IMPLEMENTATION OF SIGNAL SPACING STANDARDS

J D SAMPSON

Jeffares & Green Inc., P O Box 1109, Sunninghill, 2157

INTRODUCTION

Mobility, defined here as the ease at which traffic can move at relatively high speeds without unnecessary disruption, is essential to a successful city and a growing economy. While a limited amount of congestion during peak periods may be acceptable, this should not be caused by poor access spacing policies. To achieve proper signal coordination throughout the day on a two-way street, the average spacing between intersections must be properly managed. It is universally accepted that on higher standard arterials (Class 2), a minimum average spacing between access points of around 800 m (½ mile) is required, while on lower standard arterials (Class 3), a spacing of around 600 m can be accepted.

In practice however, most traffic engineers find they are faced with the situation where the spacing between signals is less than ideal and in contrast to being able to improve the situation, there is great pressure to allow even further compromises.

These engineers will therefore argue that the standards are impractical and cannot be applied in urban areas. The result is that the mobility function has been severely degraded on many of the arterial roads in our cities.

If road access management principles are to be applied in practice therefore, there must be more flexibility than allowed by current standards. The purpose of this research is to suggest a more flexible standard which, if applied, will result in an improvement to the severe disruption to traffic flow and safety sometimes found on city arterials.

ACCESS SPACING CRITERIA

Access spacing standards, such as contained in "National Guidelines for Road Access Management in South Africa" (RAM Guidelines), October 2001, are based on the ability to properly coordinate traffic signals. Three criteria determine this:

- The spacing between intersections
- The cycle time
- The average running speed

Typical values of these criteria are given in Table 1.

21st Annual South African Transport Conference
'Towards Building Capacity and Accelerating Delivery'
ISBN: 0-620-28855-8

South Africa, 15 - 19 July 2002
Conference organised by: Conference Planners
CD-ROM produced by: Document Transformation Technologies

Table 1 : Criteria for signalized intersections (various references)

	Range	Typical Class 2		Typical Class 3	
		Off-peak	**Peak**	**Off-peak**	**Peak**
Spacing between intersections (m)	450 – 1000	800	800	600	600
Cycle time (secs)	50 – 100	70	90	70	80
Running (progression) speed (km/h)	54 – 80	80	64	60	54

Note 1: The lowest cycle time of 50 secs, although possible using 2 phase signals on narrow Class 3 arterials, is rarely used in practice. Cycle times of 70 seconds or more are necessary for 3 phase signals and on higher speed roads.

Note 2: Progression speed must be kept within a certain practical range. The lowest acceptable progression speed is around 54 km/h. It can be shown that at ½ ideal spacing the progression speed is halved, but at such low speeds motorists will ignore the apparently coordinated green band and reach the downstream signal before green is given. The mobility function is therefore lost.

Note 3: With the criteria for Class 2 and 3 in Table 1, 100% utilization of green time for through traffic is achieved, the bandwidth is maximized (equal to the green time on the main road) and a perfect "green wave" is achieved.

VARIATION FROM IDEAL SPACING

In practice, it is often impractical and probably impossible to achieve intersection spacings of exactly 800,0 or 600,0 m. Some allowance must be made to deviate from the ideal. The extent to which this can be allowed and still achieve both an acceptable bandwidth and progression speed is the subject of this research.

In Table 2, the ideal spacing (100% of green bandwidth) for various speeds and cycle times is given. The two typical cases, 800 m for Class 2 and 600 m for Class 3, are highlighted in bold. The numbers in the box indicate the distance on either side of the ideal that a signal can be placed in order to achieve a bandwidth of the specified percentage. For example, in the 800 m case a signal within 120 m of the average spacing will allow 70% of the bandwidth to be available. 50% of the bandwidth is available if the signal is within 200 m of the average, requiring in this case a gap of at least 400 m between signals.

If there is no restriction on bandwidth reduction (0% case) then signals can be placed within 400 m on either side of the 800 m ideal, i.e. anywhere.

Table 2 – Distance (m) by which spacing can vary from ideal

Class	Speed m/s	km/h	Cycle secs	**Ideal spacing m**	**Allowance either side of ideal to achieve bandwidth of: 90%** m	**80%** m	**70%** m	**60%** m	**50%** m	**0%** m
2	22.2	80	70	**778**	39	78	117	156	194	389
2	22.2	80	80	**889**	44	89	133	178	222	444
2	22.2	80	90	**1,000**	50	100	150	200	250	500
2	22.2	80	100	**1,111**	56	111	167	222	278	556
2	20.0	72	70	**700**	35	70	105	140	175	350
2	**20.0**	**72**	**80**	**800**	**40**	**80**	**120**	**160**	**200**	**400**
2	20.0	72	90	**900**	45	90	135	180	225	450
2	20.0	72	100	**1,000**	50	100	150	200	250	500
2	18.5	67	70	**648**	32	65	97	130	162	324
2	18.5	67	80	**741**	37	74	111	148	185	370
2	18.5	67	90	**833**	42	83	125	167	208	417
2	18.5	67	100	**926**	46	93	139	185	231	463
3	16.7	60	60	**500**	25	50	75	100	125	250
3	16.7	60	70	**583**	29	58	88	117	146	292
3	16.7	60	80	**667**	33	67	100	133	167	333
3	16.7	60	90	**750**	38	75	113	150	188	375
3	16.7	60	100	**833**	42	83	125	167	208	417
3	15.0	54	60	**450**	23	45	68	90	113	225
3	15.0	54	70	**525**	26	53	79	105	131	263
3	**15.0**	**54**	**80**	**600**	**30**	**60**	**90**	**120**	**150**	**300**
3	15.0	54	90	**675**	34	68	101	135	169	338
3	15.0	54	100	**750**	38	75	113	150	188	375

IMPLEMENTATION PROCEDURE

To implement this table in practice, the following procedure is recommended:

1. Calculate the average spacing between signals (or signal groups) on an arterial or in a network (of two-way streets). This figure must be at least 450 m, but ideally should be in the range of 600 to 800 m. Treat signal groups or clusters as single intersections. (A signal group or cluster is defined as two or more closely spaced signals, such as at an on-and off-ramp or on separate legs of a staggered junction). If the average spacing is less than 450 m, identify a signal or signals that may have to be removed if coordination is to be achieved and exclude it/them when determining the average. If the spacing exceeds 1200 m, either assume a signal will be placed at the mid-point or treat the sets of signals on either side of the long gap separately.

2. Select the cycle time and (off-peak) speed appropriate to the ruling average spacing (see Table 2). While cycle times have traditionally been exact multiples of 10, with modern equipment there is no need to have this. Rather select a cycle time to give the desired travel speed.

3. Determine the percentage reduction in bandwidth which is acceptable. Note that the RAM guidelines allow a 10% variation in access spacing, provided the average spacing is retained. This will ensure a bandwidth of 80% of the maximum. In this paper, achieving 70% of the maximum bandwidth on a Class 2 road, and a 60% on a Class 3 road is considered to be acceptable and practically implementable. Further research and modelling is however required to confirm or reject this.

JUSTIFICATION FOR REDUCING THE BANDWIDTHS

The extent to which bandwidths can be reduced requires considerably more research. A limited literature search was carried out, but there did not seem to be any reference on what the minimum acceptable through bandwidth would be.

If the bandwidth reductions proposed above (30% less than ideal for Class 2 and 40% less than ideal for Class 3) are accepted and it is assumed that at least 50% of the total cycle is available as green time on the main road, then the effect is to reduce the total available green bandwidths from 50% of the cycle time to 35% and 30% for Class 2 and 3 roads respectively. 30% of a 60 to 100 sec. cycle time would result in a green band of between 18 and 30 seconds. This range would seem to be in the right order. As cycle times are usually longer during peak periods, this also allows for a wider bandwidth and lower speeds in peaks.

Note that the reduction in bandwidth does not necessarily translate to an equivalent increase in delay. Theoretically, provided the through volume is less than 70%/60% of capacity, all vehicles could utilise the green bandwidth and none would need to stop, hence there would be no additional delay caused by narrowing the bandwidth.

This is particularly relevant in off-peak periods when volumes are lower. In peak periods, traffic signals are normally coordinated to give preference to the predominant tidal flow of traffic. In this case the higher directional flow can be given 100% of the bandwidth at the expense of the traffic moving against the peak direction. The effect of the reduction of bandwidth allowed by the non-ideal spacing is therefore minimized.

If the bandwidth becomes too narrow, motorists travelling down the road could “lose” the green wave and will therefore be stopped and delayed, hence 60% is considered to be the lower limit. Again, further research is necessary to confirm this.

The wider 70% bandwidth on the higher standard (Class 2) road, takes into account that speeds are higher hence: (1) not having to stop as often will improve safety, (2) there is a greater standard deviation around the average travel speed resulting in a greater platoon dispersion and (3) the percentage of “strangers” is likely to be higher.

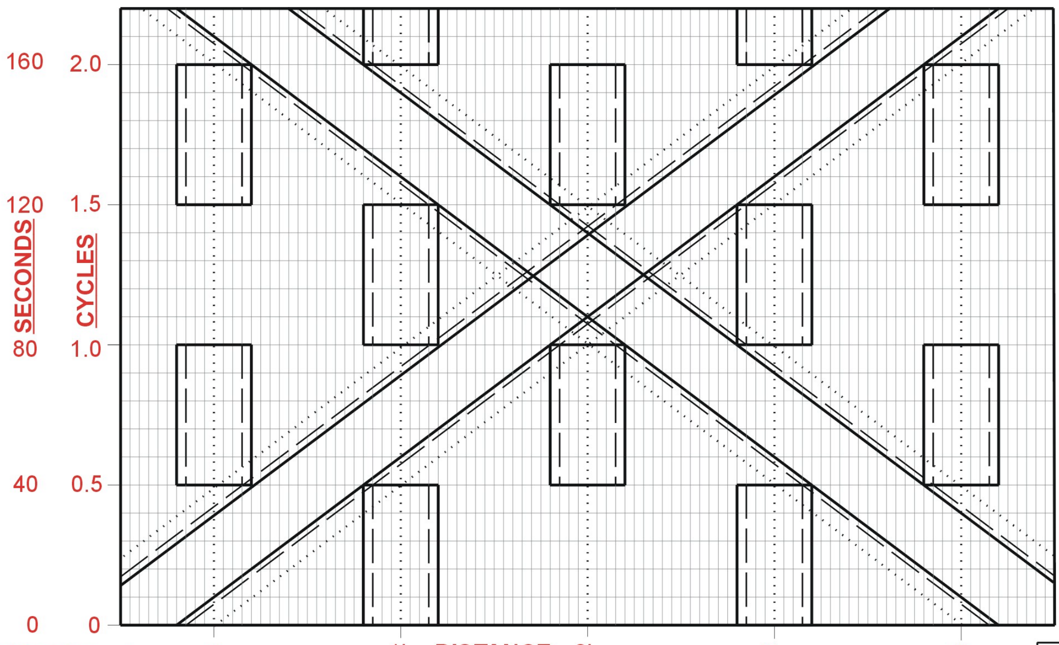
A space time diagram for the general case (70%/60% of ideal bandwidth) with the main road green receiving 50% of the cycle time is provided in Figure 1. This general figure can be used for any of the “70%/60%” cases in Table 1, but for illustration the Class 2, 800 m, 72 km/h, 80 sec. cycle and the Class 3, 600 m, 54 km/h, 80 sec. cycle examples have been included. The vertical gridlines are 5% of the average spacing apart.

ADDITIONAL FLEXIBILITY OPTIONS

The minimum criteria set out above define the limits within which the signal may be placed, i.e. 15%/20% on either side of the average spacing for Class 2 and Class 3 roads respectively. The analysis assumes limited platoon dispersion and side road and turning volumes such that 50% of green time is provided on the main road at each intersection.

Given these limits and ideal spacing, it can be seen from Figure 1 that the green time given to the main road can be reduced from 50% to 35%/30% without affecting the green bandwidth. It can also be seen from Figure 1 that if the green time given to the main road is more than 50%, then the signal could be placed at a distance greater than 20% from the average spacing without reducing the through bandwidth. This is illustrated in Figure 2.

It is recognised however, that the split of green time between the various phases is usually determined by side road and main road demand, delay and capacity, not by bandwidth required. Nevertheless, if a signal will never require more than 30% of the cycle time, it can be placed outside the 15%/20% limit as long as it is within 35%/40% of the average spacing on either side of the ideal for Class 2/3 respectively.



Average Spacing = L	0	1L	DISTANCE 2L	3L	4L
Class 2 - Ideal	0	800	1600	2400	3200
Class 2 - Variance	-120 to +120	680 to 920	1480 to 1720	2280 to 2520	3080 to 3320
Class 3 - Ideal	0	600	1200	1800	2400
Class 3 - Variance	-120 to +120	480 to 720	1080 to 1320	1680 to 1920	2280 to 2520

KEY
Ideal
Class 2, 70% speed 72km/h
Class 3, 60% speed 54km/h

FIGURE 1: Space Time Diagram - Bandwidth 70%/60% of Ideal - Fixed (50%) Green Time

SUMMARY

While there is general acceptance that the ideal or standard spacing for Class 2 and Class 3 roads should be 800 m and 600 m respectively, if the guidelines are to be applied in practice, there must be scope to allow for a variance around this ideal. In this report it is argued that the ideal green bandwidth of 50% of the total cycle time can be reduced to 35% on Class 2 roads and 30% on Class 3 roads without significantly affecting the coordination objective.

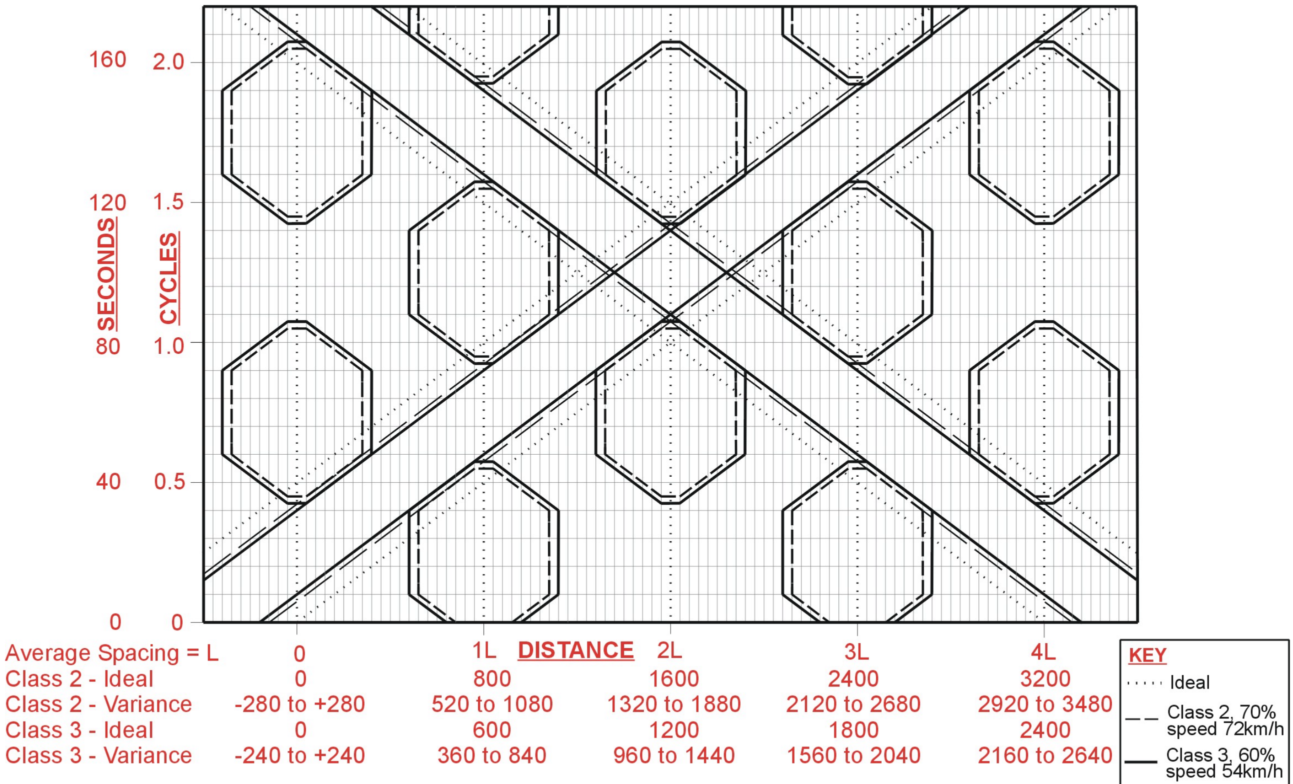


FIGURE 2: Space Time Diagram - Bandwidth 70%/60% of Ideal - Green time varies

In Figure 2, it is proposed that the areas bounded by the octagonal shapes represent the limits within which red signals can be given to the main road. The boundaries of these octagons are as follows:

	Green time to main road as % of cycle (G/C)	Variance on either side of average spacing
Class 2	40%	5%
	70%	35%
Class 3	35%	5%
	70%	40%

SIGNAL GROUPS OR CLUSTERS

Theoretically it does not matter how many signals are placed around the average (within the octagon) provided the green time required by the cross road and by the right turn phases does not go outside the boundaries given in Figure 2. More than one signal in the vicinity of the average spacing does not affect the bandwidth.

In determining the acceptability of having two or more signals clustered within the above boundaries therefore, factors such as safety and storage (queuing) length must be the guiding criteria.

CONCLUSION

The requirement for a minimum spacing between signals (e.g. 800 m for Class 2 and 600 m for Class 3) is based on mobility. Mobility requires that vehicles can proceed through a series of signals without stopping. In order to achieve this, it is necessary to provide a green through band of adequate width to enable two-way traffic to proceed at reasonable speeds in both directions.

It is postulated in this paper that it is possible to obtain a reasonable green band and still allow for considerable variation around the ideal spacing. While recognising the need for further research, the variation considered acceptable as a result of this initial research is 70%/60% of ideal bandwidth as shown in Figure 2 and Table 3.

Table 3 – Range of ideal spacing requirements and allowable variations

	Class 2	**Class 3**
Ideal Spacing	650 to 1 100	450 to 900
Min green bandwidth as % of cycle time	35% (70% of 50%)	30% (60% of 50%)
Variance on either side of ideal if main road G/C is		
35%	-	5%
40%	5%	10%
50%	15%	20%
70%	35%	40%
Maximum range for placing signals in the 800/600 m case	560 m (800 (±280))	480 m (600 (±240))
Minimum gap between signals at extreme in exceptional circumstances	240 m	120 m

The ranges given in Table 3 allows the practitioner far more flexibility than was previously the case. Even though the allowances may seem generous, if these standards are accepted and applied, an improvement in traffic flow on most of the major arterials in South African cities can be guaranteed.

IMPLEMENTATION OF SIGNAL SPACING STANDARDS

J D SAMPSON

Jeffares & Green Inc., P O Box 1109, Sunninghill, 2157

Dr. JOHN DAVID SAMPSON - CV SUMMARY

Dr. John Sampson is a Professional Engineer, BSc (Civil Engineering) (Witwatersrand 1971), MS (Transportation Engineering) (California, Berkeley 1975), BCom (Economics with distinction, Industrial Psychology) (UNISA 1977), PhD (Witwatersrand 1992), is a Fellow of the SA Institution of Civil Engineering (FSAICE), a Principal of a SA Association of Consulting Engineers (MSAACE) member firm and a member of the Institute of Transportation Engineers (MITE). His PhD thesis was entitled “Warrants for Traffic Signals”. He holds Certificates in Project Management, Traffic Control and various other diplomas.

Dr Sampson spent twenty-one years with the (then) City Engineer's Department of Johannesburg where he rose to the position of Deputy City Engineer. Most of that time was spent in the Road Planning and Traffic Engineering Branch of the Department. In 1988 he joined the Urban Foundation as General Manager (Housing), FHA Homes.

In 1990, he was appointed as a partner of Jeffares & Green and a Director of Jeffares and Green Inc. where he is in charge of the Traffic and Transportation Division. He has lectured at the University of the Witwatersrand and from 1995 to 1998, he was "Extra Ordinary Professor" in the Civil Engineering Department of the University of Pretoria.

Dr Sampson’s main fields of specialization include transportation planning, transportation engineering, economic analysis of projects, road financing, inter-modal infrastructural development, traffic engineering (especially traffic signs, signals and road markings) and project management. He has been extensively involved in drawing up national specifications for traffic signals, road signs, route marking and access management and is the longest serving member on the committee responsible for drawing up the SADC Road Traffic Signs Manual.