(ii) Co-ordinated Control in small area linking systems

(iii) Isolated vehicle actuated control.

6.2.1.3 Each of these control strategies is discussed in the succeeding paragraphs.

6.3 Area Traffic Control

6.3.1 General

6.3.1.1 Area traffic control, sometimes called Urban Traffic Control is the centralized control of traffic signals on an area-wide basis by means of computer.

6.3.1.2 Usually the traffic signal controllers on street are linked to the central computer in the control centre via data transmission cables. The cable network can either be provided as a dedicated network or private circuits leased from the Telephone Company.

6.3.1.3 The main facilities provide by ATC Systems are

(i) Optimized signal co-ordination
With the aid of centralized computer control, signal settings can be optimized on an area basis to provide minimum overall delay and reduced journey times.

(ii) Control flexibility
Changing traffic conditions can be catered for by vehicle actuation or pre-determined multi-plan operation. The time settings of traffic signals on the street can also be altered very quickly by manual intervention such as modifying the existing signal timing plan or replacing it with a new plan.

(iii) Fault Monitoring
One of the most important facilities offered by ATC Systems is the continuous monitoring of the operation of the traffic signal equipments linked to the computer. Any fault condition detected can be reported to the Control Room almost immediately and fault repairs can be carried out very much quicker than was possible under the old system of local control.

(iv) Priority for emergency and public transport vehicles
For fire appliances which always start from a certain fire station and usually travel only short distances to the scene of a fire, special plans may be prepared for predetermined ‘preferred routes’ and stored in the central computer. When an appliance leaves the station on one of these routes, these special plans are triggered and implemented by the computer so that signals on the route may be changed to provide a zero-delay or ‘green wave’ route to the fire appliance.
Alternatively, priority arrangements can also be given to other emergency vehicles and public transport vehicles by using some special detection equipments installed on the vehicles. On the detection of the approach of these special vehicles, signals will react directly or via the computer to make a priority signal change or give a priority green extension.
Movement of buses can also be enhanced by implementing traffic signal timings, calculated by the ‘Bus Transyt’ computer program which takes into account the speed of bus and dwell times at bus stops.

6.3.1.4 The development of traffic control on an area basis has led to the development of a number of methods of signal control. These can be broadly classified as fixed time, Semi-Responsive System and fully Responsive System.

6.3.2 Fixed Time ATC Systems

Fixed time ATC systems operate around a strategy of fixed time traffic signal plans for each controller. Signal timings plans for junctions alter in accordance with pre-set timetables held in the central computer. These systems works very well for traffic patterns which are predictable and which change quite slowly. Traffic signal timings are developed from historical traffic flow data collected for the junctions and the timings require updating periodically, depending on the traffic fluctuations at each site. Experience has revealed that fixed time systems are cheap and simple to install and maintain and when properly managed they can be as efficient as the responsive systems.

Transyt, a computer program is used in most fixed time systems as a tool for calculating optimized signal settings. The current version is Transyt 9 which permits priority junctions and opposing right turning streams of traffic to be modeled, and in common with previous versions give Performance Index for a network based on delays and stops experienced by traffic.

6.3.3 Semi-Responsive Systems

6.3.3.1 To overcome some of the rigidities inherent in the fully fixed time strategy, whilst avoiding some of the sophistications and complexities accompanying fully responsive strategies, some degree of traffic responsive control can be introduced into the fully fixed time philosophy. This can take two main forms :

(i) Using strategic detectors to detect fluctuations in traffic flow, the computer automatically changes from one fixed time traffic plan to another.
Basically all one is doing with this type of system if introducing a flexible timetable.

(ii) Installing vehicle presence detectors and pedestrian push buttons at junctions and introducing a V/A ‘window’ into the traffic signal timing plans. The difficulty with fully traffic actuated signals is that the concept of signal linking within a fixed cycle time breaks down under fully traffic-actuated control. The VA-window concept allows a certain amount of ‘local discretion’ in the traffic signal plan. This permits the controllers at certain times in the signal cycle to decide whether to change to the next stage or whether to remain on the stage running. Forced stage changes are still included in the signal cycle to maintain the fixed cycle time and hence maintain linking within signal groups.

6.3.3.2 System (i) is very effective in overcoming difficulties in defining accurately plan change points. Also, as only a relatively small number of detectors may be required, a heavy on-going maintenance commitment on detectors is unnecessary. Semi-responsive systems such as (i) should not require markedly more complex computer systems or controllers than fixed time systems.

6.3.3.3 System (ii) can be very effective in coping with minor fluctuations in traffic flow and with the problems of light vehicle and pedestrian flows in the off peak period. The number of detectors required however is larger than for (i) with a consequent increase in maintenance responsibilities. Semi-responsive systems using system (ii) strategy do require more complex signal controllers on street.

6.3.4 Fully Responsive Control

6.3.4.1 The logical extension of the computerized traffic control philosophy is the fully automated system, where the computer automatically calculates and adjusts signal timings to suit actual traffic condition on street. The two most prominent strategies for accomplishing this are discussed in this section

6.3.4.2 <u>The SCAT System</u>

(i) The SCAT (Sydney Co-ordinated Adaptive Traffic) System is based on a limited distributive intelligence system with a main computer performing certain monitoring functions and several satellite computers controlling a group of controllers on street.

(ii) Each regional computer maintains autonomous traffic responsive control of up to 120 local controllers without reference to the central computer, which is provided only for centralized monitoring of system performance and equipment status. The local controllers within each region are grouped into ‘systems’ and ‘sub-systems’. Systems of signals do not interact with each other as they are typically geographically unrelated. Sub-systems, however, do interact and may link together to form systems.

(iii) The sub-system may be considered as the basic element of control at the ‘strategic’ or multi-intersection level and may consist typically of between one and ten intersections which comprise a discrete traffic entity. The strategic control algorithms select, in response to detected variations in demand and capacity, the appropriate green splits, offsets and cycle length for each sub-system and the offsets which are to apply between sub-systems. Four ‘background’ green split plans are provided for each intersection and the selection of split plans is made at the sub-system level, based on the requirements of the critical intersection in the sub-system, which, therefore, contains only one such intersection. Five background internal offset plans, which determine the offsets between intersections within the sub-system and five external offset plans for linking adjacent sub-systems, are provided. All intersections within a sub-system operate on a common cycle length.

(iv) All intersections are equipped with inductive loop vehicle detectors on all approaches. These are located in each lane immediately in advance of the stop-line and perform the dual functions of providing traffic flow data for strategic control and local or ‘tactical’ vehicle actuation. For strategic operation the local controller passes the regional computer, for each detector defined as a strategic detector, the number of vehicles counted during green on the approach and the total time that the loop was unoccupied during the green.

6.3.4.3 The SCOOT System

(i) The SCOOT (Split Cycle Offset Optimisation Technique) System consists a number of SCOOT cells or computers, each cell being able to control up to 60 junctions, handling input data from up to 256 vehicle counting detectors on street. Unlike with the SCAT system, the SCOOT detectors are placed as far upstream from the approach to the junction as possible and are then calibrated to strike a balance between flow and occupancy.

(ii) In normal operation SCOOT is estimating whether any advantage is to be gained by altering the timings. If an advantage is predicted then one or more of the timings are changed by small amounts. By this means frequent but small changes allow the signals timings to match the fluctuations in traffic demand. There are no large and abrupt changes in signal timings, although over time major changes in splits, cycle time and offset can occur due to the additional small incremental changes.

(iii) The decisions to alter the signal timings are taken on the basis of the calculated queuing behaviour of traffic. All significant movements are monitored using inductive loop detectors. This information enables on-line estimates to be made of traffic behaviour at the junctions. This traffic model information is used by the optimizers to adjust splits (ratio of green time available to conflicting approaches to the junction), offsets (time of stage 1 green start of a junction in relation to a time datum for the cycle time region) and cycle time (the repetition time of the stage patterns of all junctions in the cycle time region) at the junctions. Special procedures are implemented for congestion. SCOOT provides powerful traffic monitoring facilities.

(iv) The five major subsystems of the SCOOT strategy are :

(a) Detector Analysis;

(b) Traffic Model;

(c) Optimisers;

(d) Signal Control;

(e) Monitoring.

6.3.4.4 Advantages/Drawbacks of Fully Responsive Systems

(i) It is immediately apparent that an automatic traffic control system offers advantages over other ATC systems :

(a) As timings are calculated automatically the heavy on going workload in manual signal timing updating is obviated

(b) Fluctuations in demand during both peak and off peak conditions can be efficiently catered for.

(c) Unforeseen situations such as breakdowns or roadworks can be automatically adjusted for

(ii) There are however some drawbacks with these types of systems :

(a) The systems are very dependent upon the traffic signal detector data for efficient operation. A large number of detectors are necessary (approximately 4 to 5 per intersection). This necessitates a very high maintenance involvement in ensuring rapid detector repair.

(b) The system itself is far more sophisticated and complex than the fixed time systems and therefore system maintenance and system development are consequently more complex.

(iii) On balance however experience in UK and Australia with these systems has indicated that the benefits accruing from their introduction generally more than outweigh the possible difficulties.

6.3.5 Compact ATC Systems

6.3.5.1 For large urban areas with possibly several hundred traffic signal controlled intersections, a large (maxi) system as described above with its purpose constructed computer and monitor rooms with wall maps, VDU’s and possibly closed circuit television is an entirely appropriate arrangement. Usually this type of maxi system will demand (and can justify) its own dedicated team of hardware and systems engineers, traffic engineers and technicians and system operators.

6.3.5.2 For medium-sized cities or smaller towns, with perhaps up to 60 sets of traffic signals, the benefits accruing from the installation of a maxi system cannot be justified in terms of the initial costs and staff resources demanded to run it. Up until the mid 70’s these smaller urban areas had to operate their signals in small linked systems which, whilst generally satisfactory, could not provide the flexibility of control nor degree of signal fault monitoring which are characteristic of computerized traffic control. The requirement for an intermediate scale computer system to serve the needs of these smaller urban areas was recognized and by the mid 1970’s several ‘mini ATC’ or ‘Compact ATC’ systems as they are known became available. The features of these systems are fairly standard :

(i) Computer and data transmission system in a stand-alone unit which does not require a specially controlled environment.

(ii) 'OFF the shelf' system operating software

(iii) Automatic printout of faults; can be left to run virtually unattended.

6.3.5.3 Usually these systems are purchased as a complete package to a standard specification. This minimizes the staff input at the outset of the scheme.

6.3.5.4 Standardisation usually means that the costs involved in the purchasing of such a system are modest. As the system requires no special architectural/environmental arrangements, and will virtually ‘run itself’ the staff input on the part of the purchaser is also small. Much of the flexibility and monitoring facilities of the maxi systems are however maintained and signal timings can be kept up to date by a small TE team, possibly on a part-time basis in addition to normal traffic engineering duties.

6.4 Small Area Linking Systems

6.4.1 Master linking systems

6.4.1.1 For smaller areas where compact ATC are not provided or could not be justified signals may be co-ordinated in small linking groups where local controllers are cable linked to a master controller.

6.4.1.2 With the recent rapid advancement of microprocessor technology the facilities offered by the latest type of master-linked system are very much extended. Depending on the equipment and supplier, the usual facilities may be a combination of the following :

(i) Signal co-ordination effected by implementing control messages sent out from master controllers to local controllers which control the traffic lights in the intersections.

(ii) Capability of fixed time multi-plan operation to cater for traffic variations.

(iii) Capability of semi-VA operation such as selection of pre-determined plan by means of traffic actuation.

(iv) Capability of linking the master controller to other linking group masters or to a supervisory master controller or to a manual control panel.

6.4.2 Cables Linking Systems

6.4.2.1 Co-ordination of signals in small areas may also be achieved by use of a real time clock synchronized by the mains frequency and incorporating a solid state memory store. Stage timings, cycle times and stage offset periods between junctions are stored in memory and these plans are selected according to the time of the day to cater for variation in overall traffic pattern. The plan sequence can also be varied according to the day of the week.

6.4.2.2 Usually one demand dependant stage which can be selected by a vehicle demand or a pedestrian demand can be incorporated. If such a stage is not demanded, then the time is added to the preceding stage.

6.5 Isolated Vehicle-actuated Signals

6.5.1 With vehicle-actuated signals the duration of green periods and the cycle time will vary in relation to the traffic flow into and through the control area. Vehicle-actuated signals will be appropriate for isolated junctions where co-ordination with other neighbouring signals is not important. It is also suitable for locations with fluctuating traffic flows and where traffic is not very heavy. (See 3.2.4 for further details)

6.6 Further Developments in Traffic Control

6.6.1 DUET – Dial-up Equipment Testing

6.6.1.1 It is arguable whether the greater benefit obtained from an ATC system is derived from signal co-ordination or from the ability to monitor continuously the performance of signal equipments. For signals in remote locations where the cost of connection to an ATC System is not justified, DUET may provide a compromise solution. With the aid of this technology the equipment can be interrogated over the public telephone lines as and when necessary.

6.6.1.2 Each local controller will be connected to the normal public telephone system. Communication is achieved by dialing a conventional telephone number from the Central Office, which connects the local controller to some special equipment in the Central Office for testing/fault reporting purposes.

6.6.1.3 The arrangement avoids the need for a dedicated private circuit but provides only a limited fault monitoring facility as equipment faults will only be detected when the interrogation takes place, which may be some time after the fault has occured.

6.6.2 Lamp Monitoring

6.6.2.1 One aspect of monitoring which is notable for its omission from ATC systems to date is lamp monitoring. Most authorities operate inspection routines or have fault reporting centres, but these can be costly and delay in attending to faulty lamp bulbs inevitably takes place. Research woks are being carried out on the feasibility of automatic lamp monitoring by ATC systems. If successful within cost limits, it will provide a more efficient and cost effective service and the traditional policy of bulk replacement of lamps may be reviewed.

7.1 References

1. Laws of Hong Kong Chapter 374 "Road Traffic Ordinance and Subsidiary Legislation"

2. Transport Department Specifications for Traffic Signal Equipment:-

   (i) TCS-005 Specification for Traffic Signal Controller for Use Outside Existing ATC Systems (Issue 1-October 2002)

   (ii) TCS-006 Specification for Traffic Signal Controller for Use In Existing ATC Systems (Issue 1-October 2002)

   (iii) TCS-012 Specification for Pedestrian Traffic Signal Controller (Issue 1-October 2002)

   (iv) TCS-013 Specification for Portable Road Traffic Signals (Issue 2-March 2005)

   (v) TCS-013A Guidance Notes for the Use of Portable Road Traffic Signals (Issue 1-March 2005)

   (vi) TCS-021 Specification for Road Traffic Signals (Issue 1-October 2002)

   (vii) TCS-022 Specification for LED Road Traffic Signals (Issue 2-February 2006)

   (viii) TCS-031 Specification for Audible Traffic Signals and Related Equipment (Issue 1-October 2002)

   (ix) TCS-032 Specification for Pedestrian Flashing Green Countdown Display (Issue 1-October 2002)

   (x) TCS-033 Specification for Vehicle Detector (Issue 1-October 2002)

   (xi) TCS-041 Specification for High Mast Mounting CCTV Camera (Issue 1-October 2002)

   (xii) TCS-100 Specification for Environmental Requirements (Issue 1-October 2002)

   (xiii) TCS-200A Specification for Prequalification Procedures for Traffic Signal Control Equipment (Issue 1-December 2002)

   (xiv) TCS-210 Specification for Type Approval for Portable Road Traffic Signals (Issue 2-February 2004)

7.2 Introduction

7.2.1 Approval, Evaluation and Procurement

7.2.1.1 All road traffic signal equipments shall be approved by the Transport Department before they can be installed for the control of traffic and pedestrians.

7.2.1.2 The approval, evaluation, procurement, storage and allocation of road traffic signal equipment are handled as follows:

(i) Approval and evaluation of traffic signal equipment by Traffic Control Division (TCD).

(ii) Procurement, storage and allocation of traffic signal equipment (other than signal controllers) by EMSD.

(iii) Procurement, storage and allocation of signal controllers by TCD.

7.2.2 Specifications

7.2.2.1 Current Specifications for Traffic Signal Equipment are as follows:-

(i) TCS-005 Specification for Traffic Signal Controller for Use Outside Existing ATC Systems (Issue 1-October 2002)

(ii) TCS-006 Specification for Traffic Signal Controller for Use In Existing ATC Systems (Issue 1-October 2002)

(iii) TCS-012 Specification for Pedestrian Traffic Signal Controller (Issue 1-October 2002)

(iv) TCS-013 Specification for Portable Road Traffic Signals (Issue 2-March 2005)

(v) TCS-013A Guidance Notes for the Use of Portable Road Traffic Signals (Issue 1-March 2005)

(vi) TCS-021 Specification for Road Traffic Signals (Issue 1-October 2002)

(vii) TCS-022 Specification for LED Road Traffic Signals

(viii) TCS-031 Specification for Audible Traffic Signals and Related Equipment (Issue 1-October 2002)

(ix) TCS-032 Specification for Pedestrian Flashing Green Countdown Display (Issue 1-October 2002)

(x) TCS-033 Specification for Vehicle Detector (Issue 1-October 2002)

(xi) TCS-041 Specification for High Mast Mounting CCTV Camera (Issue 1-October 2002)

(xii) TCS-100 Specification for Environmental Requirements (Issue 1-October 2002)

(xiii) TCS-200A Specification for Prequalification Procedures for Traffic Signal Control Equipment (Issue 1-December 2002)

(xiv) TCS-210 Specification for Type Approval for Portable Road Traffic Signals (Issue 2-February 2004)

7.3 Commonly-used Equipments

7.3.1 General

7.3.1.1 The following discussion on commonly-used traffic signal equipments outlines the general requirements only. For further details, the user should consult available specifications and supplier's manual/handbook for the particular equipments concerned.

7.3.2 Traffic Signal Controllers

7.3.2.1 The present day controllers are microprocessor based which enable them to possess very versatile and powerful control functions. They normally have modular designs that allow the controllers to be expanded to control, depending on the different types of controllers, up to a maximum of 16, 32 or 64 phases. Whilst the permanent control data are customized and stored in the erasable programmable read only memories (EPROM), the controllers allow users to, via a hand held engineer's terminal or note book computer, amend temporary data such as signal plan timings and timetables.

7.3.2.2 Most signal controllers possess the following features:

(i) Capability of operating in any of the following modes:

  (a) Hurry Call – This mode may be requested by the local detector or by switch input to allow priority to be given to a particular movement for the passage of emergency vehicles e.g. fire engines.

  (b) Manual – This mode will allow the controller to operate under manual control, usually by Police.

  (c) Local Co-ordinate Mode – Multi-plan operation in this mode shall be possible in accordance with plans and timetable stored.

  (d) Local Isolated Vehicle Actuated Mode – The controller in this mode may operate with a mixture of fixed-time, demand dependent and vehicle-actuated phases.

(ii) Capability of cableless linking.

(iii) Capability of linking to a pedestrian controller for co-ordinated control.

(iv) Capability of incorporating pedestrian push buttons, pedestrian wait indicators and pedestrian audible signals.

(v) Capability of lamp failure monitoring.

(vi) Capability of logging controller faults.

(vii) Capability of dimming lamps in the hours of darkness.

7.3.3 Pedestrian Traffic Signal Controllers

7.3.3.1 Pedestrian Traffic Signal Controller is a simple and economical controller designed specially for use at mid-block crossings. A number of them have been installed in the past. However, since the price of normal and more versatile traffic signal controllers have reduced substantially, the merits of pedestrian controllers have diminished and no new pedestrian controllers have been purchased since the mid 90's. As a result, pedestrian controllers are being phased out.

7.3.3.2 Basic facilities of Pedestrian Controllers are:-.

(i) Simple 2 stages, 2 phases controller of which one phrase shall be vehicle phase and the other the pedestrian phase.

(ii) The vehicle phase shall operate on a fixed time or vehicle actuated basis.

(iii) The pedestrian phase shall be either demand dependent (pedestrian push button) or fixed cycle operation.

(iv) It shall be possible to link the controller to remote traffic signal controller to provide co-ordinated signal operation.

(v) Capacity of working in manual mode for police control.

(vi) Capacity of working in pedestrian push button, pedestrian 'wait' indicators and pedestrian audible signals.

7.3.4 General Road Traffic Signals

7.3.4.1 Equipment and material should be in accordance with Specification TCS-021 (Issue 1-October 2002).

7.3.4.2 The size, colour, type and arrangement are governed by the Third Schedule of Road Traffic (Traffic Control) Regulations.

7.3.4.3 Vehicular signals should contain three optical systems arranged vertically each having a nominal diameter of 200mm.

7.3.4.4 Pedestrian signals should contain two optical systems arranged vertically and shall normally each have a nominal diameter of 300mm, an alternative size of 200mm nominal diameter may also be used where necessary.

7.3.4.5 Where an optical system incorporating a green arrow is used, it shall normally have a nominal diameter of 300mm but an alternative size of 200mm nominal diameter may also be used if necessary.

7.3.4.6 Signal head should have adequate mechanical strength and durability to withstand the conditions of installation and normal use operations. It should be dust proof and weatherproof against corrosion and action of direct sunlight without significant deterioration in mechanical strength. The signal head assembly together with the attachment of a backing board shall be capable of withstanding wind velocities up to 160 km/hour in any direction and temperature over a range of -25ºC to 70ºC.

7.3.4.7 Normal traffic signals are lighted by halogen light bulbs. At the time of updating this volume of TPDM. Transport Department was evaluating the feasibility of LED traffic signals. It is likely that LED signals will be extensively used because of lower power consumption, longer service life, less maintenance and reduced phantom effects, despite a higher capital cost. Currently, the signal controllers are designed to detect lamp failure of halogen bulbs. They cannot detect LED lamp failure because of the latter's low power consumption. It is expected that the next generation signal controllers would be able to detect failure of LED lamp.

7.3.4.8 Overhead traffic light signals are more expensive than ordinary pole mounted signals and may be used on high speed roads and at other locations where its use could be justified e.g. to overcome site constraints and obstruction problems, increase visibility and improve safety etc. It is however recommended that overhead signals should preferably be used to complement pole mounted signals rather than exclusively used in a traffic light installation. Reference should be made to 4.3.3.3 for detailed recommendations on the use of overhead signals.

7.3.5 Portable Signals

7.3.5.1 Portable traffic signals are used for 2 phase shuttle working at roadworks on roads other than limited access roads.

7.3.5.2 Portable signals should be in accordance with Specification TCS-013 (Issue 2- March 2005).

7.3.5.3 The features of portable signals are prescribed in the Third Schedule of the Road Traffic (Traffic Control) Regulations. No portable traffic signals equipment may be used at roadworks unless it has received Type Approval from Transport Department.

7.3.5.4 An updated list of approved manufacturers is available from Traffic Control Division.

7.3.5.5 Similar to ordinary vehicular signals each portable signal head is composed of 3 optical systems arranged vertically and the sequence of operation of the signals is identical i.e. red, red/amber, green and amber.

7.3.5.6 The height of the center of green lens shall be not less than 1.5 meters nor more than 2.5 metres from the surface of carriageway. The signal may be mounted on a post or a tripod but either case the colour of the post or tripod shall be yellow.

7.3.5.7 The equipment shall be capable of operation in the vehicle actuated, fixed time and manual mode. Equipment which operates in Fixed Time and Manual modes without VA mode option may also be considered for evaluation and approval.

7.3.5.8 Normally overhead vehicle detectors (e.g. passive infrared detector) or inductive loop vehicle detectors are used with the portable signal controller. Overhead vehicle detectors are usually mounted just above the red signal light on each approach and shall be directed generally along the axis of the traffic signal optical system.

7.3.5.9 Use of portable traffic signals in roadworks should be in accordance with 'Code of Practice for the Lighting, Signing & Guarding of Roadworks' prescribed by the Highways Department and 'Guidance Notes for the Use of Portable Traffic Signals' (TCS-013A(Issue 1-March 2005)) .

7.3.6 Vehicle Detection Equipments

7.3.6.1 All vehicle detection equipment for traffic control purposes should be approved by Transport Department. Generally, the detectors should achieve a minimum count accuracy and presence certainty of 95% and 98% respectively.

7.3.6.2 Inductive loop detectors

(i) The basic system consists of a loop of wire (typical 2 or 3 turns) buried approximately 50mm below the road surface. The ends of the loop are returned, via a twist pair of feeder cable to the vehicle detector usually housed some distance away in the controller cabinet. A small electric current is passed through the loop and this causes an electric field to be built up. A change in the inductance of the loop occurs when a vehicle is positioned over it or is passing over the loop. The change in inductance is sensed by the vehicle detector unit and a signal is output to indicate the presence of a vehicle.

(ii) Provided that loop detectors are properly installed, tested and maintained they will work reliably and offer very efficient and accurate detection. They can provide counting, occupancy data and speed (for double loops) data. With the advance of modern technology this type of detector may be further developed to provide congestion, and vehicle classification information.

(iii) The inductive loop vehicle detector equipment should comply with U.K. Department of Transport Specification MCE0100. The equipment should have a fully automatic self-tuning capability for overcoming detector tuning drift problems.

(iv) It is recommended that the specifications and installation guidelines given in 'Welsh Office Standard for the Installation of Inductive Loops for Vehicle Detection (1981)' should be followed wherever practicable.

(v) All loop detector systems should have a built-in mechanism to check the working conditions of the loops. Traffic signal controllers normally have a feature to proclaim a loop faulty if no vehicles were detected within a prescribed period (normally 1 to 24 hours) and create a permanent demand in the absence of the detector.

(vi) Despite their very efficient and accurate detection, inductive loop detectors have a number of disadvantages: Installation and maintenance require lane closure; detectors are liable to damage and dislocation by road traffic; and Highways Department's frequent resurfacing works require loop detector re-installation. Practical experience in Hong Kong shows that loops detectors are very difficult to maintain and once damaged, it takes very long time for reinstatement. Non-inductive technologies can overcome these disadvantages.

7.3.6.3 Microwave detectors

(i) The method of detection is based on the principles of Doppler effect or radar. The operation of the vehicle detector is by transmitting a microwave beam from a detector mounted above ground and as vehicle moves within this beam a signal is reflected back to the detector. Microwave detectors should be designed to the requirements of U.K. Department of Transport Specification MCE0114.

(ii) Microwave vehicle detectors would appear to be an attractive alternative to loop detectors as the installation is relatively cheap and it can overcome the problem of loop failures which have occurred with inductive loop detectors. However, the microwave frequency of the detectors do not meet the requirements of the Office of the Telecommunications Authority, which are different from the standards of the manufacturers' home countries. This obstacle has hampered the introduction of microwave detectors to Hong Kong.

7.3.6.4 Ultrasonic detectors

(i) Passive acoustic sensors and information-processing systems that collect the noise generated by stationary or moving vehicles in a detection zone on the roadway. Only those vehicle sounds from within a specific detection zone are retained. Sounds from locations outside the detection zone (such as an adjacent lane) are severely attenuated and are ignored.

(ii) Active acoustic sensors and collect ultrasound emitted by the detector and reflected by the vehicles.

The detectors are normally overhead-mounted. They can provide volume, speed, occupancy, presence, and classification data. It should be noted that adverse weather conditions such as strong winds and rain might affect the detector efficiency.

7.3.6.5 Infrared detectors

(i) There are two types of infrared detectors: active and passive. Infrared detection systems can provide volume, speed, occupancy, presence, and classification data.

(ii) Active infrared detectors focus a narrow beam of energy onto an infrared-sensitive cell, and vehicles are detected when they pass through the beam, interrupting the signal. These detectors can be used either as presence or pulse detectors. Detector performance can be affected by weather conditions (fog, rain, snow) causing inconsistent beam patterns. It may be difficult to maintain alignment on vibrating structures. Passive infrared detectors do not transmit energy, but measure the amount of energy emitted by objects in their field of view.

7.3.6.6 Video image processing

(i) TWith video image processing, CCTV cameras provide images that are used by a video processor to emulate traffic data. It is possible to define multiple detection locations within the camera viewing area. These “pseudo-detectors” are not fixed, but may be moved by the operator if desired. The type of signal processing algorithm used by the image processor dictates the type of data obtainable by the system.

(ii) These systems can provide volume, occupancy, and presence detection. In more advanced systems, individual vehicles are tracked as they pass through the field of view, allowing identification of speed, vehicle classifications and travel times in the detection zone. Most processing algorithms have been optimized to reduce the effects of shadows, illumination changes, and reflections.

(iii) It should be noted that inclement weather and poor lighting could affect performance. The transmission of CCTV signals requires a wide communication bandwidth. However, the latest products have the processor incorporated into the camera which outputs processed data for direct feed to the detector card of a traffic signal controller.

8.1 References

(1) Departmental Advice Note TA/14/81 'Procedures for Installation of Traffic Signals And Associated Equipments' DTp, UK.

(2) Department Advice Note TA/13/81 'Requirements for the Installation of Traffic Signals and Associated Equipment' DTp, UK.

(3) Code of Practice for the Lighting, Signing and Guarding of Roadworks, Highways Department, Hong Kong.

(4) Departmental Instructions, Transport Department, Hong Kong.

(5) TCS-02/83 – The Programming and Implementation of Traffic Management Schemes.

8.2 Introduction

8.2.1 General

This Chapter outlines the normal works and procedures involved in the implementation of signal schemes. Procedures for signal schemes in the New Territories may be slightly different.

8.2.2 Initiation

8.2.2.1 Pressure for new signals/signal modifications may come from a variety of sources. The following are the most common sources :-

(i) Complaints from the general public;

(ii) Input from District Councils;

(iii) Suggestions from Police;

(iv) Schemes suggested by various Divisions/Sections in Transport Department;

(v) Schemes generated by other Government Departments.

8.3 Preparation and Funding

8.3.1 Preparation of Signal Schemes

8.3.1.1 Virtually all Suggestions/requests for traffic management measures including signals are funneled down to the Traffic Engineering Divisions. It usually falls upon the Traffic Engineering Division to examine and prepare a signal proposal for circulation and discussion internally in the Transport Department. When an agreements is reached, the Traffic Engineering Division well then circulate the scheme to outside bodies such as Police, Highways Office and District Boards etc. for comments/agreement.

8.3.1.2 Signal schemes forming part of Consultant projects may be prepared and circulated by Consultants. Normally these proposals would be circulated initially to Transport Department for agreement in principle before circulating to other offices.

8.3.2 Funding of Signal Installation

8.3.2.1 After the scheme has been finalized and agreed, the Traffic Engineering (TE) Division will produce the necessary working drawings and pass them to the appropriate Works Division, Highways Department and the involved parties such as, EMSD, TCD etc. for estimating purposes. The Divisions involved will provide the appropriate Works Division, Highways Department with estimates of the cost of works they are required to carry out. The appropriate Works Division, Highways Department will then produce a consolidated estimate and pass this to the Traffic Engineering Division.

8.3.2.2 Similar consultants handling signal projects may have to liaise with relevant involved bodies to obtain a consolidated cost estimate.

8.3.2.3 Depending upon the cost and scope of the scheme, it will be funded :-

(i) By the Traffic Engineering Division out of its traffic management improvement vote except for the cost of laying tele-communication cable and duct network in the ATC area which would be borne by TCD.

(ii) By the Highways Department from minor improvements.

(iii) By other Divisions after creation and approval of a special project item in the Lands and Works Programme.

8.4 Work Implementation

8.4.1 Procurement, customization and installation of traffic signals

8.4.1.1 (a) Procurement of traffic signal equipments (other than signal controllers) is handled by EMSD.
(b) Procurement of signal controllers is handled by TCD.

8.4.1.2 Traffic Engineering Divisions or other user Offices such as CEDD, Highways Department etc. inform EMSD/TCD of the requirement for traffic signal equipment including quantity, programme and any other required options such as controller customization and installation.

8.4.1.3 Upon confirmation of funds, EMSD/TCD invite tender and process the procurement of the signal equipment in conjunction with Government Supplies Department.

8.4.1.4 EMSD/TCD co-ordinate with the Contractor on the subsequent equipment delivery and customization/installation if necessary.

8.4.2 Associated Civil Engineering Works

8.4.2.1 Civil engineering works in signal projects generally include :-

(1) Excavation and trenching in carriageway and footway.

(2) Laying of cable ducts, including the provisions of draw wires and construction of draw-pits.

(3) Backfilling and reinstatement of excavations and trenches.

(4) Removal of surplus spoil, stones from site.

(5) The setting Out, provision and leveling of foundations for receiving the equipments.

(6) Installation of street furnitures such as guard-rails, traffic signs, signal posts etc. and the painting of road markings,

8.4.2.2 These works are normally carried out by the regional Highways Works division.

8.4.2.3 Preferred standard of cable ducts installation is given in Appendix II for reference purpose.

8.4.3 Associated Electrical Works

8.4.3.1 These works include :-

(i) Laying of aspect cables, linking cables or tele-communications cables in the ATC area.

(ii) Necessary cable jointing work.

(iii) Erection of signal aspects including wiring connection works.

8.4.3.2 The above works are normally carried out by Electrical and Mechanical Services Division.

8.4.3.3 Preferred standard on cable network provision is given in Appendix II for reference purpose.

8.4.4 Power Supply Arrangement

8.4.4.1 Arrangements with the Power Companies i.e. China Light & Power Co. Ltd. or Hong Kong Electric Co. Ltd. have to be made for providing electricity supply to the equipments.

8.4.5 Traffic Signal Controller Works

8.4.5.1 These works include the following:

(1) Customization of controller to suit the designed method of control.

(2) Installation of controller.

(3) Termination of cables and provision of earthing.

(4) Instation and outstation testing.

8.4.5.2 These works are either carried out by EMSD or by the signal supplier under the supervision of the T E Divisions or TCD.

8.4.5.3 Controller Testing

As a general practice, it is recommended that a traffic signal controller shall have undergone the following test prior to acceptance:-

(i) Quality Assurance Test

Each controller shall be inspected for quality of construction and workmanship and for any damage sustained during transit. The controller shall then be powered up and be set to operate continuously for at least 48 hours. Operation tests shall be performed to demonstrate the equipment's correct operation and to demonstrate that all faults identified in factory tests have been rectified and that no damage has occurred during transit.

(ii) Post-Customization Tests

After the controller has been customized in accordance with the Engineer's instruction, full operational test shall be performed to ensure correct functioning of the equipment and to confirm the controller has been correctly customized to the specific site requirements including all time settings, plan data etc. On satisfactory completion of the operational tests, the controller shall be left to operate continuously in Local Co-ordinated mode (or any other mode as specified by the Engineer) for at least 7 days. The Engineer and his representative shall perform random tests and observation on the controller during this 7 days period. During this test, the controller will be connected to either a purpose built lamp box or high intensity signals, or a mixture of both.

(iii) On-Site Commissioning Tests

On completion of the installation work, tests shall be carried out with signal lamps connected. The test shall primarily consist of two parts :-

(a) Wiring Test – Each phase will be switched on in turn to check that connections to aspect lamps and cables are correct, and to confirm that all conflicting phases are displayed red signals when the tested phase is on green. The phase sequence is also checked.

(b) Full Operational Tests – Correct operation of each mode and the switching between modes will be tested, All pre-set timing data will be examined and measured, All safety features, e.g. conflicting green and inhibit movements will be checked for correct operations,

During the test, it shall be necessary to temporarily remove the reflectors on the signal aspects (or to open the door of the signal aspect housing) to avoid confusion to motorists using the junction and Police's assistance to manually control the traffic is also required.

(iv) Period of Satisfactory Operation

After the completion of the Test (iii), the equipment shall operate satisfactorily for 60 days without a single fault.

8.5 Monitoring

8.5.1 Progress Monitoring of Signal Projects

8.5.1.1 Depending on the importance, complexity, seriousness and urgency of the signal scheme, a target completion date will have to be set for each project.

8.5.1.2 For this target date to be realistic and practicable, it has to be checked against component activities. It is in fact advisable to set individual target dates for the following component activities for assessing the overall project target completion date and subsequent monitoring of progress:-

(i) Equipment availability – Normally a lead time of 9 months will be required for the procurement of new signal equipments. Equipment may also be available from floating stock or by re-scheduling the programme of other signal schemes.

(ii) Civil Engineering works – Timely completion of civil engineering works is important as many other activities such as EMSD, controller installation works etc, are dependent upon the completion or substantial completion of the civil engineering works.

(iii) Electrical works by EMSD – normally these works take about 3 weeks time to complete after the civil engineering works.

(iv) Controller works by EMSD or TCD – Normally a lead time of about five weeks is required before the switching on of signals. Provided that other works are properly co-ordinated and scheduled, switching on of signals can be effected in one week after completion of electrical and power supply works.

(v) Power Supply works – The arrangement normally requires a lead time of approximately two months.

(vi) Others – Usually a minimum of two weeks should be allowed for processing press notice works or arranging police assistance on the day of commissioning the new signals.

8.5.1.3 The co-ordination of the involved bodies in a signal project is the responsibility of the appropriate TE Divisions and Highways Department. The progress of the signal project should be closely monitored and the target dates of component activities should be re-scheduled if slippages have occurred.

8.5.2 Monitoring and Review of Signals Performance

8.5.2.1 New Signals

New signals after commissioning/modification should be monitored closely for a period of time say 2 to 4 weeks to cheek for the following :-

(i) Performance of the signals to cope with different traffic situations i.e. peak hour, off-peak, tidal flows and light traffic conditions etc.

(ii) Co-ordination of signal with neighbouring signals it should however be noted that the progressions in light traffic condition should not be so good as to encourage speeding of vehicles.

(iii) Pedestrians facilities provided should be adequate. Minimum pedestrian crossing times, flashing green times and clearance periods should be checked on site.

(iv) Vehicle green times should not be excessive. Unused vehicle green can lead to non-observance of the signals by pedestrians, and to speeding through the junction by vehicles.

(v) It is desirable that before and after vehicle journey time surveys should be carried out to assess the performance of the signals. This would also provide a reference for subsequent evaluation.

8.5.3 Monitoring of Existing Signals

8.5.3.1 To meet changing patterns and demands of traffic, it is desirable that a review of performance of exiting signals should be carried out on a regular basis, at approximately 18 months intervals, or earlier if staff resources permit.

8.5.3.2 For the purpose of the review, the following data needs to be collected:-

(i) Up-to-date traffic counts

(ii) Up-to-date junction layouts

(iii) Any journey time survey data

(iv) Other information on signal performance such as complaints, records of police control incidence, accident statistics.

8.5.3.3 The signals will be reviewed in conjunction with the above data to see if there has been any degradation on performance of signals as reflected in the journey time survey or as indicated by changes in traffic patterns or demands which would warrant a revision of the traffic plan timings or the method of control.

8.5.3.4 In updating the traffic plan timings of road network, the computer facilities in TCD may be used for running TRANSYT programs.

8.5.3.5 New traffic plan timings require testing on site and tuning i.e. minor adjustments in offsets and green splits to suit site characteristics before permanent incorporation into the controller or computer.

8.5.3.6 Before and after journey time surveys should be carried out for any major revision in the method of control or traffic signal timings for performance evaluation purposes.

8.5.3.7 The above signal review exercise may also be performed on an adhoc basis where and when there is a requirement for so doing such as: -

(i) Roadworks, diversions etc. which would affect traffic for quite some time.

(ii) Opening of new roads.

(iii) Marked deterioration in the performance of signals, i.e. feedback from Road Safety and Standard Division, site observations, Police, public etc.

8.5.3.8 Should resources permit it is desirable to conduct random journeys by car throughout the signal control area. This would serve to monitor the signal performance as well as to feedback any noticeable change in traffic patterns e.g. due to road opening etc. This is particularly applicable to areas not covered by surveillance cameras.

Appendix I – summary or Formula and specimen Calculations

Part I) Summary of commonly used formula

c	Cycle time
c_o	Optimum cycle time
c_m	Minimum cycle time
c_p	Practical cycle time
d	Average delay
g	Effective green time
G	Green time
I	Intergreen time
K	Combined green and amber period
	Lost time for a single phase
L	Total lost time per cycle
N	Average queue at the beginning of green period
No	Average overflow queue
q	Flow
Q	Capacity of approach
r	Effective red time
R.C.(c)	Reserve capacity at current cycle time c
R.C.(ult)	Ultimate reserve capacity
S	Saturation flow
W	Width of approach
X	Degree of saturation
X_o	Degree of saturation under optimum signal timings
X'	Degree of saturation below which the average overflow queue is approximately zero
Y	Flow factor
Y	Summation of flow factors
Ymax	Maximum possible Y at current cycle time c
Yult	Ultimate Y value
	Proportion of cycle which is effectively green for a particular phase

$Q = \frac{gS}{C}$	(1)
$g = k - l$	(2)
$g = G + 1$	(3)
$L = \sum(I - 1)$	(4)
$y = \frac{q}{S}$	(5)
$Y = \sum y$	(6)
$C_o = \frac{1.5L + 5}{1 - Y}$	(7)
$C_m = \frac{L}{1 - Y}$	(8)
$C_p = \frac{0.9L}{0.9 - L}$	(9)
$\frac{g1}{g2} = \frac{y1}{y2}$ etc.	(10)
$g = \frac{y(c - L)}{Y}$	(11)
$Y_{max} = 1 - \frac{L}{c}$	(12)
$Yult = 0.9 * 0.0075L$	(13)
$R.C(ult) = \frac{Yult - Y}{Y} * 100\%$	(14)
$R.C.(c) = \frac{0.9Y_{max}Y}{Y} * 100\%$	(15)
$X = \frac{q}{Q}$ or $\frac{qc}{gS}$	(16)
$X_o = \frac{2Y}{1 + Y}$	(17)

Delay and Queues by Webster

$$d = \frac{C(1-\lambda)^2}{2(1-\lambda X)} + \frac{X^2}{2q(1-X)} - 0.65 \left(\frac{c}{q^2}\right)^{\frac{1}{3}} X^{(2+5\lambda)} \qquad (18)$$

$$N = q\left(\frac{r}{2} + d\right) \quad \text{or} \quad = qr \text{ whichever the greater} \qquad (19)$$

Delay and Queue by Akcelik

$$No = \begin{cases} \frac{Qt}{4}\left(Z + \sqrt{Z^2 + \frac{12(X - X^1)}{Qt}}\right) \text{ for } X > X^1 \\ \text{zero} \qquad \text{otherwise} \end{cases} \qquad (20)$$

where $Z = X - 1$

$$X^1 = 0.67 + \frac{Sg}{600} \qquad (21)$$

$$d = \frac{C(1-\lambda)^2}{2(1-y)} + \frac{NoX}{q} \qquad (22)$$

$$N = qr + No \qquad (23)$$

Part II) Specimen Calculations
Example 1: Signal Calculations for a Fixed Time Signal

Junction: Nathan Road / Kansu Street
Time of day: A. M. Peak Hour Conditions
Data Sheets: ATC/B26/1A - Layout
DS2/008F - Method of control
TTSD's movement count dated 27.2.84

1) Saturation Flow Estimation

Nathan Road S/B width = 10.0 m
Nearside lane S = 1940 + 100 (w - 3.25) p.c.u. = 1948 p.c.u.
Non-nearside lane S = 2080 + 100 (w - 3.25) p.c.u. = 2088 p.c.u.
assuming no gradient effect
Total saturation flow = 6124 p.c.u.

Nathan Road N/B
assuming 2 lanes of width 6.6 m
Nearside lane S = 1940 + 100 (w - 3.25) p.c.u. = 1945 p.c.u.
Non-nearside lane S = 2080 + 100 (w - 3.25) p.c.u. = 2085 p.c.u.
assuming no gradient effect
Total saturation flow = 4030 p.c.u.

Nathan Road N/B right turn lane
taking an average turning radius of 12.1 m
Adjust for lane with mixed traffic
assuming no gradient effect S_M= 1807 p.c.u.
Total saturation flow = 1807 p.c.u.

Gascoigne Road W/B straight ahead and right turning movements

width = 10.3 m, and taking an average turning radius of 12.1 m
assume lane width = 10.3/3 = 3.433 m

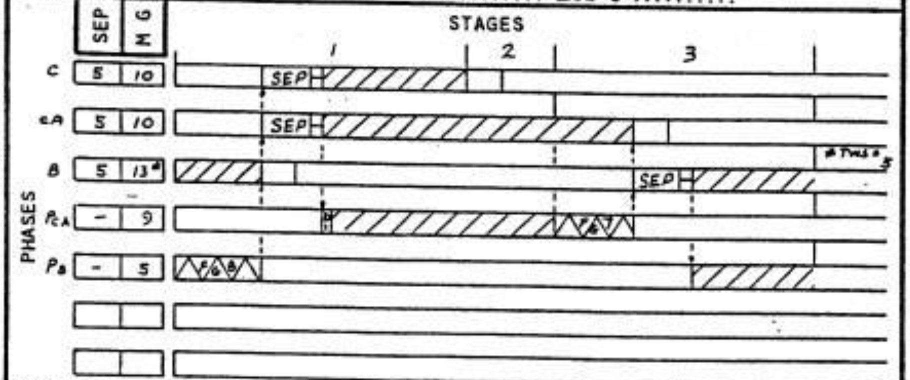
Nearside lane S = 1940 + 100 (w - 3.25) p.c.u. = 1958 p.c.u.
Non-nearside lane S = 2080 + 100 (w - 3.25) p.c.u. = 2098 p.c.u.

Adjust for turning lane S_R = 1867 p.c.u. for unoppposing turning traffic
Adjust for lane with mixed traffic S_M= 2006 p.c.u.

Total satuartion flow = 5831 p.c.u.

AREA TRAFFIC CONTROL DIVISION, T.D.
WEST KOWLOON AREA TRAFFIC CONTROL SYSYEM

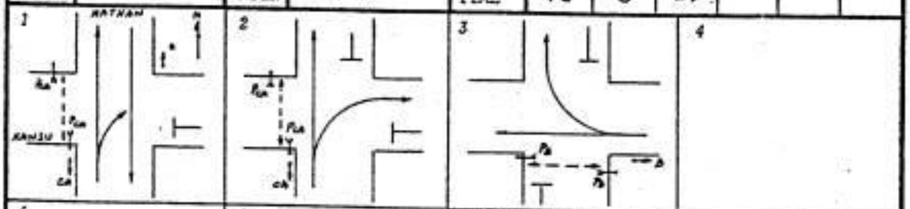
NAME	NATHAN / KANSU		SCN B 26 B
S.F. ~~YES~~/NO	MASTER YES/~~NO~~	MASTER SCN B26 B	LOCAL STAGE..-..CALL..-..SEC AFTER CALL MASTER STAGE.3. / SWITCH ON STAGE ..1....
LIMIT GREEN ~~64~~/128/~~256~~	WALL MAP STAGES LAMP 1 .....1..... LAMP 2		



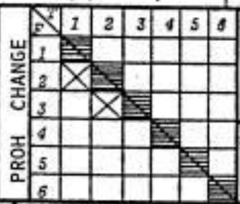
Note: Leaving amber 3 sec. Starting amber 2 sec. Dn is delay F/Gn is flashing green

LOCAL PLAN	CYCLE 77 SEC	STAGE ORDER	1, 2, 3	STAGE TIME	1: 43	2: 5	3: 29	4	5	6

1 2 3 4



5 6



SITE DRG. NOS.

APPROVED BY: K. H. LEE (SD)
DATE: 14. 10. 74

REF	REVISION	INIT	DATE
A	FALL BACK PLAN REVISED	–	23. 6. 76
B	STAGE 2 SEP REVISED	–	18. 4. 77
C	METHOD OF CONTROL REVISED FOR MIS REINSTATEMENT (INTERIM SCHEME)	BJC (SD)	12-2-80
D	MIS REINSTATEMENT (FINAL SCHEME) INCORPORATED	[illegible]	17-3-80
E	FALL BACK TIMING REVISED	[illegible]	8-12-80
F	SCN NO. REVISED FROM C12 TO B26	[illegible]	15-5-81
G	FIG OF PCA INCREASED FROM 6 SEC TO 7 SEC	TS	6 2 85

REMARKS
2 SEC ALL RED AFTER B & CA

LOCAL CONTROLLER DATA SHEET

D S 2 / B26 4

2) Flows and Flow Factors

a p.c.u. factor of 1.15 has been assumed for converting counts from vehicles to p.c.u.

flow factor $y = \frac{q}{S}$

Nathan Road S/B

flow = 1579 p.c.u./hour

$y = \frac{1579}{6124} = 0.258$

Nathan Road N/B Straight ahead

flow = 651 p.c.u./hour

$y = \frac{651}{4030} = 0.162$

Nathan Road N/B right turning

flow = 155 p.c.u./hour

$y = \frac{155}{1807} = 0.086$

Gascoigne Road W/B

$y = \frac{1024}{5803} = 0.176$

since 0.086 + 0.258 > 0.162

the higher value of 0.086 + 0.258 is used in calculation Y,

the summation of flow factors

$Y = \Sigma y = 0.086 + 0.258 + 0.176$

$= 0.52$

3) Lost times

$L = \Sigma (I - 1)$

referring to the data sheet DS2/008G

intergreen between stage 2 and 3 = 7

intergreen between stage 3 and 1 = 7

and disregarding the overlapping stage

L = (7 - 1 + 7 - 1) sec

= 12 sec

4) Cycle Time

Optimum cycle time

$c_o = \frac{1.5\,L + 5}{1 - Y}$ sec

$= \frac{(1.5 * 12) + 5}{1 - 0.52}$ sec

$=$ 48 sec

Minimum cycle time

$$c_m = \frac{L}{1 - Y} = \frac{12}{(1 - 0.52)}$$

$= 25$ sec

Practical cycle time

$$c_p = \frac{0.9\,L}{0.9 - Y} = \frac{0.9 * 12}{0.9 - 0.52}$$

$= 28$ sec

The above calculations are for illusion only, as a cycle time of 90 sec will be chosen for reasons of linking with other signals along Nathan Road.

5) Green Times

$$g = \frac{y}{Y} * (c - L) \text{ and } G = g - 1$$

Nathan Road S/B straight ahead

effective green time $g = \frac{0.258}{0.52} * (90 - 12)$ sec = 39 sec

actual green time G = 39 - 1 = 38 sec

Nathan Road N/B Right turn overlap

effective green time $g = \frac{0.086}{0.52} * (90 - 12)$ sec = 13 sec

Gascoigne Road W/B

effective green time $g = \frac{0.176}{0.52} * (90 - 12)$ sec = 26 sec

actual green time G = 26 - 1 = 25 sec

6) Capacity Analysis

assuming an ultimate situation of 120 sec cycle time

Yult = 0.9 - 0.0075 L

= 0.9 - 0.0075 * 12

= 0.81

The ultimate reserve capacity

$$R.C.\ (ult) = \frac{Yult - Y}{Y} * 100\ \%$$

$$= \frac{0.81 - 0.52}{0.52} * 100\ \%$$

$$= 55.8\%$$

R.C. (c). Resrve capacity of the signals operating under the current situation
i.e. cycle time c = 90 sec

maximum allowable Y

$$Ymax = 1 - \frac{L}{c}$$

$$= 1 - \frac{12}{90} = 0.867$$

assuming a practical Y of 0.9 Ymax

$$R.C.\ (c) = \frac{0.9\ Ymax - Y}{Y} * 100\ \%$$

$$= \frac{0.9 * 0.867 - 0.52}{0.52} * 100\ \%$$

$$= 50.1\%$$

7) Degree of Saturation

Degree of saturation for various critical approaches may be computed:

$$X = \frac{q\,c}{g\,S}$$

For cycle time c = 90 sec

Nathan Road S/B

$$X = \frac{1579 * 90}{39 * 6124} = 0.6$$

Nathan Road N/B straight ahead

$$X = \frac{651 * 90}{(39 + 13) * 4030} = 0.28$$

Nathan Road N/B right turn

$$X = \frac{155 * 90}{13 * 1807} = 0.59$$

Gascoigne Road W/B

$$X = \frac{1024 * 90}{26 * 5831} = 0.61$$

8) Traffic Signal Calculation sheet
The process of calculations could be conveniently recorded and summarized as shown on the specimen traffic signal calculation sheet.

9) Checking adequacy of pedestrian phase timings by a walking speed of 1.2 m/sec

Across Kansu Street P_{CA}
width of road = 8.5 m

$$\text{minimum flashing} = \frac{8.5}{1.2} \text{ sec} = 7 \text{ sec}$$

For a nominal pedestrian green period of 5 sec, minimum provision of green plus flashing green period
= (5 + 7) sec
= 12 sec < (12 + 38) sec provided
∴ O.K.

Across Nathan Road P_B
width of central divider = 2 m
greater half-road width = 10 m
whole road width = 22 m

$$\text{minimum flashing green period} = \frac{10}{1.2} \text{ sec} = 8 \text{ sec}$$

$$\text{minimum pedestrian green period} = \frac{10+2}{1.2} \text{ sec} = 10 \text{ sec}$$

minimum green plus flashing green period = 10 sec + 8 sec
= 18 < 28 sec provided
∴ O.K.

Pedestrian capacity of crossings should be calculated using the formula shown in para. 3.2.5.6 and should be checked against actual pedestrian flows for adequacy.

TRAFFIC SIGNAL CALCULATION SHEET

Location: NATHAN / KANSU (B26)
Date: 17. 8. 85
Time of day: A. M.

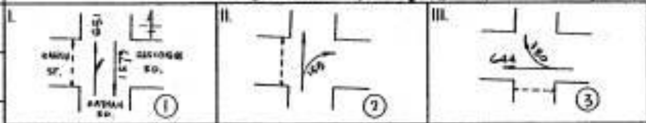
Sheet No.: 1 OF 1
Division: T C D
Designed by:
Checked by:

Movement / phase	Stage	(1) Width (m)	(1) Rad. (m)	(2) Design flow (pcu/hr)	(3) Gradient effect	(4) Sat. flow (pcu/hr)	(5) Propn. of turning	(6) Rev. sat. flow	(7) y= (2)/(6)	(8) greater y	(9) Y=Σ y	(10) L = Σ (I-1) (sec.)	(16) Assigned C (sec.)	(19) g = y(c-L)/Y	(20) Deg. sat. (2)x(16) / (6)x(19)
NATHAN RD. S/B ↓	I	10		1579	-	6124		6124	0.258	0.258	0.52	12	90	39	0.600
NATHAN RD. N/B ↑	I	6.6		651	-	4030		4030	0.162					(39 + 13)	0.280
NATHAN RD. N/B	I, II		12.1	155	-	1807	0.21	1807	0.086	0.086				13	0.590
GASCOIGNE RD W/B	III	10.3		1024	-	5831	0.37	5831	0.176	0.176				26	0.610

P.C.U. factor =

(11) Optimum Cycle $C_o = \frac{1.5L + 5}{1 - Y}$	48.0
(12) Minimum Cycle Time $C_m = \frac{L}{1 - Y}$	25.0
(13) $Y_{ult} = 0.9 - 0.0075\,L$	0.81
(14) R.C. $_{(ult)} = \frac{Y_{ult} - Y}{Y} \times 100\,\%$	55.8%
(15) Practical Cycle Time $C_p = \frac{0.9\,L}{0.9 - Y}$	28.0
(16) Assigned C =	90
(17) $Y_{max} = 1 - \frac{L}{C}$	0.867
(18) R.C. $_{(p)} = \frac{0.9\,Y_{max} - Y}{Y} \times 100\%$	50.1%

Stage / Phase sequence diagram (with flows in p.c.u.)



I.	II.	III.	IV.
I = 7 G = 38	I = 0 G = 12	I = 7 G = 26	I = G =

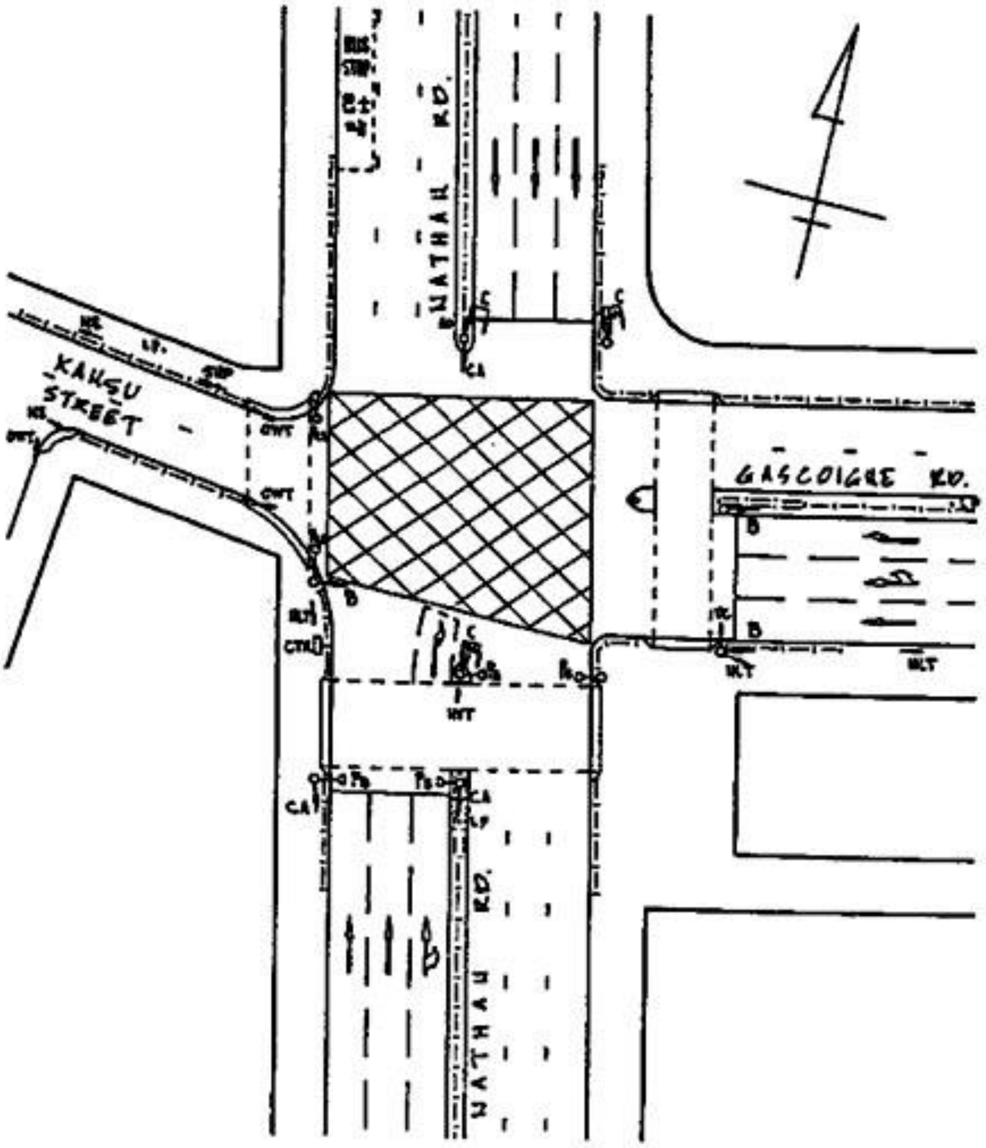
(i) Exclusive straight-ahead lane { S = Saturation flow in pcu/hr; W = lane width at entry in m }
S = 1940 + 100(W - 3.25) for nearside lane or single lane entries
S = 2080 + 100(W - 3.25) for non-nearside lane

(ii) Exclusive turning lane { r = radius of curvature of vehicle paths in m }
Sk = S/(1 + 1.5/r) for unopposing turning
Sk = (S - 230)/(1 + 1.5/r) for opposed turning

(iii) Lanes with mixed traffic { f = proportion of turning vehicles in a lane }
Sm = S/(1 + 1.5 f / r) for unopposing turning traffic
Sm = (S - 230)/(1 + 1.5 f / r) for opposed turning traffic

Site factors : For each 1% of uphill gradient the saturation flow (S) should be decreased by 42 pcu/hr, downhill gradients have no effect.

Pedestrian crossing minimum green & flashing green times checked : Yes ( ) No ( )



LAYOUT AS ON 28/5/83
CHECKED ON SITE BY M. L. KUNG

EQUIPMENT						
	LAMP TYPE		NORMAL	N. I.	CONTROLLER	TYPE: T 2000
ASPECTS	VEH.	200 mm		24		N.K.E./C.L.P. METER
		300 mm		3	DATA TRANSMISSION	TELE. CO. LINE CCT No
	PED.	200 mm		-		P.W.D. CCT No/SPARE: /
		300 mm		12	DETECTORS	PASSAGE
	TRAM			-		Q/RIGHT TURN
INT. ILLUMIN. TRAFFIC SIGNS				-	PEDESTRIAN PUSH BUTTON	

title	drawn by	date	DATA SHEET	scale
JUNCTION LAYOUT OF NATHAN RD. / KANSU ST.	Y. C. LEUNG	27 9 82	ATC/B26/1	1:500
	approved: P. L. CHO	date: 10 6 83	TRANSPORT DEPARTMENT HONG KONG	
	office: Area Traffic Control Div.			

GF 507

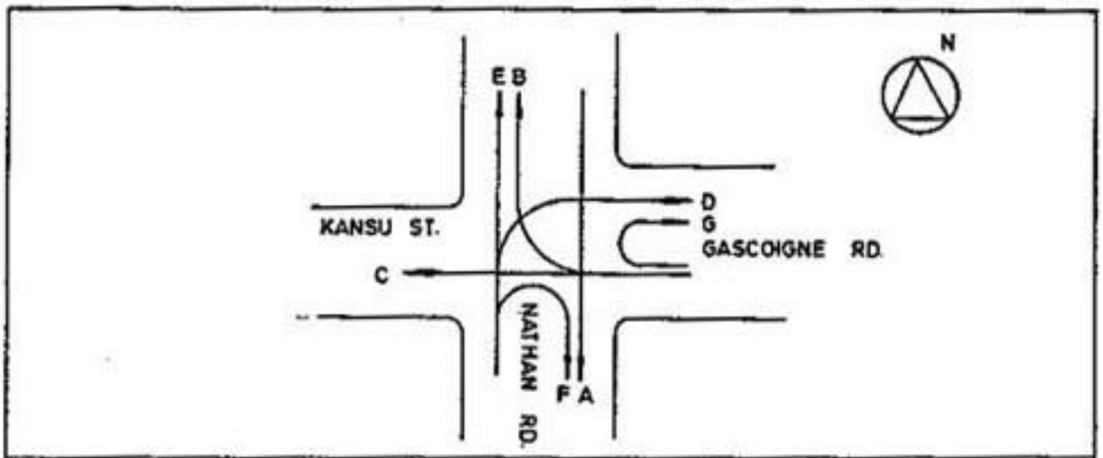
A4 210 × 297

TRAFFIC & TRANSPORT SURVEY DIVISION T.D.

________ Movement Count

Location (1) J/O NATHAN ROAD / KANSU STREET B26

Date & Day 27.2.84. Weather ________ Observer ________



FLOW / HOUR BEGINNING	A	B	C	D	E	F	G							TOTAL
0800	259	69	92	30	72	0	0							522
	239	64	109	18	87	2	0							519
	334	54	89	30	79	3	1							590
	363	71	102	29	114	4	0							683
0900	378	83	121	33	121	6	2							744
	374	75	135	41	129	8	0							762
	335	75	136	31	171	3	0							751
	286	97	168	30	145	1	0							727
PEAK HOUR TOTAL	1373	330	560	135	566	18	2							2984
1600	223	180	142	46	194	1	0							786
	234	126	111	29	197	6	3							706
	284	110	133	41	123	2	0							693
	269	101	131	30	167	1	1							700
1700	305	110	169	42	191	1	1							819
	311	102	152	40	174	3	2							784
	325	107	159	33	154	0	1							779
	288	90	157	40	174	3	3							755
PEAK HOUR TOTAL	1229	409	637	155	693	7	7							3137

Example 2 : <u>Delay and Queue Estimation for Fixed Time Signals</u>

1) One approach to an intersection has a flow of 1020 vehicles per hours, a saturation flow of 2400 vehicles per hour, an effective green period of 30 seconds and a cycle time of 60 seconds. What is the estimated average queue (N) at the beginning of the green period using the T.R.R.L Method.
Using the delay formulae

$$d = cA + \frac{B}{q} - C$$

c = 60 sec	S = 2400 veh/hr.
g = 30 sec	q = 1020 veh/hr.

$$\lambda = \frac{g}{c} = 0.5$$

$$X = \frac{q}{\lambda s} = \frac{1020}{0.5\,(2400)} = 0.85$$

From Table 2.5.2.1	A = 0.217
	cA = 13.0
From Table 2.5.2.2	B = 2.41

$$\frac{B}{q} = \frac{2.41}{1020/3600} = 8.5$$

$$M = q\,c = \frac{1020}{3600}(60) = 17$$

From Table 2.5.2.3
C = 12.3 per cent of the first two terms

d = 13 + 8.5 - C
= 21.5 - 12.3/100 * (21.5)
= 18.9 seconds

Using the Queue formulae

$N = q\,(\frac{r}{2} + d)$ or $N = qr$, whichever the greater

$r = c - g = 30$ sec

$$N = \frac{1020}{3600}\left(\frac{30}{2} + 18.9\right) \text{ or } \frac{1020}{3600}(30)$$

= 10 or 8.5 whichever the greater
= 10 vehicles

2) If in case (1) above, the flow were increased suddenly to 1260 vehicles per hour and this transient situation lasts for half an hour, what would be the estimated average delay and queues, using the Akcelik's time - dependent formula?

q = 1260 veh/hr. S = 2400 veh/hr.
c = 60 sec g = 30 sec
t = 0.5 hr.

$$X = \frac{q}{\lambda S} = \frac{1260}{0.5(2400)} = 1.05$$

$$Q = \lambda S = 0.5 * 2400 = 1200 \text{ veh/hr.}$$

$$y = \frac{q}{S} = \frac{1260}{2400} = 0.525$$

$$X' = 0.67 + \frac{S g}{600}$$

$$= 0.67 + \frac{2400(30)}{3600(600)}$$

$$= 0.7 < X = 1.05$$

$$No = \frac{Q t}{4} \left(Z + \left(Z^2 + \frac{12(X - X')}{Q t} \right)^{½} \right)$$

where Z = X - 1

$$No = \frac{1200(0.5)}{4} \left((1.05 - 1) + \left((1.05 - 1)^2 + \frac{12(1.05 - 0.7)}{1200(0.5)} \right)^{½} \right)$$

$$= 22.12$$

$$\text{Average delay } d = \frac{c}{2} \frac{(1 - \lambda)^2}{(1 - y)} + \frac{No\, X}{q}$$

$$= \frac{60}{2} \frac{(1 - 0.5)^2}{(1 - 0.525)} + \frac{22.12(1.05)}{1260/3600}$$

$$= 82.15 \text{ sec}$$

<u>Average Queue</u>

N = q r + No
r = c - g = 30 sec

$$N = \frac{1260(30)}{3600} + 22.12$$

$$= 32.62 \text{ vehicles}$$

Appendix II - Ducting Installation & Cable Network Standard

10.2.1 Ducting Installation

1. Cable ducts

   For maintenance reason all traffic signal aspect cables, linking cables and telecommunication cables should he housed in cable ducts.

2. Wherever possible, ducts will be laid under the footway pavement.

3. 100mm internal diameter U.P.V.C. ducts will be laid in footway to a minimum cover of 450mm.

4. 102mm internal diameter G.I. ducts will be laid 600mm beneath carriageway and 450mm beneath run-ins.

5. Draw pits or Draw/Jointing Chambers (DJC) should be provided :-

   (i) Where there is a change in either direction, level or section that could not be permitted for that type of duct.

   (ii) Where U.P.V.C. duct would change over to G.I. ducts for crossing the road.

   (iii) Fronting each outstation housing.

   (iv) At intersection of ducts.

   (V) To facilitate subsequent cable pulling, desirable spacing of draw pits for long and straight ducts is 70m.

6. To ensure the correct alignment of ducts, a wooden mandrel shall be used, being drawn forward as the ducts are laid.

   On completion of a duct line between any two duct jointing chambers or sites of such DJCs, a cylindrical brush, connected to the following end of two mops (connected one to each end of a wooden test mandrel) shall be passed twice through each 'way' to clean the duct and to remove any foreign matter which may have entered.

   The wooden test mandrel shall be 241mm in length and 89mm in diameter and the cylindrical cleaning brush shall be 102mm in diameter.

7. A hardwood plug or PVC cap shall be inserted at the ends of each 'way' in a line of ducts until the length has been tested and passed.

8. After the line of ducts between the DJC 's has been tested and passed, each duct entry shall be blocked by a hardwood plug or any other approved means to prevent, as far as possible, the ingress of foreign matter.

9. Two 10mm diam. nylon draw wires shall be threaded through and left behind in each 'way ' in a line of ducts between two draw/jointing chambers.

   This nylon wire will be used later for drawing in the cable rope.

10. Rattan rods should be used to clear any blockage of a pipe and to locate exact blockage or damage position of a pipe.

Traffic Signal Aspect Duct Network at Junctions

11. Single U.P.C. ducts will be provided between a signal post to the nearby drawpit.

12. For maintenance reasons it is desirable that twin ducts should be provided across the junction legs and the ducts should be linked together to form a closed loop system.

13. Standard E&M type drawpits should be used for the signal aspect cable duct network.

Telecommunication and Link Cable Network

14. Each length should be clearly and durably marked at 1.0m spacing such that it may be easily identified to be an ATC/link cable duct when exposed.

15. ATC type drawpits should be used for easy identification.

16. Minimum clearance of 300mm for high voltage electrical cables should be observed.

10.2.2 Traffic Signal Cable Network Standard

1. A minimum of 25% spare cores should be provided for each aspect cable.

2. Aspect cable branching out from the controller should be connected to another one by a spare cable between nearby signal poles.

3. Two primary aspects of the same phase should be powered up by two separate aspect cables or have one aspect connected to the aspect of another phase via a spare aspect cable.

4. The maximum number of aspect cables should not exceed six normally.

5. 12 core aspect cable should be used. Aspect cable with less cores may he used for connecting the last signal pole.

Appendix III - Using the TRANSYT PROGRAM

Preparing Transyt Input

Step 1
ASSEMBLE the following DATA:-

1) Up-to-date traffic counts of junctions in network
2) Methods of control for signal junctions.
3) Large scale plans (Approx. 1:500) signal junctions (For determining saturation flows).
4) Large scale drg. (approx. 1:1000) of area. To determine distances between stoplines.
5) Site measurements of saturation flow where necessary

↓

Step 2
From 1) & 4), prepare diagrammatic layout of area and traffic movements

↓

Step 3
From 2) & 3), determine which flows should be separately modeled and from 3) & 5) determine saturation flows.

↓

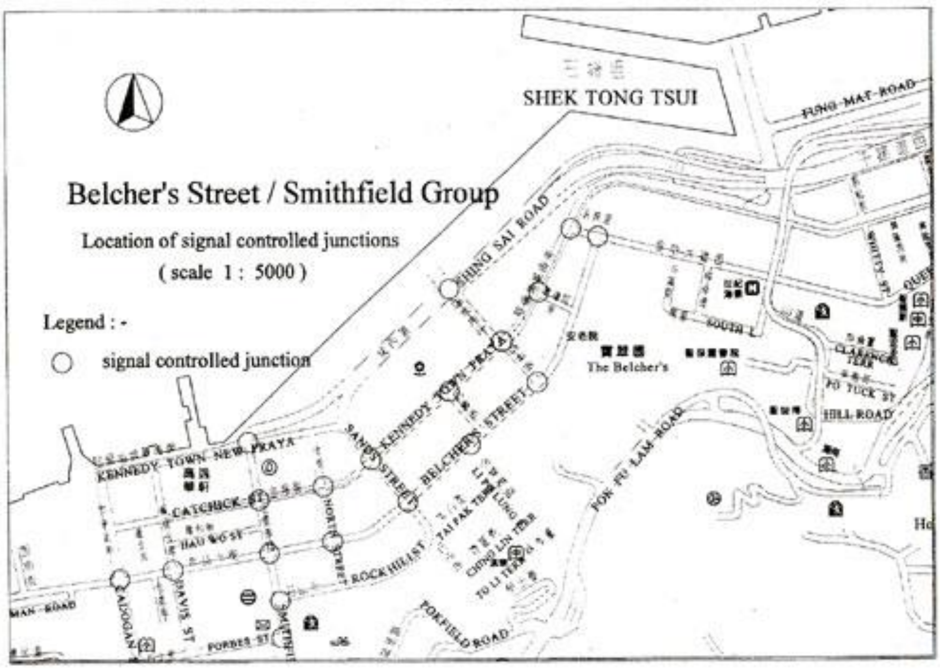
Step 4
Draw up link and node diagram, showing all flows to be separately modeled and saturation flows

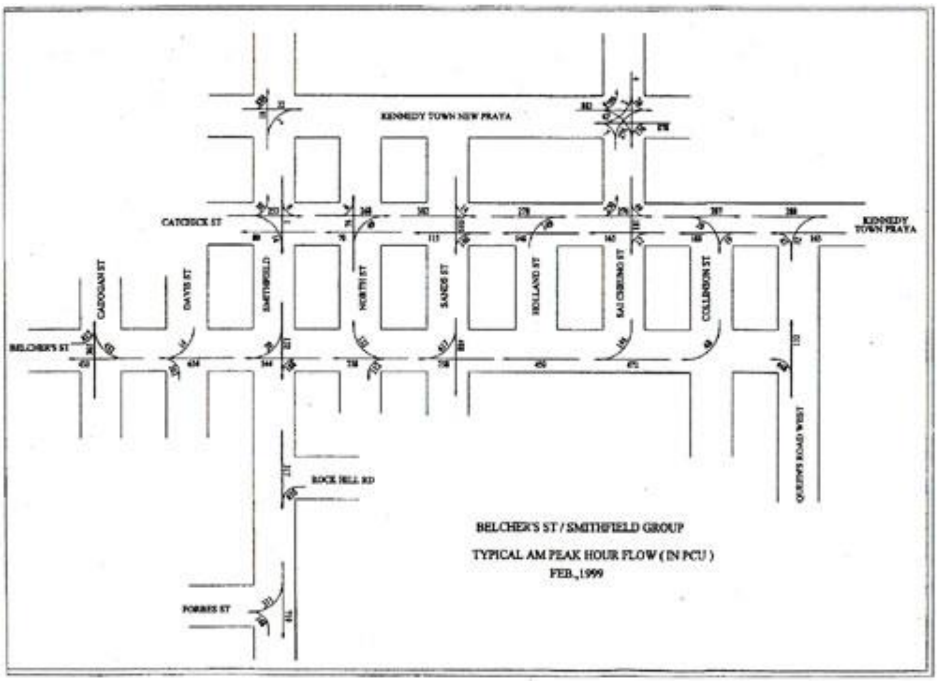
↓

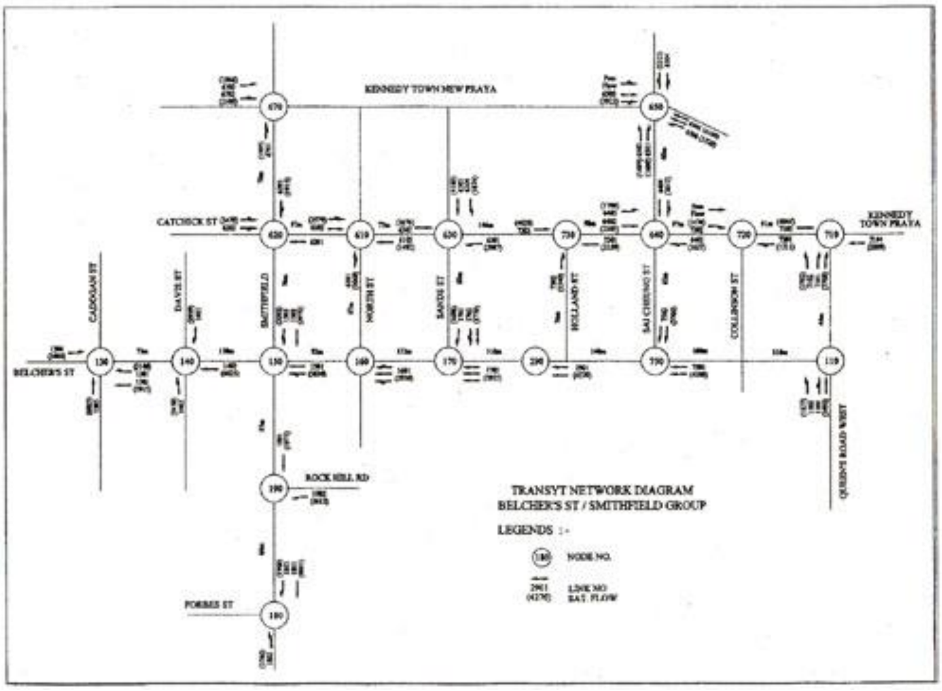
Step 5
On a PC, produce input data file

↓

Step 6
Run TRANSYT Programme




KENNEDY TOWN NEW PRAYA
CATCHICK ST
KENNEDY TOWN PRAYA
CADOGAN ST
DAVIS ST
SMITHFIELD
NORTH ST
SANDS ST
HOLLAND ST
SAI CHEUNG ST
COLLINSON ST
BELCHER'S ST
QUEEN'S ROAD WEST
ROCK HILL RD
FORBES ST
BELCHER'S ST / SMITHFIELD GROUP
TYPICAL AM PEAK HOUR FLOW (IN PCU)
FEB.,1999


KENNEDY TOWN NEW PRAYA
CATCHICK ST
KENNEDY TOWN PRAYA
CADOGAN ST
DAVIS ST
SMITHFIELD
NORTH ST
SANDS ST
HOLLAND ST
SAI CHEUNG ST
COLLINSON ST
BELCHER'S ST
QUEEN'S ROAD WEST
ROCK HILL RD
FORBES ST
TRANSYT NETWORK DIAGRAM
BELCHER'S ST / SMITHFIELD GROUP
LEGENDS :-
NODE NO.
LINK NO.
SAT. FLOW

Typical Input Data File for Transyt 9

(Details refer User Guide To Transyt Version 9 by TRRL Laboratory Report 888)

```
BELCHER's ST. FROM 1B11 TO 1A13 ; CATCHICK ST. FROM 4W62 TO 4W71 ( AM PEAK )
   1  180   45  120    2    3    1    0    0    0    1    2    0    0  390   70
   2  110  750  290  170  160  150  140  130  620  610  630  730  640  720  710
   2  650  670  190  180
   4   15   40   -1   15   40    1   -1    1
   6 1000 1000  100  100   10   10    1    1
  12  110    0   26    0   13
  12  750    0   17    0   19
  12  290    0   30    0   14
  16  170    0   18    0   25    0   14    0   18    0   25    0   14
  12  160    0   29    0   16
  16  150    0   25    0   25    0   13    0   25    0   25    0   13
  16  140    0   23    0   21    0   19    0   23    0   21    0   19
  16  130    0   23    0   24    0   20    0   23    0   24    0   20
  14  620    0   21    0   15    0   11    0   17
  16  610    0   22    0   20    0   15    0   22    0   20    0   15
  16  630    0   26    0   23    0   13    0   26    0   23    0   13
  14  730    0   21    0   19    0   21    0   19
  14  640    0   28    0   18    0   28    0   18
  14  720    0   15    0   15    0   15    0   15
  16  710    0   19    0   27    0   14    0   19    0   27    0   14
  16  650    0   24    0   16    0   14    0   24    0   16    0   14
  12  670    0   17    0   18
  14  190    0   22    0   19    0   22    0   19
  14  180    0   22    0   19    0   22    0   19
  31 1101  110    1   15    2    0    0    0    0    0 1000    0 3992
  31 1102  110    1   15    2    0    0    0    0    0 1000    0 1637
  31 7501  750    1   10    2    7    0    0    0    0  220    0 4100
  31 7502  750    1   10    2    7    0    0    0    0  180    0 3800
  31 7503  750    2   13    2    5    0    0    0    0   65    0 3564
  31 2901  290    1   13    2    0    0    0    0    0  141    0 4270
  31 1701  170    2   14    3    0    5   14    6    0   68    0 1686
  31 1702  170    2   14    3    0    5   14    6    0   68    0 3779
  31 1703  170    1   12    2    8    4   12    5    8  110    0 6025
  31 1601  160    1   13    2    0    0    0    0    0  132    0 5930
  31 1501  150    1   13    2    9    4   13    5    9   92    0 5930
  31 1502  150    2   14    3    0    5   14    6    0  350    0 3970
  31 1503  150    2   14    3    0    5   14    6    0   76    0 2002
  31 1401  140    3   14    4    9    6   14    1    9 1000    0 2939
  31 1402  140    1   14    2    9    4   14    5    9  138    0 6025
  31 1403  140    2   14    3    9    5   14    6    9 1000    0 3458
  31 1301  130    2   15    3    5    5   15    6    5   75    0 3140
  31 1302  130    2   15    3    5    5   15    6    5   75    0 1915
  31 1303  130    3   13    4    7    6   13    1    7 1000    0 6025
  31 1304  130    1   14    2    8    4   14    5    8 1000    0 3484
  31 6201  620    4   11    1    0    0    0    0    0   95    0 1572
  31 6202  620    1    5    2    0    0    0    0    0  290    0 3478
  31 6203  620    2    7    3    0    0    0    0    0   70    0 1915
  31 6101  610    2   14    3    0    5   14    6    0   67    0 2060
  31 6102  610    1   13    2    5    4   13    5    5   97    0 1975
  31 6103  610    1   13    2    5    4   13    5    5   88    0 1492
  31 6301  630    1   15    2    6    4   15    5    6  142    0 2987
  31 6302  630    1   15    2    6    4   15    5    6   77    0 3676
  31 6303  630    2   12    3    0    5   12    6    0 1000    0 4160
  31 6304  673    2   12    3    0    5   12    6    0 1000    0 1874
```

31	7301	730	1	12	2	3	3	12	4	3	107	0	3559
31	7302	730	2	12	3	7	4	12	1	7	176	0	3540
31	7303	730	1	12	2	3	3	12	4	3	146	0	4020
31	6401	640	1	19	2	5	3	19	4	5	89	0	1637
31	6402	640	1	19	2	5	3	19	4	5	100	0	2105
31	6403	640	1	19	2	5	3	19	4	5	100	0	1708
31	6404	640	2	12	3	12	4	12	1	12	60	0	3812
31	7201	720	1	7	2	0	3	7	4	0	120	0	1711
31	7202	720	2	7	3	0	4	7	1	0	97	0	1474
31	7101	710	2	19	3	0	5	19	6	0	44	0	3788
31	7102	710	2	19	3	0	5	19	6	0	44	0	1702
31	7103	710	1	13	2	12	4	13	5	12	91	0	4044
31	7104	710	1	13	2	12	4	13	5	12	150	0	3793
31	6501	650	2	5	3	0	5	5	6	0	60	0	1650
31	6502	650	2	5	3	0	5	5	6	0	60	0	1486
31	6503	650	1	13	2	0	4	13	5	0	380	0	3922
31	6504	650	2	5	3	0	5	5	6	0	1000	0	3313
31	6505	650	1	13	2	0	4	13	5	0	1000	0	4160
31	6506	650	1	13	2	0	4	13	5	0	1000	0	1526
31	6701	670	2	12	1	5	0	0	0	0	70	0	1995
31	6702	670	1	12	2	7	0	0	0	0	1000	0	2100
31	6703	670	1	12	2	7	0	0	0	0	1000	0	1966
31	1901	190	1	11	2	6	3	11	4	6	65	0	5974
31	1902	190	2	12	3	6	4	12	1	6	1000	0	3613
31	1801	180	1	10	2	5	3	10	4	5	66	0	5902
31	1802	180	2	10	3	5	4	10	1	5	1000	0	3760
32	1101	132	0	0	0	45							
32	1102	448	0	0	0	45							
32	7501	424	0	1102	448	45							
32	7502	48	0	7201	19	45	7202	29	45				
32	7503	144	0	6401	12	45	6404	181	45				
32	2901	450	0	7501	310	45	7502	35	45	7503	105	45	
32	1701	617	0	6301	81	45	6303	536	45				

32	1501	732	0	1601	758	45						
32	1502	132	0	1304	70	45	1303	60	45			
32	1503	20	0	6202	14	45						
32	1401	14	0	1303	18	45						
32	1402	654	0	1503	20	45	1501	544	45			
32	1403	201	0	0	0	45						
32	1301	432	0	1401	10	45	1402	290	45	1403	130	45
32	1302	431	0	1401	10	45	1402	350	45	1403	70	45
32	1303	365	0	0	0	45						
32	1304	415	0	0	0	45						
32	6201	80	0	6103	70	45						
32	6202	297	0	1301	104	45	1303	89	45	1304	100	45
32	6203	10	0	0	0	45						
32	6701	20	0	6202	30	45						
32	6702	32	0	0	0	45						
32	6703	886	0	0	0	45						
32	1901	317	0	1501	188	45	1502	132	45			
32	1902	615	0	0	0	45						
32	1801	1030	0	1901	317	45	1902	655	45			
32	1802	148	0	0	0	45						
32	6101	125	0	1601	132	45						
32	6102	160	0	6202	155	45						
32	6103	70	0	6301	115	45						
32	6301	160	0	7301	148	45						
32	6302	274	0	6101	49	45	6102	160	45			
32	6303	1055	0	0	0	45						
32	6304	14	0	0	0	45						
32	7301	148	0	6401	165	45						
32	7302	149	0	7501	102	45	7502	12	45	7503	35	45
32	7303	278	0	6302	274	45	6304	14	45			
32	6401	177	0	7201	188	45						
32	6402	168	0	7302	58	45	7303	110	45			
32	6403	250	0	7302	87	45	7303	163	45			
32	6404	230	0	6503	42	45	6504	10	45	6506	156	45
32	7201	207	0	7102	47	45	7104	163	45			
32	7202	208	0	6402	168	45	6404	49	45			
32	7101	52	0	1101	68	45						

32	7102	47	0	1101	62	45		
32	7103	190	0	7202	179	45		
32	7104	163	0	0	0	45		
32	6501	276	0	6403	250	45		
32	6502	10	0	6403	10	45		
32	6503	925	0	6703	886	45		
32	6504	32	0	0	0	45		
32	6505	878	0	0	0	45		
32	6506	156	0	0	0	45		
35	1101	1102	7501	7502	7503	2901	1701	1702
35	1703	1601	1501	1502	1503	1401	1402	1403
35	1301	1302	1303	1304	6201	6202	6203	6101
35	6102	6103	6301	6302	6303	6304	7301	7302
35	7303	6401	6402	6403	6404	7201	7202	7101
35	7102	7103	7104	6501	6502	6503	6504	6505
35	6506	6701	6702	6703	1901	1902	1801	1802

Part III) - Analysis of Transyt Output
Explanation of Transyt Output

INITIAL SETTINGS
This is a full output based upon initial offsets input or assumed zero offset for all controllers.

INTERMEDIATE SETTINGS
The program alters the offset of one of the signals by predetermined number of steps (time units) and recalculates the performance Index of the network.

FINAL SETTINGS
The offset of each signal in turn is adjusted in the same way as describe in the intermediate settings in a specified order until an optimized offsets is obtained.

Pulse Call Times
These relate to call times of stages expressed in terms of STEPS not seconds.

Degree of Saturation

$$\frac{Flow}{Saturation} * \frac{CycleTime}{EffectiveGreenTime} * 100\%$$

Distance Traveled (D)

$$\frac{Flow \times Link\ Length/1000}{1000}$$

Time Spent

$$\frac{D(Derived\ as\ above)}{Journey\ Speed\ Fed\ In} + Uniform\ Delay + Random\ Delay$$

<u>Stops (S)</u>

$\frac{Max.Flow\ on\ Histogram}{Steps/Cycle} * \frac{1}{3600\times24} * \sum(1's\&@'s)$ up to point where flow ceases to discharge at saturation

$$(X\%) = \frac{No.of\ Vehicle\ Stopped/Cycle}{Total\ No.of\ Vehicle\ Arriving/Cycle} * 100\%$$

<u>Max. Uniform Queue</u>

$$\sum 1'sx \frac{Max.Flow\ on\ Histogram}{\frac{Steps}{Cycle}} * \frac{C_T}{3600 \times 24}$$

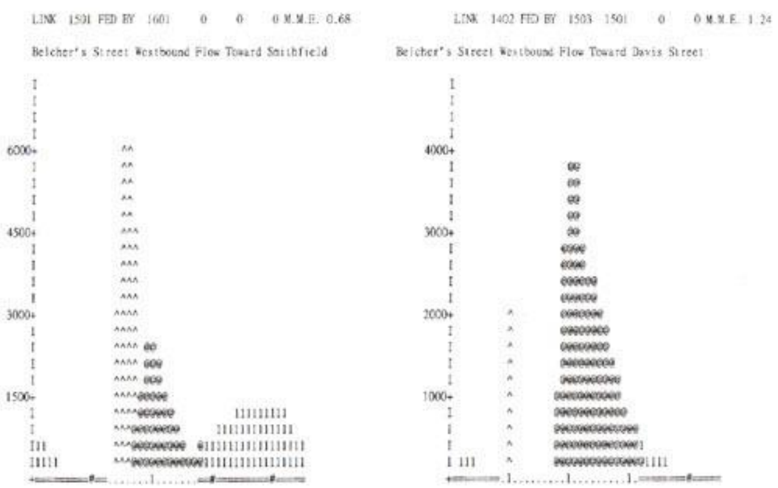
<u>Performance Index</u>

∑ Random Delay + ∑ Uniform Delay + K x stops
Where K = Stop Penalty at Card I

<u>Speed</u>

$$\frac{Total\ Distance\ Traveled}{Total\ Time\ Spent}$$

TYPICAL TRANSYT GRAPHICAL OUTPUT



EXPLANATION OF TRANSYT GRAPHICAL OUTPUT