

ISSUES WITH TRAFFIC SIGNALS

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ABSTRACT

In 2000, the National Department of Transport commissioned the redrafting of Volume 3, Traffic Signal Design and related chapters of the Road Traffic Signs Manual. The first draft was completed in April 2001 and has been in use since that date. Various changes to the design of traffic signals appear in this draft, requiring changes to the National Road Traffic Regulations. The changes to the Regulations were promulgated in September 2003.

During the preparation of the document a number of issues arose that were not dealt with, mainly because the research necessary had not been undertaken.

Most of the issues relate to the configuration of signal faces, and include amongst others the following:

- Traffic operations during right-turn phases are often inefficient because drivers are not able to anticipate the flashing green arrow and sometimes do not see it.
- The lagging right-turn phase has several advantages when compared with the leading right-turn phase, but its effectiveness is currently being limited due to the signaling system. There is a need to consider changes to the system.
- A protected-only right-turn phase is one in which the right-turn movement is allowed only when a green flashing arrow signal is indicated. A new signal face and road sign is now provided for this in the regulations. Experience with the signal face, however, has shown that while it serves this purpose, it does have a number of disadvantages. An alternative approach may be required and is discussed in the paper.

This paper also addresses some alternative signaling methods. It is proposed that a research project be commissioned to properly investigate and evaluate both existing and alternative traffic signal systems.

1. INTRODUCTION

Volume 3 of the Road Traffic Signs Manual (RTSM) deals with traffic signal design. It has been developed as a companion to other volumes in the manual and is intended to provide basic practical guidance on the motivation, planning, design, installation, operation and maintenance of traffic signals. It was originally written in 1992, but developments in the field of electronics as well as traffic engineering resulted in the original document being outdated in a number of respects.

In 2000 the National Department of Transport therefore commissioned the redrafting of Volume 3 and related sections of the manual. This redrafting was completed in April 2001. The project also included the drafting of recommended changes to the South African Road Traffic Regulations. The changes to the regulations were promulgated in September 2003.

Due to the lack of research, however, it was not possible to resolve all issues related to the design of traffic signals during the project. This paper outlines some of these unresolved issues and suggests a way forward.

2. MOST IMPORTANT CHANGES

Volume 3 of the manual together with other chapters from other volumes (Chapter 6 of Volume 1 and Chapter 10 of Volume 4) were rewritten and upgraded during the project. The manual was significantly extended by new material related to traffic signal management.

Important technical changes to traffic signals introduced during the project include the following:

- All traffic signals must in future be approved by either a responsible registered professional engineer or professional technologist of the road authority concerned.
- Three principal traffic signals are now prescribed for each approach to all signalised junctions. Previously only two signals were required on the far side of a junction. A third principal signal is now prescribed on the near side of the junction (at the stop line).
- At least two signal faces containing flashing green left arrow signals are now prescribed for left-turn phases (This is an existing requirement for right turns).
- Background screens (backboards) are prescribed for all traffic signal faces, except pedestrian and pedal cyclist signals.
- Yellow retro-reflective strips can be installed on signal posts to improve visibility of signals.
- New traffic signal faces S1L and S1R and traffic signal arrow signs ST1 to ST5 have been introduced for the signalling of protected-only left- and right-turn signal phases.
- Traffic signal faces S13, S14 and S15 are now obsolete and will not be permitted in future.
- LTORAS (Left turn on red after stop) signals is no longer allowed in any form. (Local experience has indicated that the majority of drivers abuse these signals, and do not comply with the traffic regulations, resulting in unsafe traffic situations).
- Only traffic signal faces allowed by the traffic regulations may be installed. No duplicate light signals will be allowed in a traffic signal face. (These requirements are not new requirements, but are given more emphasis in this edition of the manual).
- Steady green arrows may not be displayed together with green disc signals. Such green arrows may also not be displayed when there is a conflicting traffic movement. (These are also not new requirements, but are given more emphasis in the new manual).
- The planned operation of traffic signals in flashing mode for part of the day or night is not recommended, and alternative methods of accommodating low traffic volumes are suggested (for example short cycle times and vehicle actuated operation).
- A new start-up method for traffic signals is given.
- Pedestrian crossing lines should in future, as a general rule, be provided at all signal controlled junctions, even if no or few pedestrians use the junction (except where pedestrians are specifically prohibited to cross the junction). This is necessary to improve the visibility of the intersection.
- A “pelican stage” at mid-block crossings is allowed in which the red vehicular signals are permitted to flash during the flashing red phase for pedestrians.
- Minimum green intervals are now prescribed for safety.
- A new approach to the establishment of the intergreen period is followed in which the yellow is kept as short as possible, and a longer all-red period is provided for clearance purposes.
- A recommendation is included that an enforcement tolerance should be provided during the all-red period to accommodate drivers who are unable to stop during the short yellow interval. Law enforcement should only commence during the last one second of the all-red interval.

3. OUTSTANDING ISSUES

The most important outstanding issues relate to the signalling of right-turn phases.

These issues include the following:

- Traffic signal indications for right-turn phases.
- Restrictions on the use of lagging right-turn phases.
- Signalling of protected-only right-turn phases.

Right-turn phases are classified in the manual as permitted, prohibited or protected.

The following modes of operation are allowed:

- Permitted-only mode in which a right-turn movement is permitted but no exclusive turning phase is provided.
- Protected/permitted mode in which an exclusive protected turning phase is provided, but the right-turn movement is also permitted during the main phase.
- Protected-only mode in which vehicles are allowed to turn right only during a protected phase.
- Prohibited mode in which no right-turn movement is allowed.

4. TRAFFIC SIGNALLING OF RIGHT-TURN PHASES

Traffic signal operating sequences for protected right-turn phases are shown in Figures 1 and 2. Figure 1 shows sequences for *protected/permitted* right-turn phases and Figure 2 shows sequences for *protected-only* phases.

The figures also show the signal sequences required for single and double right-turn phases:

- The single right-turn phase protects the right-turn movement from one side only. Straight-through and left-turn traffic also receives right of way during the phase, and all traffic on the opposite approach must stop.
- The double right-turn phase protects the right-turn movements from both sides. The two right-turning movements receive flashing green light signals at the same time and no straight-through traffic on the road receives right of way during this time.

According to the manual, the double right-turn phase has the disadvantage that the flashing right-turn arrow signals are sometimes not noticed by drivers. With the single right-turn phase, a green disk is displayed with the flashing arrow which is more visible to drivers. The manual states that this problem can to some extent be addressed by providing additional signal faces that contain the flashing green arrow signals.

No formal research has been undertaken on the degree to which double right-turn phases are noticeable to drivers, and such research is required to confirm the following discussions. Experience however, confirms that the right-turn flashing arrows tend to be the least noticeable of all the available sequences.

With a leading green, the problem is that the double right-turn flashing arrow is often unexpected and cannot be anticipated by strangers to the intersection. Right turners are accustomed to the rule of the road that requires them to give way to opposing traffic before turning. The right-turn flash coming before the through movement therefore contradicts this expectation and is sometimes not even seen by the turning driver.

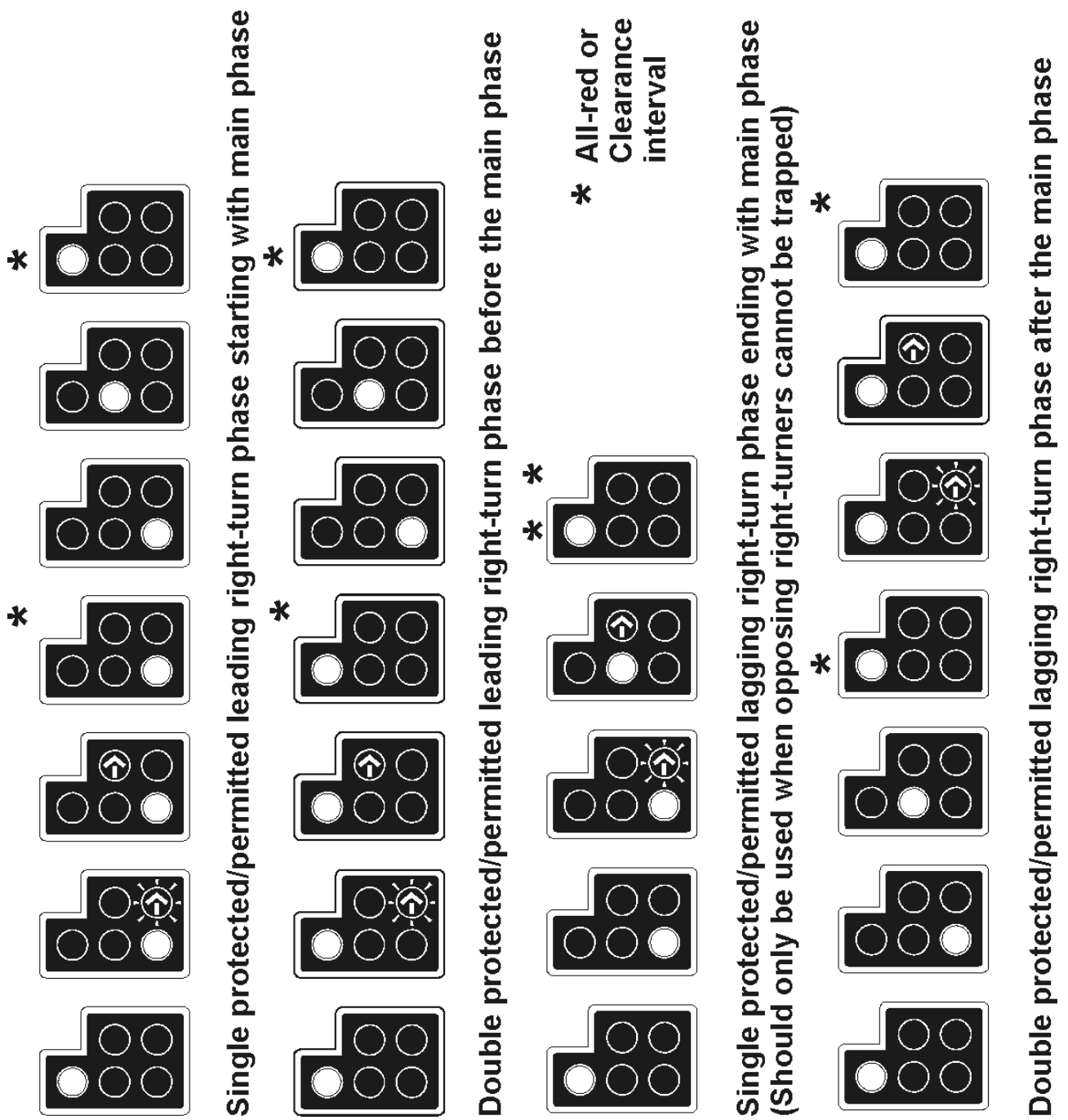


Figure 1. Traffic signal sequence for protected/permitted right-turn phases using the S8 face (Volume 3, RTSM).

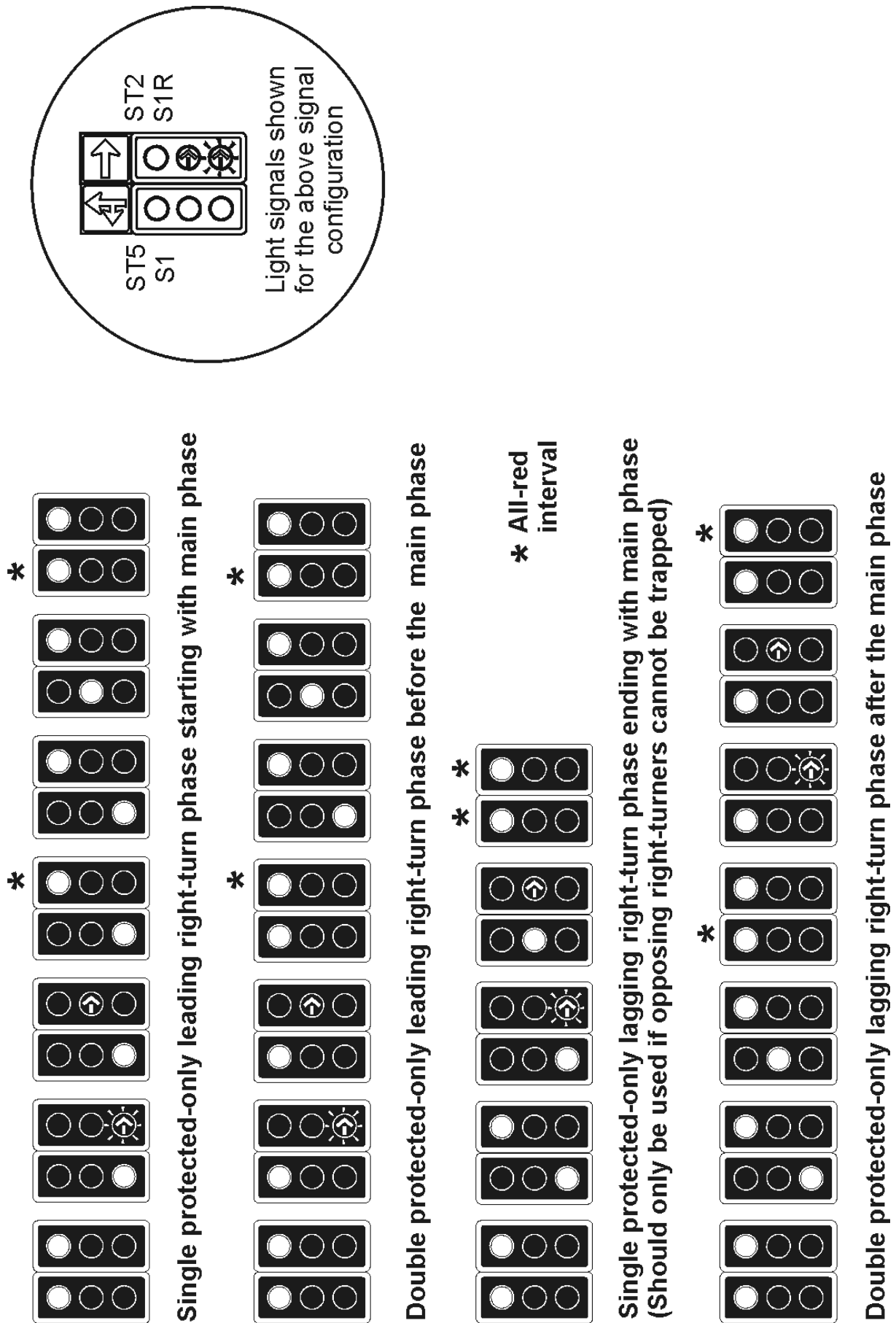


Figure 2. Traffic signal sequence for protected-only right-turn phases using the S1 and S1R signal faces in conjunction with ST5 and ST2 traffic signal arrow signs (Volume 3, RTSM).

With the lagging right-turn green an entirely different problem exists. The manual currently requires a minimum of two seconds all red after the termination of the through green and yellow signal before the right-turn flash can begin. When the through road turns red, right turn drivers look for the green flash to start. When it does not appear, those drivers in the intersection proceed to clear during the intergreen while those drivers behind the stop line stop looking for the flash and wait for the next green signal. The right-turn phase is then not utilised.

The simplest method of addressing the lagging right-turn phase problem is to eliminate the requirement for an all-red interval. There may, however, be a danger that this could result in unsafe operations. Research is therefore required to establish whether the problem will in the first place be addressed by the elimination of the all-red interval, and whether such reduction creates safety problems.

An alternative approach that could be considered, but which would constitute a major deviation from existing practice, is to display the right-turn yellow arrow together immediately prior to the flashing green signal. The purpose of the yellow arrow is to provide an indication that that a right-turn phase will be provided. There is a danger that drivers may become confused by the yellow signal and consider it as an indication that a right-turn phase is being terminated. Experimentation would be required to establish the reaction of local drivers to this yellow arrow.

5. RESTRICTIONS ON THE USE OF LAGGING RIGHT-TURN PHASES

Right-turn phases can be provided either before or after the through phase (leading or lagging). The leading right-turn phase appears with or before the main phase on the same approach, while the lagging right-turn phase appears after or during the final part of the main phase interval.

The single lagging right-turn phase (from one side only) cannot be used in most circumstances because it results in a situation where a yellow light signal is displayed to right-turning traffic while conflicting traffic movements receive a green light signal - a combination of light signals which is not allowed. The right-turning traffic receiving yellow has no way of knowing that opposing traffic is still receiving green, and may turn right in the face of this oncoming traffic, which is exceptionally dangerous. This problem is sometimes called the "yellow trap" or the "right-turn trap".

Due to the above problem, the single lagging right-turn phase is not allowed by the manual, unless there is no right-turning traffic in the opposite direction, such as at a T-junction or on a one-way street.

Apart from the situations where a single lagging right-turn phase is not allowed, provision is made for both leading and lagging right-turn phases.

The following advantages and disadvantages of leading versus lagging right-turn phases are quoted from the manual:

- *The leading right-turn phase has the important advantage, particularly on high-speed roads, that vehicles will only turn when opposing traffic has been at rest for some time. When a lagging phase is provided, vehicles will turn while opposing traffic is in the process of stopping.*
- *The leading green also has the advantage that it could reduce the number of gap acceptance conflicts, which may lead to safer operations. With lagging green, more vehicles may accept gaps while waiting for the right-turn phase.*
- *The leading green, however, has the disadvantage that it may be creating a habit in which drivers turning right tend to pre-empt right of way, even when no right-turn phase is provided. The lagging phase has the advantage that normal signal operations and normal driving behaviour are better approximated.*

- *A second disadvantage of the leading green is the tendency for false starts on the opposite approach. It is not a rare occurrence to find vehicles on the opposite approach pulling away at the same time as traffic receiving the leading green.*
- *An advantage of the lagging right-turn phase is that it provides significantly better separation between right-turning vehicles and pedestrians. This is a particularly important advantage in areas with high pedestrian volumes.*
- *A further advantage of the lagging right-turn phase is that it can be more efficient when vehicle-actuated control is implemented. The lagging phase is only called at the end of the main phase if right-turning vehicles remain that could not accept gaps. With leading green, the phase will be called independent of whether right-turning vehicles will be able to accept gaps.*

A further advantage of the lagging right-turn phase not discussed in the manual is that it often has a greater capacity than a leading right-turn phase. The reason for this is that vehicles turning right would already be waiting within the intersection at the commencement of the lagging green. With a leading green, the vehicles would be waiting on the approach to the intersection, with the result that a few seconds will be lost while vehicles enter the intersection at the start of the green flash.

According to the manual, no absolute advantages are inherent in either leading or lagging configurations. The choice of the optimum configuration will be dictated by specific conditions at a particular junction.

The above list of advantages and disadvantages, however, indicate that lagging right-turn phases generally have more advantages than leading phases. The general utilisation of lagging right-turn phases (particularly on low-speed roads), however, is currently being restricted due to the yellow trap problem.

Because of the advantages of lagging green arrows, various proposals have been made to address the yellow trap problem with single lagging right turns. Most of these proposals involve the use of an additional yellow signal to indicate to right-turn drivers that they must continue to yield to the opposing traffic stream. Different types of yellow signals have been proposed, such as a flashing disc, flashing arrow and a steady or flashing triangle. Examples of such signals are shown in Figure 3. It is important that these alternatives should be investigated and a possible solution to the problem found so that lagging right-turn phases could more readily be used.

6. PROTECTED-ONLY RIGHT-TURN PHASES

Protected-only right-turn phases are considered when sight distance is poor or when allowing right turners to utilize gaps in the opposing traffic stream could lead to unsafe situations. Sight distance is often restricted by right-turn vehicles waiting in an opposing right-turn lane. This problem is most acute at intersections located on a curve, or when very wide medians are provided. Another cause of poor sight distance is the provision of double or triple right-turn lanes. The ability of vehicles in the right hand turning lane/s to see can be significantly reduced by vehicles in the left lane, particular if the vehicles in the left lane are large trucks or buses.

The sight distance problem can be effectively dealt with by the use of protected-only right-turn phases. No vehicles are permitted to turn right by accepting gaps, which largely eliminates the need for adequate visibility.

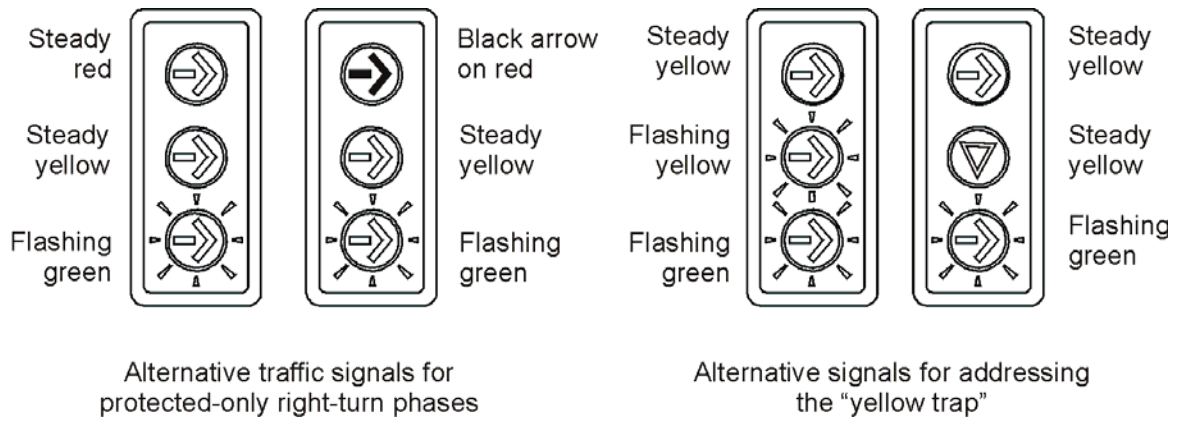


Figure 3. Some alternative traffic signals.

The main problem with protected-only right-turn phases is that most drivers have become used to accepting gaps when turning right. A very clear and strong red signal is therefore required to prevent such gap acceptance. The system that is now being allowed by the manual and the National Road Traffic Regulations is shown in Figure 4. The system utilises a combination of signs and signals to indicate the direction to which the red disc signal is applicable.

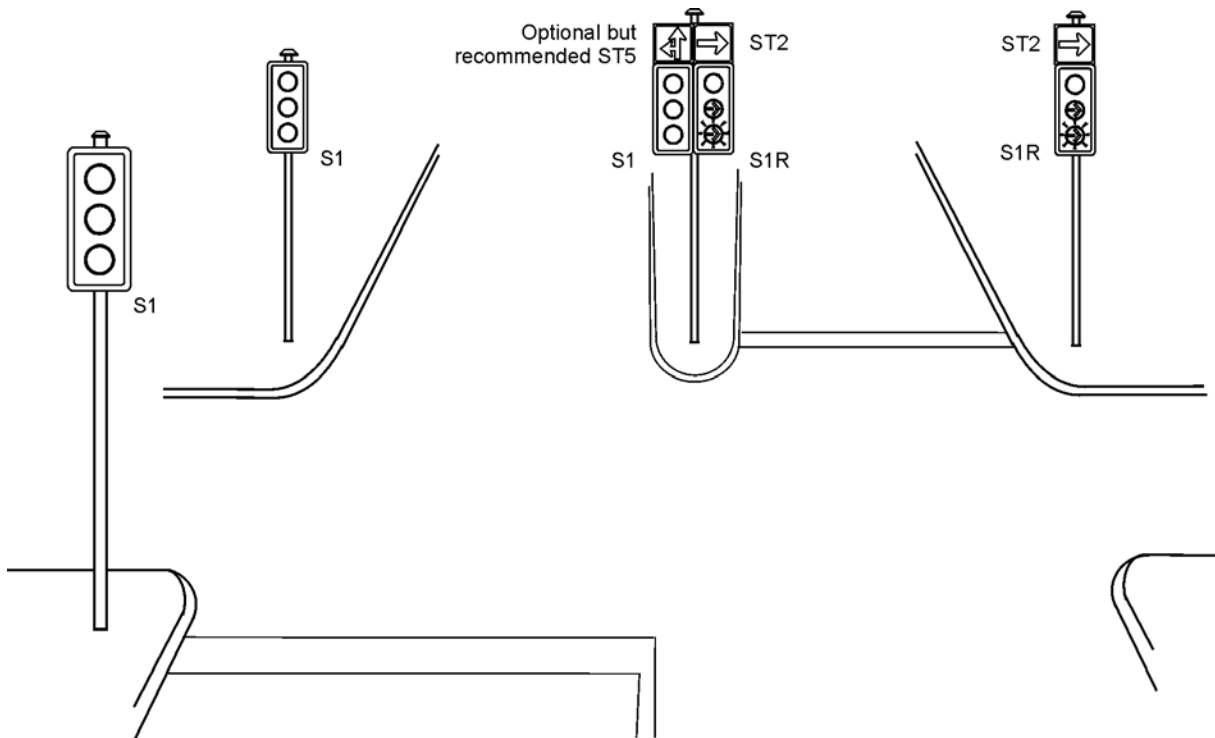


Figure 4. Signalling for protected-only right turn (Volume 3, RTSM).

The advantage of the system is that the red signal is very visible, and that many drivers instinctively stop when they see the traffic signals. Most drivers seem to understand the system immediately they encounter it.

A problem with the system shown in Figure 4 is that it requires a right-turn phase throughout the day, irrespective of whether it is needed. Due to the arrow signs, it is not possible to switch the right-turn phase off and to allow gap acceptance during the main phase. Another problem is that the arrow signs may not always be visible, particularly at night (although no problems have been reported in this regard, most drivers seem to react to the physical location of the signal rather than the arrow sign).

A system which does not rely on the traffic signal arrows signs would have been ideal because this would allow the right-turn phase to be switched off during periods when it is not required. One such system was investigated during the project, namely the use of a red arrow rather than the red disc (shown in Figure 3). Such a system was installed in Pretoria, but it was found to be ineffective. Most drivers continued to turn right in spite of the red signal. It appears if drivers tend to react to the arrow rather than the colour.

A further alternative that can be considered is to use a painted black arrow on the red disc as shown in Figure 3. This system would however represent a major deviation from the current signalling system and experimentation would be required to establish the advisability of using such an approach.

7. CONCLUSIONS AND RECOMMENDATIONS

The purpose of the paper was to indicate that although the updated manual introduced a significant number of important improvements to traffic signals, a number of issues still remain unresolved.

These issues include the following:

- Drivers sometimes do not anticipate the flashing green arrow with the result that traffic operations may become inefficient.
- The effectiveness of the lagging right-turn phase is currently being limited due to the signalling system, while it has several advantages when compared with the leading right-turn phase.
- The signal face and road sign for protected-only right-turn phases is effective but has a number of disadvantages. Alternative approaches should be considered.

There is an urgent need to address the above issues and a research project should be undertaken to properly investigate and evaluate both existing and alternative traffic signal systems in South Africa.

8. REFERENCE

- [1] National Department of Transport, South African Road Traffic Signs Manual, Volume 3, 2001.

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KEY EXPERIENCE

Dr Sampson spent twenty-one years with the (then) **City Engineer's Department of Johannesburg** where, in 1986, 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.

He lectured part-time at the **University of the Witwatersrand** during the 1980's. In 1988 he joined the Urban Foundation as General Manager (Housing), **FHA Homes**.

In 1990, he was appointed as a partner of **Jeffares & Green**, Consulting Engineers and a Director of Jeffares and Green Pty. Ltd. From 1995 to 1998, he acted as an "extra-ordinary" Professor in the Civil Engineering Department of the **University of Pretoria**.

In 2003, he started **Transportation and Traffic Technology Africa Pty Ltd**, a BEE company, where he is managing director.

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), environmental impact of roads, project management, general management and financial administration.