TRAFFIC GROUP TECHNOLOGY

PROTECTING THE CYCLE

A scenario-based approach for improving traffic flow and reducing driver frustration at portable signals.

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GLOSSARY

AG	AutoGreen® - a registered trademark
DfT	Department for Transport
DMRB	Design Manual for Roads & Bridges
EVO	Pike Signals Evolution
FMCW	Frequency Modulated Continuous Wave
JT	Journey Time
KCC	Kent County Council
MOVA	Microprocessor Optimised Vehicle Actuation
RC2	Hollco RadioConnect 2
TGS	Traffic Group Signals
TMO	Traffic Management Operative
TOPAS	Traffic Open Products and Specifications
UAP	Urban All-Purpose Road
UKPN	UK Power Networks
UTC	Urban Traffic Control
VA	Vehicle Actuation
VPH	Vehicles Per Hour
VRM	Vehicle Registration Mark

ABOUT THIS PAPER

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The paper and trial data has been produced by Traffic Group Technology, the Research & Development division of The Traffic Group.

Traffic Group Signals incorporates some of the UK's leading brands in portable and temporary traffic signals, Hollco and Pike Signals, which are featured in this paper.

For more information about Traffic Group Signals, please visit: **TrafficGroupSignals.com.**

PROTECTING THE CYCLE: A SCENARIO-BASED APPROACH FOR IMPROVING TRAFFIC FLOW AND REDUCING DRIVER FRUSTRATION AT PORTABLE SIGNALS.

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Traffic Group Technology

ABSTRACT

Results are presented in this paper from a collaboration between the Kent Lane Rental Scheme, UK Power Networks and The Traffic Group to investigate and improve the efficiency of vehicle movements at street works controlled by portable traffic signals. Extensive road trials have been undertaken in order to understand the factors which limit the effectiveness of current control methods including manual control and traditional Vehicle Actuation (VA) operation.

Use of a scenario-based operating mode, called AutoGreen, is presented as a means of addressing current limitations, improving efficiency and reducing the likelihood of specific situations which create driver frustration. The tendency of VA to over-extend green times is demonstrated using real-world data and compared with an alternative approach based on the use of high fidelity FMCW radar data.

A key finding of the trial is that the most significant impact on journey times occurs when shuttle working sites become congested with queuing traffic causing them to be unable to service phases effectively. Techniques for preventing this issue are presented and these provide the headline title for this paper, 'Protecting the cycle'.

Trial data, including ANPR based journey times, is presented in order to provide a comparison between traditional VA operation and the new scenario-based operating mode.

A recent achievement of the trials has been the successful deployment of portable signals, on a main route out of Dover with traffic flows of up to 845vph and located just 130m from a junction controlled by permanent signals. AutoGreen operated at the site for 48 hours during a Thursday and Friday in July (prior to school holiday breakup) throughout which time it required no human intervention and was successful in minimising impact on journey times.

INTRODUCTION

Portable signals are employed for a wide range of purposes across the UK. Of these, street works are the most common, driven by the need to maintain existing utilities and to make new connections.

Deployments are typically short in duration; usually less than a week; however, the volume of works being undertaken make it commonplace to encounter a portable signal installation on the network.

Shuttle working is a necessity for these types of works and has a significant impact on road capacity. In the case of 2-way signals, capacity can be reduced to just 45% of the original state ; however, the real figure is often lower than this owing to site-specific issues.

The challenge of deploying shuttle working at street works is further complicated by the very limited tools available to mitigate impact. Permanent shuttle sites can potentially benefit from detailed planning / modelling, additional detectors (e.g. within the shuttle area itself) or running as a stream where the shuttle is located close to other signals. These measures are simply not practical at street works sites.

Current Mitigation Strategies

Across the country, highway authorities and statutory undertakers work closely together to minimise and mitigate the impact of street works. Kent County Council (KCC) have taken this a step further by operating the first lane rental scheme outside of London.

Where a highway authority determines that the use of VA is unsuitable for a specific location, the most common mitigation applied across the network is the use of portable signals under 'Manual Control'. A human operator provides the ability to dynamically change timings to avoid congestion.

For some high-profile locations and / or long duration deployments, more advanced forms of mitigation are employed such as placing portable signals under UTC control. This can have significant benefits in mitigating local impact and maintaining the integrity of the wider network. However, UTC is available in only a small proportion of locations and even where it is available, it is not practical to deploy for large volumes of short duration works.

Current Mitigation Deficiencies

Both VA and Manual Control have significant limitations[1]. VA simply cannot move enough traffic and any attempt to make it do so, for example by configuring longer maximum green times, creates a significant risk of flow breakdown owing to the creation of congestion.

Manual Control can be very effective but in practice often isn't. Problems can occur in the planning of manual control, for example the communication of objectives for manual control at a specific site. Alternatively, and more commonly, problems occur during its execution. Long periods of concentration whilst making finely balanced decisions about phase cycling are very difficult to sustain for a human operative in the context of a repetitive task, performed in all weathers and against a backdrop of abuse from passing motorists. Visibility of traffic on different phases can also be an issue along with a tendency for operatives to subconsciously favour service of a specific phase. Manual Control also incurs a level of risk for Traffic Management Operatives which would be preferable to avoid where possible.

1 From our own observations of traffic flows at these sites, a 100m long 2-way shuttle site running pink book green times in Vehicle Actuation (VA) mode with high demand from both phases achieves a best case capacity of around 590 vph for each phase. This contrasts with 1300 vph as quoted by DMRB[7] for a 'UAP3' road with >7.3m width, single carriageway.

AutoGreen

The Traffic Group were approached by Kent County Council and UK Power Networks, both of which were acutely aware of the difficulties involved in mitigating traffic impact at street works sites and wanted to promote innovation in this area. A challenge was set, to identify and develop new technology that could alleviate the problems being experienced.

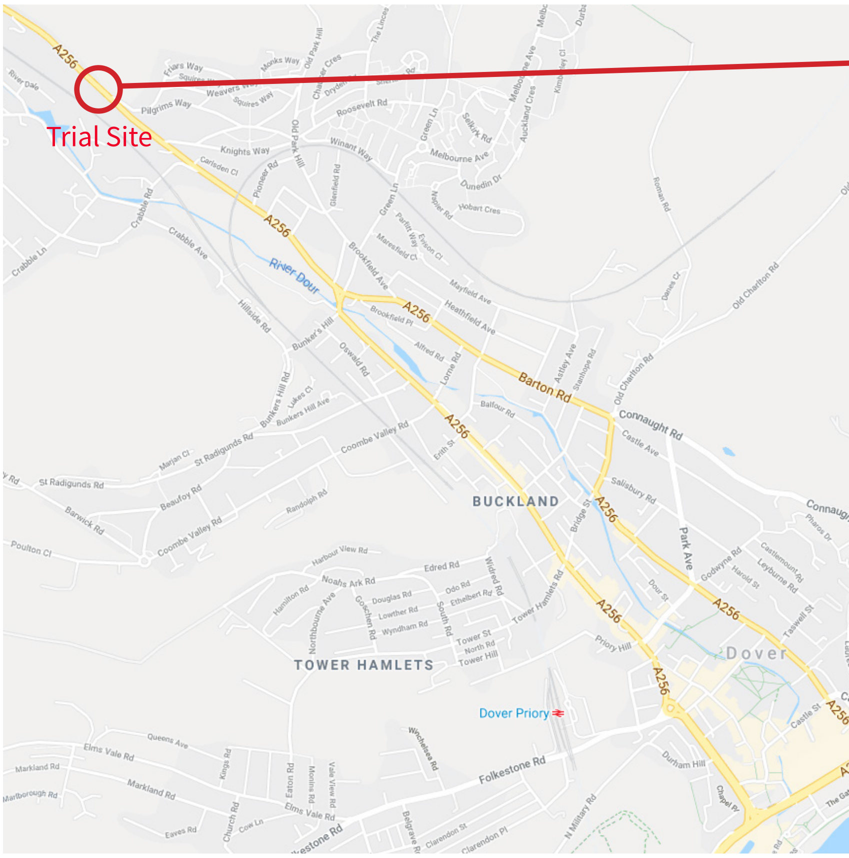
In taking on this challenge, The Traffic Group set a target to create an alternative method of control for traffic signals that could replace both VA and manual control. The system would need to be as easy to deploy and operate as VA whilst achieving the traffic moving capability and flexibility of manual control.

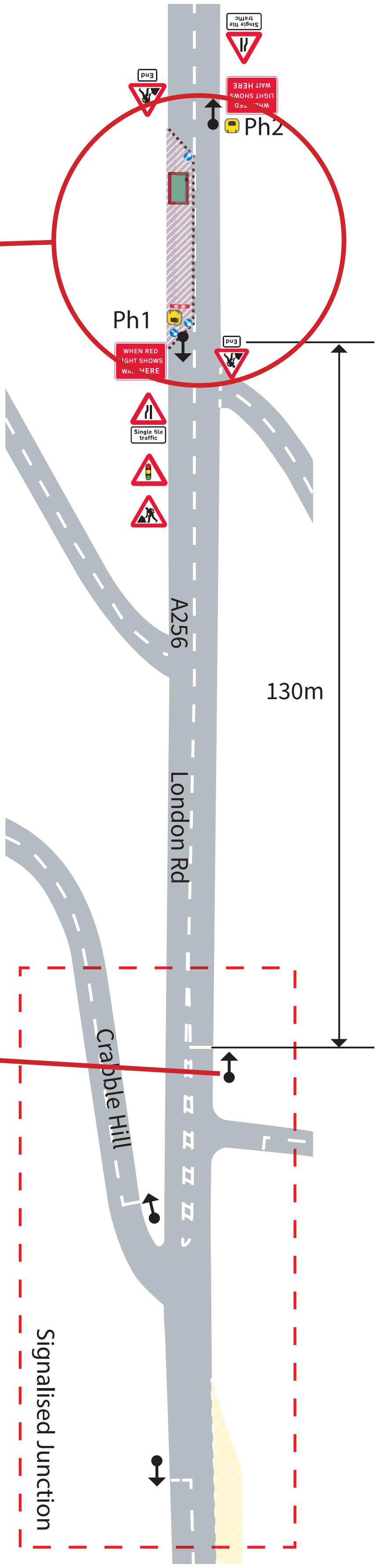
Development of the system has taken 2 years to complete, during which period extensive real-world trials have been performed, accumulating over 400 hours of supervised trials across 23 locations. These have guided the ongoing AutoGreen development product and as time has progressed, increasingly busy and increasingly complex locations have been tackled.

This paper makes use of recent trials performed in Kent to illustrate the capability and functionality of the AutoGreen system and compares this with VA operation at two recent sites. The sites usefully illustrate issues with VA operation that have been witnessed repeatedly across a number of earlier trials.

Trial Locations

The first of the two trial sites referred to in this paper is located on the A256 in Dover. This was a very challenging site owing to its proximity to a signal-controlled junction just 130m from the phase 1 head. Additionally, a side road was positioned very close to the phase 1 head.





Location: A256 in River, Dover.
Trial Dates: 17th – 19th July 2019
Peak Southbound Flow: 845vph [1]
Peak Northbound Flow: 574vph [1]
Distance from perm. signals: 130m
All Red Time: 10 secs (both directions)
Site Length: 100m
VA Phase 1 Max Green: 40 secs
VA Phase 2 Max Green: 40 secs

Data from an earlier trial performed in Maidstone is also referred to, located as follows:

Location: Tonbridge Road, Maidstone
Trial Dates: 1st – 3rd May 2019
Peak Southbound Flow: 752vph [1]
Peak Northbound Flow: 789vph [1]
Distance from perm. signals: 170m
All Red Time: 12 secs (both directions)
Site Length: 120m
VA Phase 1 Max Green: 40 secs
VA Phase 2 Max Green: 40 secs

This site was located in an area with five schools and a college in close proximity which resulted in significant volumes of bus movements. Three bus stops were located close to the site and these were difficult to pass. One of the three bus stops located 170m from the site had the effect of completely blocking traffic when occupied. Additionally, a busy right turn close to the site also contributed to the complexity of this location. Traffic flows were very high in both directions for extended periods.

Trial Configuration

Trials have been performed using both Hollco RC2 and Pike T2 AutoGreen equipment. These units employ the same FMCW radar technology (Frequency Modulated Continuous Wave) supplied by AGD Systems and both employ the same AutoGreen controller algorithms.

The version of AutoGreen functionality reported on in these trials is implemented in the following production versions of controller software:

- Hollco RC2: v1.3.0
- Pike T2 AutoGreen: v2.30

Controller log data was captured from the signals in order to allow green times to be plotted.

Journey times through the trial sites were monitored using two custom made battery operated ANPR units, each located between 400m and 600m from the site. These employ MAV IQ ANPR cameras to capture hashed VRMs which were then post-processed to determine average journey times for each 15-minute period.

EFFICIENT USE OF GREEN TIME

In looking for ways to improve the efficiency of portable signals, an obvious strategy might be to simply employ longer green times than are currently permitted for VA by TOPAS 2502b[2]. On paper there is a theoretical efficiency to be gained by reducing the percentage of time 'lost' to the inter-green period by cycling the signals at a slower rate. In reality, this approach is somewhat flawed. Aside from creating a risk of congestion, increasing max green times using current Doppler radar technology acts to exacerbate the well-documented problem of VA over-extending green times[5].

VA Over-Extension

Doppler radar technology employed in the current generation of portable signals supports only a simplistic approach to be taken in regard of green time determination as follows.

VA Green Time Algorithm

Green times are extended, up to a user defined maximum, if any vehicle is approaching the radar within its speed / range detection envelope.

Notably, VA makes all of its decisions within a single cycle. It makes no consideration of what occurred during previous cycles.

The end result is that the approach does not attempt to identify green times that are sufficient to move the underlying traffic flows being experienced.

The nature of the algorithm means that green times often vary significantly from cycle to cycle and, on the whole, tend towards over-extension. The problem is made somewhat worse by the variability in detection range experienced when using by Doppler radar technology.

Doppler Radar Technology

The very nature of Doppler detection means that in order to detect a car at 40m, the radar may well also detect a large target such as an HGV at up to 90m. Such vehicles may not even be destined to travel through the site in question. Doppler radar is also naturally susceptible to false detections from a range of non-vehicular sources.

Over-extension was observed in-person during trials and is evident also in the captured data. Figure 1 shows VA operation during the Dover trial. Notice that even during quieter periods at this site, VA has a tendency to apply its pink book derived max green time of 40 seconds.

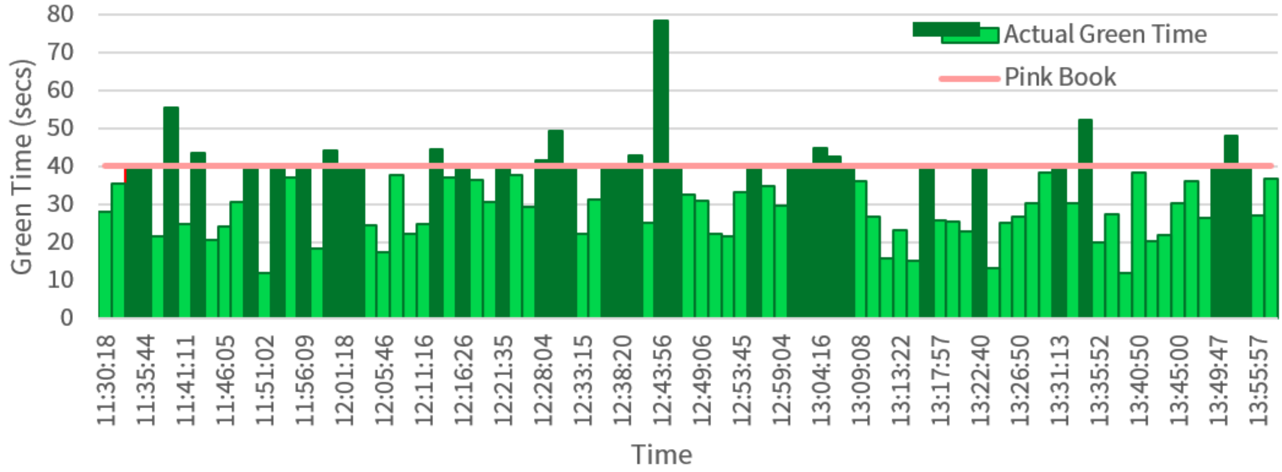


Figure 1: Phase 2 Southbound Green Times at Dover trial site operating in VA mode. Green times at or above maximum green are highlighted in dark green.

Where green times are employed that exceed the duration required to move the underlying traffic flows, a level of inefficiency in incurred. Every second of over-extension at one phase is time during which another saturated phase could be being serviced.

Permitting the use of longer maximum green times whilst still employing Doppler radar detection would simply provide a mechanism through which even greater levels of inefficiency could be incurred.

AutoGreen Green Time

In order for AutoGreen to rival manual control, it needed to be able to apply green times that were better matched with traffic flows. Where traffic levels are very high this would require the use of longer green times than VA permits, whilst also avoiding any tendency to over-extend. Achieving this required two things:

1. **A new radar** capable of providing higher fidelity detection.
2. **A new green time algorithm** for deciding green times based on overall traffic levels.

FMCW Radar Technology

The AGD 302 radar employs FMCW technology for the first time ever in the context of portable signals. The 302 provides significantly higher fidelity data than Doppler radars and has range determination that is unaffected by target size.

AGD developed this new technology which not only had to provide multi-target acquisition but also had to run at lower power consumption so that the battery life of the signal wasn't compromised.

Use of this new detection technology is critical to the success of scenario-based AutoGreen operation.

AutoGreen Green Time Algorithm

Where VA makes all of its decisions within a single cycle, AutoGreen uses information across a number of previous cycles to decide on green time. This results in a decision at the end of each cycle to either increase or decrease green time by 5 seconds on the next cycle. An example of this process is shown in Figure 2 which shows maximum green time automatically varying. Like VA operation, shorter actual green times are still employed if the density of approaching traffic falls prior to reaching the maximum green time.

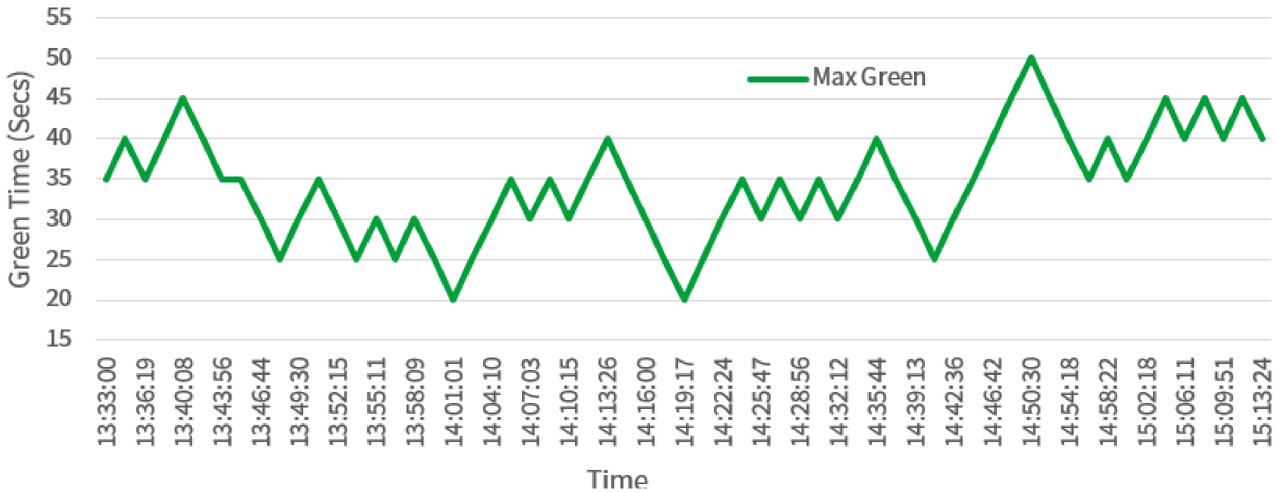


Figure 2: Green Time Seeking Process

This green time seeking algorithm in combination with the use of FMCW radar technology allows the system to apply ‘just enough’ green time to each phase. Importantly, the system closes phases once traffic density falls rather than waiting for a complete absence of approaching traffic as would be the case under VA.

The graph below shows green times for AutoGreen from the same site and time of day as shown for VA in Figure 1. Note the significant reduction in the number of cycles for which the pink book maximum green time was employed or exceeded (highlighted in dark green). Just 5 cycles met or exceeded Pink Book under AutoGreen versus 34 for the same period, on a comparable day under VA operation.

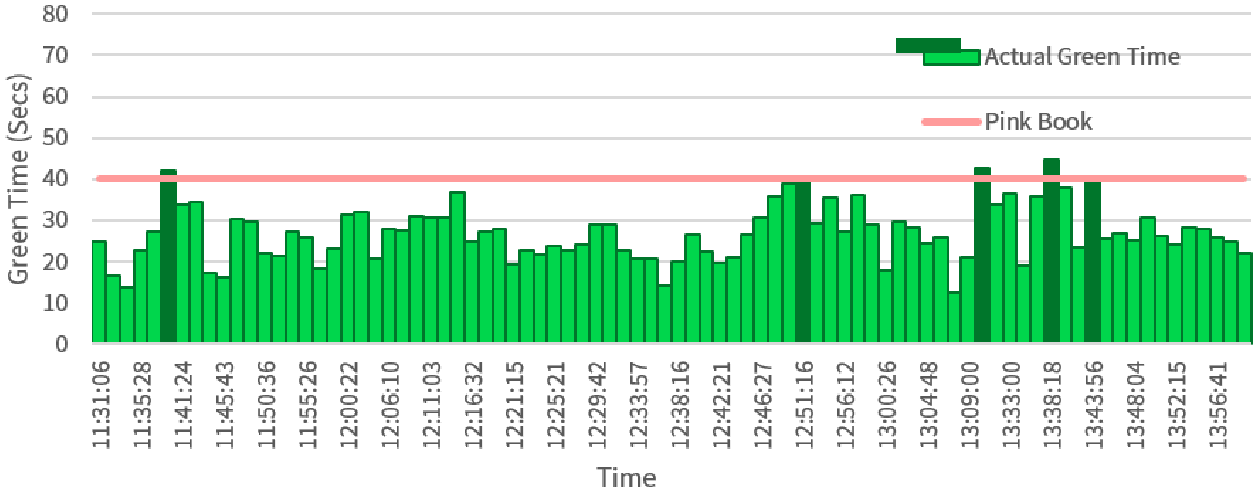


Figure 3: Phase 2 Southbound Green Times at Dover trial site operating in AutoGreen mode. Green times at or above maximum green are highlighted in dark green.

The green times employed by AutoGreen above reflect the underlying traffic conditions much better than VA. During quiet periods of the day, the system is repeatedly employing between 20 and 30 seconds of green time. Equally, where longer green times start to become required during the lunchtime rush, these are employed.

AutoGreen Scenarios

During the development of AutoGreen, Traffic Management Operatives (TMOs) were interviewed and observed performing manual control. Responses to questions about strategy for managing traffic varied significantly; however, many talked about applying different strategies at different locations and times of the day.

The use of specific strategies for managing congestion in MOVA[5] was also noted. For example, in the congested mode, MOVA operates as a capacity-maximising routine. The key point here is that different modes of operation suit specific traffic conditions.

Early trial experiences supported these observations and led to the development of scenario-based operation within AutoGreen. Four scenarios are defined covering traffic from 'Light' to 'Congested'. The system automatically picks which of these is most appropriate for the current conditions and configured site length. Once operating in a scenario, all aspects of the operation of the lights are tailored to that scenario, resulting in some significant differences in the behaviour of the signals when compared to VA.

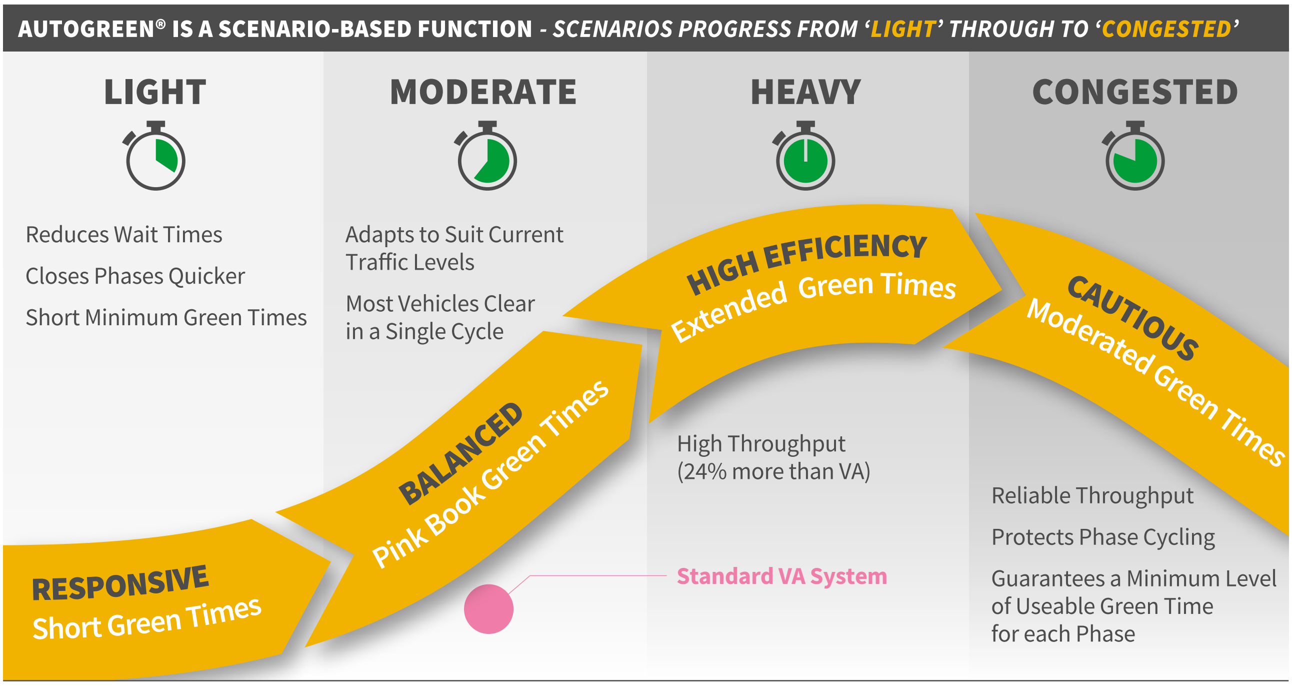


Figure 4: AutoGreen Employs Four Distinct Scenarios to Tailor Signal Behaviour to Current Traffic Conditions.

In the 'Light' scenario, the system favours rapid cycling in order to minimise wait times for individual vehicles. This scenario would typically be employed on very quiet roads and through the night.

The 'Moderate' scenario provides balanced green times that minimise the risk of congestion whilst providing just sufficient capacity to keep up with traffic flows.

The 'Heavy' scenario is employed where the signals have reached saturation. The system prioritises achieving high overall efficiency by employing longer green times. These can be up to 30 seconds above Pink Book levels where traffic conditions justify this.

Excluding the 'Congested' scenario for a moment, the determination of the scenario for each phase is independent. This allows very busy phases to gain a significant priority over quieter phases and makes the system particularly well suited to 'tidal flow' deployments.

An example of green times throughout a typical day is shown in Figure 5. Note the use of above pink book green times whilst AutoGreen is operating in its 'Heavy' scenario. The Congested scenario is also employed for a period, details of which are provided later in the paper.

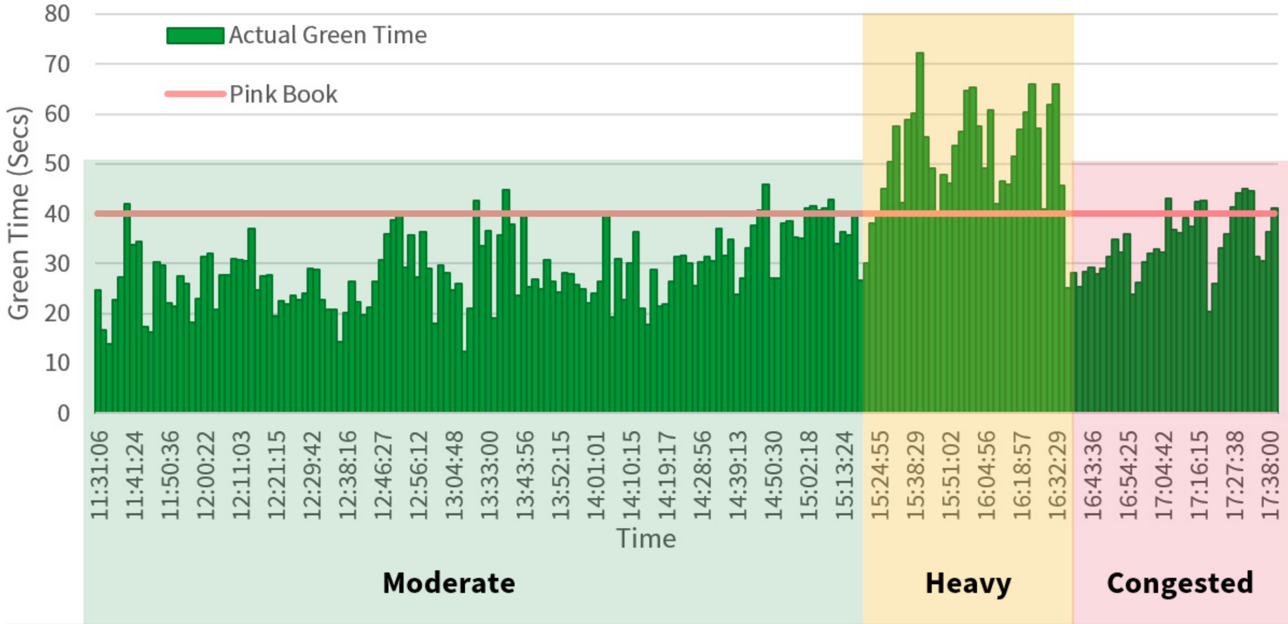


Figure 5: Phase 2 Southbound Green Times at Dover trial site operating in AutoGreen mode.

Note that the Heavy scenario was applied for just over an hour. This more efficient use of signal timings moves high volumes of traffic and can have the effect of delaying the point at which the Congested scenario is required.

Impact of Smartphones

A relatively new phenomena was observed during the trials, namely the use of smartphones by motorists waiting in queues at portable signals. Where this occurs, it typically results in a delay to vehicles pulling away at a green signal, or the opening-up of a gap in traffic further back in the queue.

This behaviour has been taken into consideration during the development of the AutoGreen scenario functionality and several optimisations have been built into the system to try to mitigate impact on other drivers. For example, in the Heavy scenario, where a single vehicle midway back in a queue is slower to pull off, the system is more patient with holding green than it would be usually. This aims to minimise the chance that a long queue of vehicles is held up by a single outlier vehicle.

PROTECTING THE CYCLE

The inefficiency of VA operation resulting from the over-extension of green times has been discussed and illustrated with real-world data. This alone does not explain the inadequacy of VA for use in complex urban environments. Consideration needs to be given to another important issue, which has an even greater impact on journey times.

The plot below shows journey times from the recent trial in Dover. Notice that journey times increase by around 150% during the school peak period at 15:30.

The cause of this significant increase in journey times is a breakdown in the service of phases owing to congestion within the roadworks site itself.

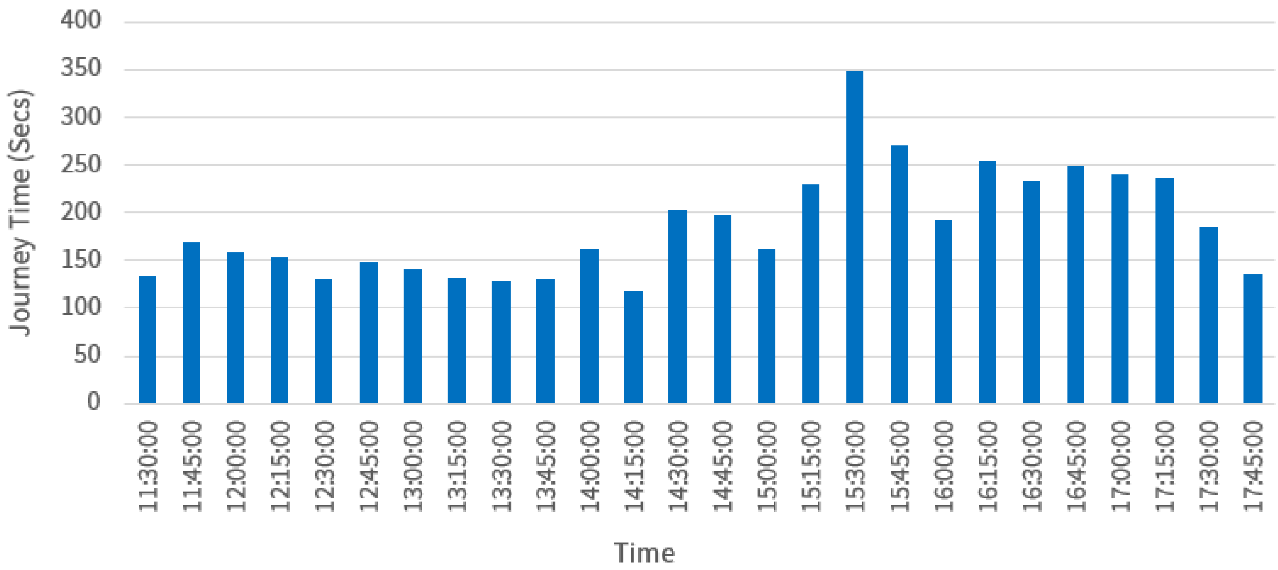


Figure 6: Northbound Journey Times at Dover trial site operating in VA mode.

Whilst attention so far in this paper has focused on the prudent use of time, specifically green time, the nature of this failed cycle issue is one that requires us to focus on the use of space.

Critical Road Space

Shuttle works have a unique characteristic in that every vehicle that passes through the site, in either direction, relies on the availability of a single piece of road space in order to complete its journey. This space will be referred to throughout this paper as the 'Red Zone'. Often, the Red Zone is a single lane and can extend for up to 300m in length, although is commonly somewhere between 70m and 120m owing to the nature of street works excavations. The Red Zone and an Amber Zone are defined for a typical 2-way configuration in Figure 7.

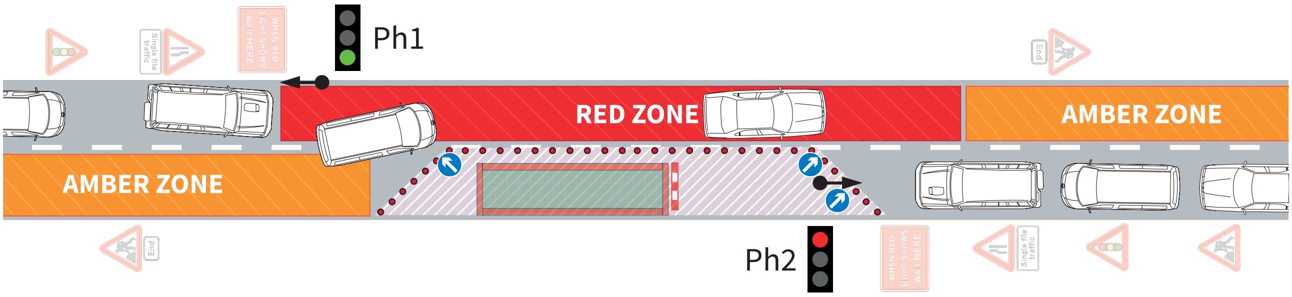


Figure 7: Critical Road Space Within Shuttle Working Sites

Congested conditions within the roadworks site itself can have a significant impact, the nature and severity of which depends on the location and extent of the congestion as follows:

Amber Zone: Anything that hinders free flowing traffic in this area, for example a parked vehicle or a queue of traffic, causes inefficient phase service. Vehicle speeds reduce in response to queues / congestion ahead.

Red Zone: In the case where this zone contains queueing traffic, the effect on traffic flow can be very severe. Normal service of phases is blocked, and a recurring problem can occur where one phase does not receive usable green time for a number of cycles in a row.

Causes of Congestion

Traffic tends to queue back into the shuttle area because of something impeding it's flow downstream. The amount and duration of this impediment along with its distance from the site all contribute to determining its impact on the efficiency of the signals. Typical sources of impediment include the nearby presence of the following:

- Pedestrian crossings.
- Signal controlled junctions.
- Poorly parked vehicles.
- A pinch point in the road where cars can pass easily but HGVs cannot.
- A bus stop where the presence of a bus blocks traffic flow.
- An entrance to premises where many vehicles slow down to give way or turn.
- Vehicles making a difficult right turn.

The distance at which these artefacts become problematic depend significantly on the amount of green time being run on each phase. By collating observations across a range of sites, it has been possible to estimate the number of vehicles that typically pass through one phase of a temporary shuttle site for varying levels of green time. Using an assumed average vehicle length and separation, this number of vehicles can be translated into an approximate amount of road space that these vehicles would take up if they were caused to queue after passing through the site. The resulting relationship is shown in Figure 8.

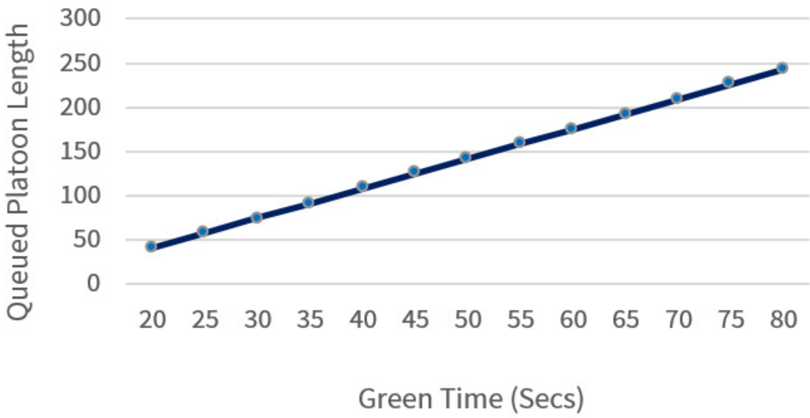


Figure 8: Road space required to hold a queued platoon of vehicles increases as a factor of green time.

This graph usefully illustrates an important point. Longer green times, whilst potentially more efficient, are also risky. Increasing green time increases the distance from the site at which an impediment to free flow of vehicles could result in a queue which stretches back into the Red Zone.

It is therefore essential that green times are kept to the shortest duration necessary to handle the current traffic flows. Anything longer introduces an increased risk of Red Zone queueing whilst also being less efficient.

Interaction with Permanent Signals

It has also been observed during trials that the impact on portable signals caused by a nearby junction under permanent signal control is highly variable. For periods of time, it is possible that the two work together without issue in a form of unplanned synchronisation. During these periods, the portable signals can 'get away' with running longer green times with no adverse effects. However, over a period of time (for example an hour), this synchronisation can drift and any form of extended green time on the portable signals becomes highly problematic.

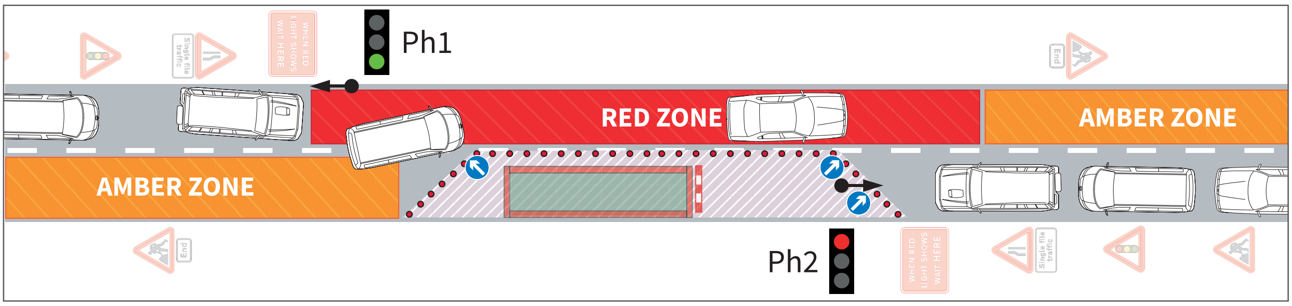
It is useful to consider Figure 8 in the context of the trial site in Dover. The works were just 130m from a permanent signal-controlled junction. Figure 8 would suggest that by running below 45 seconds of green time, there would be sufficient road space for vehicles exiting the roadworks to avoid queuing into the Red Zone in the event that they were stopped downstream by a red signal at the permanent signals.

Observation of traffic during the trial demonstrated that this relationship was largely upheld. However, problems started to occur rapidly once the permanent signals did not clear its queue of vehicles before another platoon was sent towards them by the portable signals.

This is the reason why a VA set deployed in this scenario, even with the most diligently selected maximum green times configured, would either i) fail to move sufficient volume of traffic or ii) run a significant risk of Red Zone queuing and complete breakdown of the cycle.

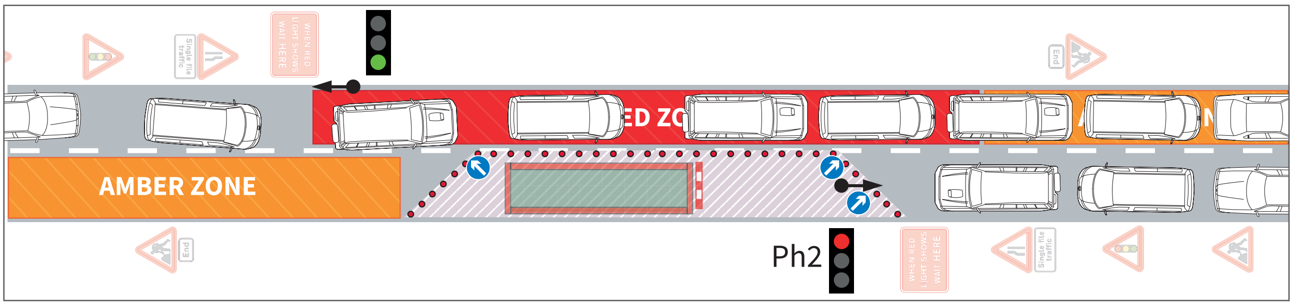
Congested VA Operation

The following sequence was experienced at nearly all busy trial sites at which VA was employed:



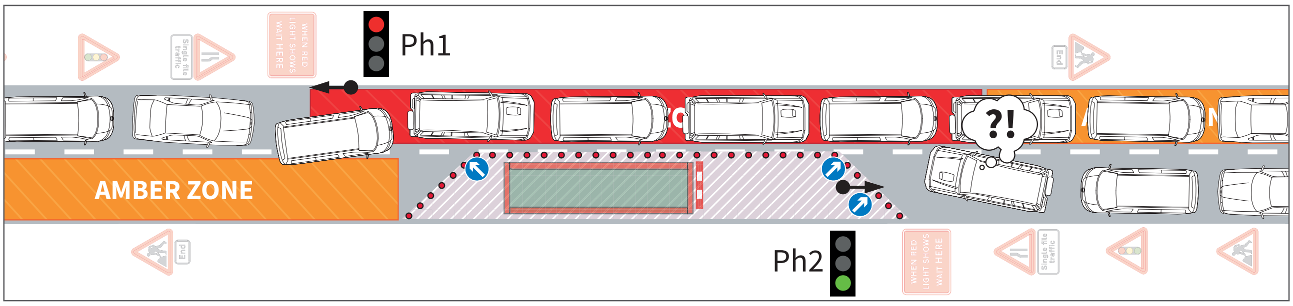
Step 1. Phase 1 traffic is shown green

Traffic moves off and, initially at least, flows normally.



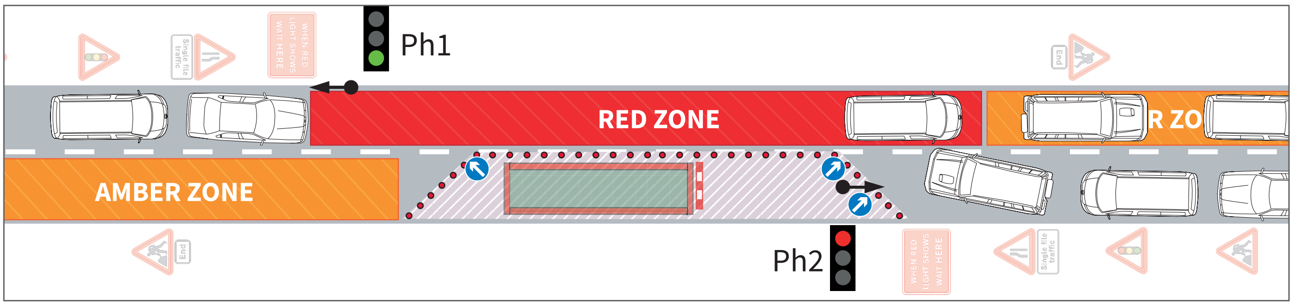
Step 2. Phase 1 traffic is impeded upstream

The obstruction results in queues back into the Red Zone.



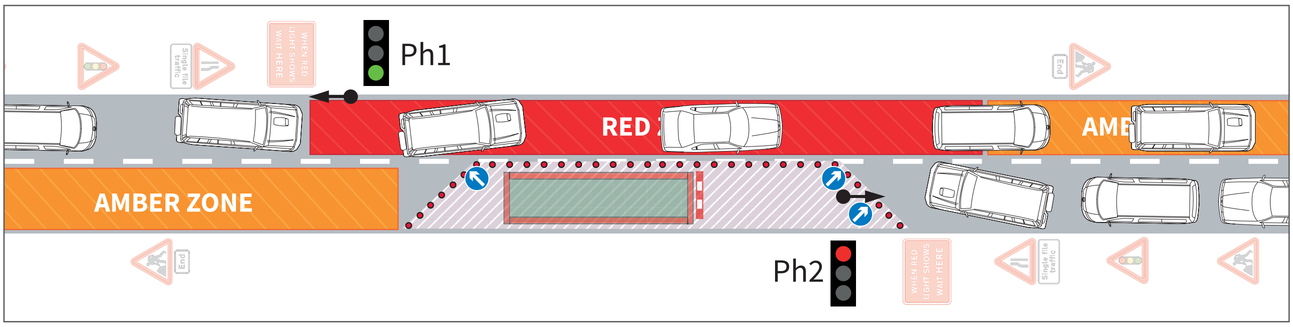
Step 3. Phase 1 returns to red and Phase 2 traffic is now shown green.

Phase 2 traffic is unable to move forward owing to queued traffic from Phase 1 service that has still not cleared.



Step 4. Phase 2 returns to red without having moved any vehicles.

The 12 second minimum green period expires for Phase 2 without any radar detection (Doppler radars cannot see stationary targets). The demand flag for phase 2 in the controller is then unlatched since VA believes it has successfully serviced the phase.

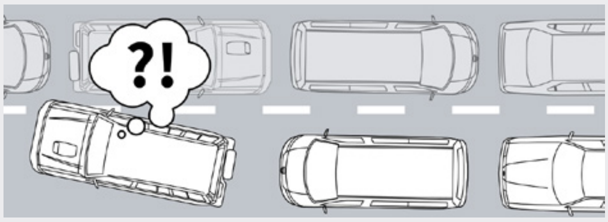


Step 5. Phase 1 is now shown green again.

Phase 1 is now very likely to queue into the Red Zone again as it has been serviced much quicker than usual. Additionally, it is possible that Phase 2 now has no radar demand and may be dependent on a radar nudge before it is serviced again.

Failed Service

Notice that the vehicles waiting at phase 2 during Step 1, are still waiting there at Step 5. We refer to this as a 'failed service' of phase 2.



At a number of trial sites, failed service was observed to repeat for several cycles in a row. The effect on journey times is severe. This is the type of situation that could result in complaints being raised with the highway authority.

Multiple recurrences of this issue during the Dover trial are highlighted in red below, including one case where it occurred on three successive cycles:

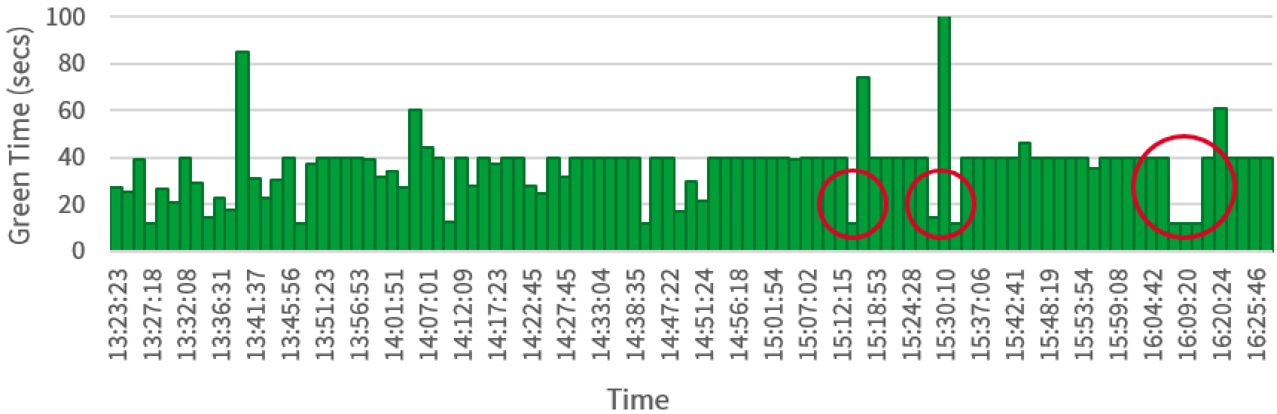


Figure 9: Northbound Green Times in VA Mode during Dover Trial

AutoGreen Congested Scenario

The AutoGreen system has a specially tailored scenario which it applies automatically in these conditions. The 'congested' scenario performs three roles:

- Minimises the general risk of Red Zone queueing.
- Mitigates the impact should Red Zone queueing occur.
- Prevents re-occurrence following Red Zone queueing.

Minimising Risk

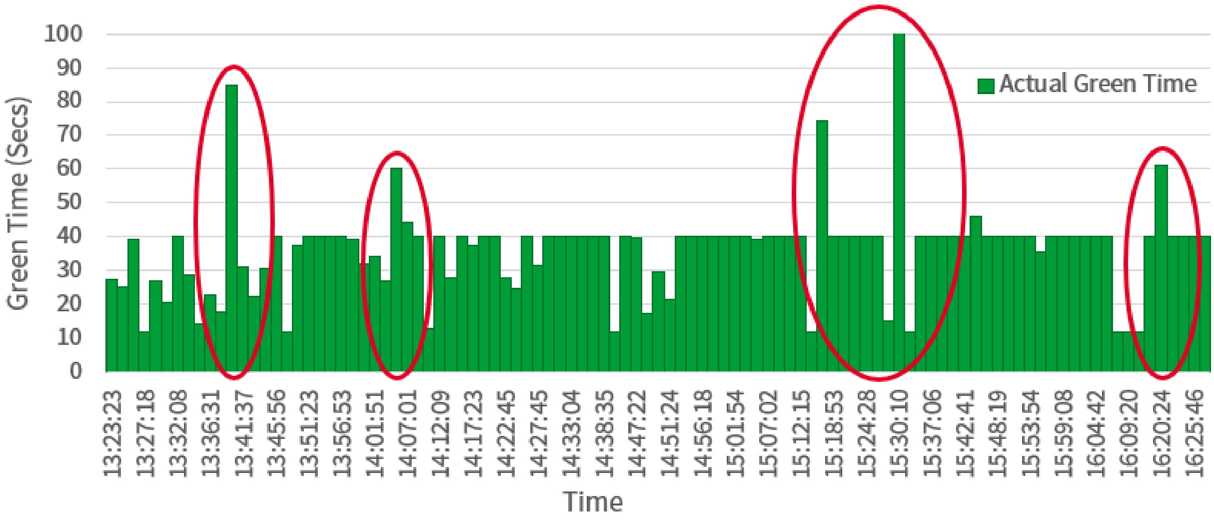


Figure 10: By Design, VA Operates Unpredictable Levels of Green Time in Excess of Maximum Green Settings

As identified earlier, longer green times incur higher levels of risk of in-site congestion. AutoGreen has therefore been developed such that it does not apply longer green times than are absolutely necessary to address the volumes of traffic experienced at a site.

Additionally, measures have been implemented which avoid unplanned jumps in green time. Looking closely at the actual green times run under VA during the Dover trial, a number of outlier values that exceed the configured maximum green time of 40 seconds can be observed, as shown below.

These longer green times each pose a significant additional risk of causing Red Zone queuing. They have two causes:

1. Where congestion has previously occurred, as per the earlier worked example, the affected phase can be left without a radar demand, making it reliant on the arrival of a radar nudge[2]. As defined in TOPAS2504A [4], this can take up to 150 seconds.

2. VA implementations typically measure green duration from the arrival of an opposing demand[2]. Where vehicles happen to be delayed in arriving at the opposing phase, this allows green to be held on for longer than the configured maximum green time.

Timing green duration from the onset of opposing demand can be traced back a long way through the specifications that have defined VA over the years including TR0111[3] and rolled forward into TOPAS2502b[2]. It has efficiency benefits in quiet traffic; however, in busy traffic it can produce a form of noise on green times that incurs an unnecessary risk of congestion.

For these reasons, this feature is retained in the 'Light' AutoGreen scenario, but this new technology employs alternative methods for managing the duration of green times in the other AutoGreen scenarios.

2 A radar nudge is an artificial demand input to a traffic signal controller that is automatically generated, usually within the radar, on a defined period. The generated demand occurs irrespective of the presence or otherwise of vehicular traffic and is intended to mitigate the impact of a radar failing to detect a vehicle.

The different pattern of green times applied by AutoGreen is illustrated clearly below:

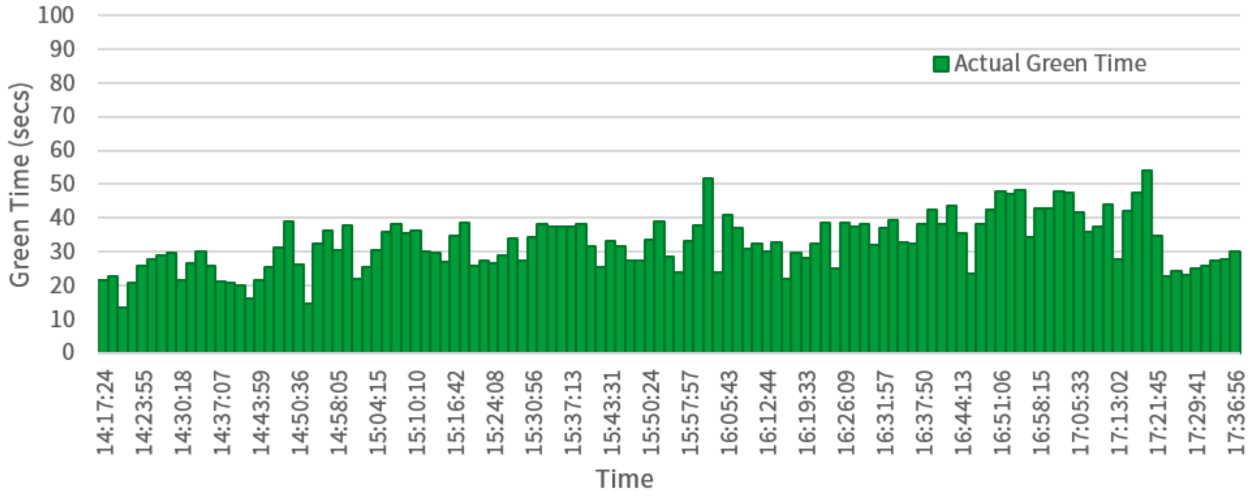


Figure 11: Green Times Employed Southbound at Dover Trial Site Running in AutoGreen Mode

Notice that sudden peaks in green time experienced under VA are avoided. Green times shift gradually in response to traffic levels.

Mitigating Impact

Despite all efforts to prevent in-site congestion from occurring, it is impossible to avoid completely. The circumstances that lead of to the formation of congestion are difficult to predict as they are so varied and because they happen very suddenly.

AutoGreen therefore monitors the site continually for signs of congestion. Where these are detected, the system takes immediate action to minimise the resulting impact.

This is achieved through the delivery of a number of short-term measures that take over control of green time and demand insertion on phases. These measures ensure that the system completely avoids cycle failure. Even in the presence of significant in-site congestion, all phases are provided with green time that is 'usable'. Traffic is not left unable to move with a signal returning to red and any phase that is likely to be adversely impacted receives a boosted level of green time.

In combination, these measures significantly reduce the level of impact experienced, to a point where, provided the behaviour is not repeated each cycle, the impact on journey times is minimal.

Importantly, the occurrence of congestion provides the system with valuable information that can be used to prevent recurrence of the problem.

Preventing Recurrence

Preventing recurrence of congestion is essential in order to achieve 'reliable' journey times, where reliable in this context means a slow changing journey times without significant short-term variations. In challenging traffic conditions, the reliability of journey times can become more important that their absolute value. Reliable journey times maintain a base level of vehicle movements and allow road users to better predict delays or plan alternative routes.

As shown in Figure 12, AutoGreen prevents recurrence of congestion by intelligently limiting green times on phases that are identified as problematic. The greater the evidence that green times on a phase result in congestion, the more aggressively the system limits green time on that phase.

In the most extreme case, AutoGreen can limit a phase to run green times that are 20 seconds below pink book values. For a 100m site, this would be a 20 second green time.

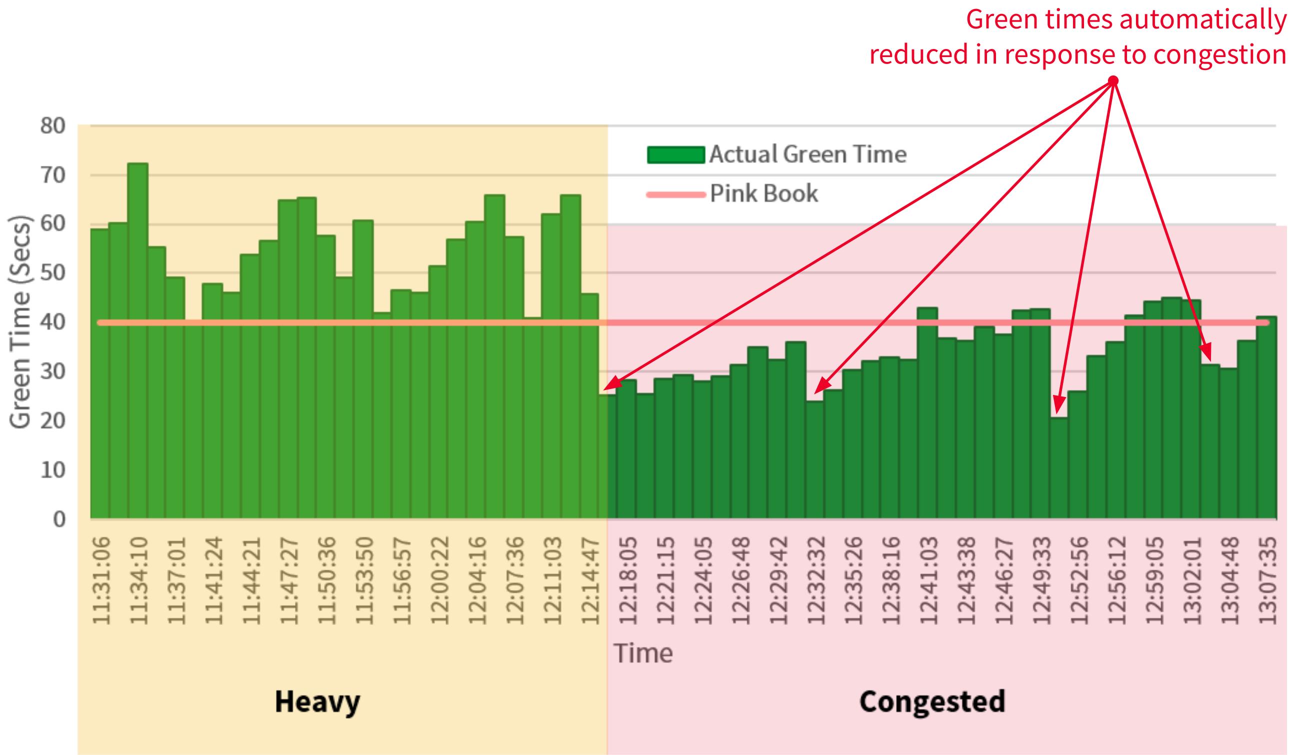


Figure 12: Automatic Reduction of Green Times on Phase 2 at Dover

As can be seen in Figure 12, the green times that can be employed by a phase vary significantly throughout the day. In this case, during the middle of the day, Phase 2 could run long green times without causing congestion whereas even moderate duration green times became problematic toward the evening peak.

Automatic determination of green times is therefore essential in order to optimise traffic flow. Traffic conditions at complex / urban sites vary too quickly to rely on a human operator periodically attending the site to manually change green time settings.

Driver Perspective

Trials experience has demonstrated that in congested conditions, VA can leave a phase effectively unserviced and awaiting a Doppler radar nudge before service is reattempted. At the same time as this is occurring, in a 2-way setup, the opposing phase is maintained at green until and even beyond the time at which the nudge occurs. This combination can have the effect of clearing the traffic on one phase whilst building a long queue at the other. This mirrors a common criticism of portable signals along the lines of "I waited a long time and when I finally got through there was nothing at the other end.".

The AutoGreen Congested scenario avoids this problem and keeps traffic on both phases moving reliably and with as much green time efficiency as can be achieved given current levels of congestion. This may mean journey times are impacted but the strategy ensures more of a sense of fairness and predictability to the operation of the signals, which should result in an improved driver perception of them.

RESULTS

Typical results from the two trials discussed in this paper are presented in this section.

A256 Dover

Detailed journey time data is provided in Figure 13 for the Dover site. Each bin shows the average journey time for vehicles commencing their journey within a 15-minute period. Figure 14 shows the same data but highlights the difference in value between the VA and AutoGreen journey times. Positive values represent the reduction in journey time achieved using AutoGreen compared with VA.

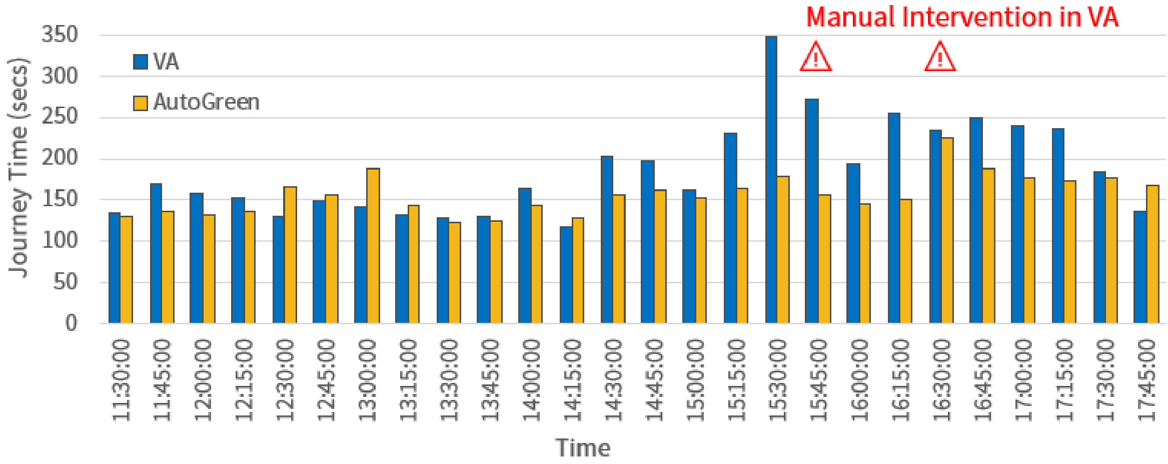


Figure 13: Northbound Journey Times at Dover Trial Site in VA versus AutoGreen

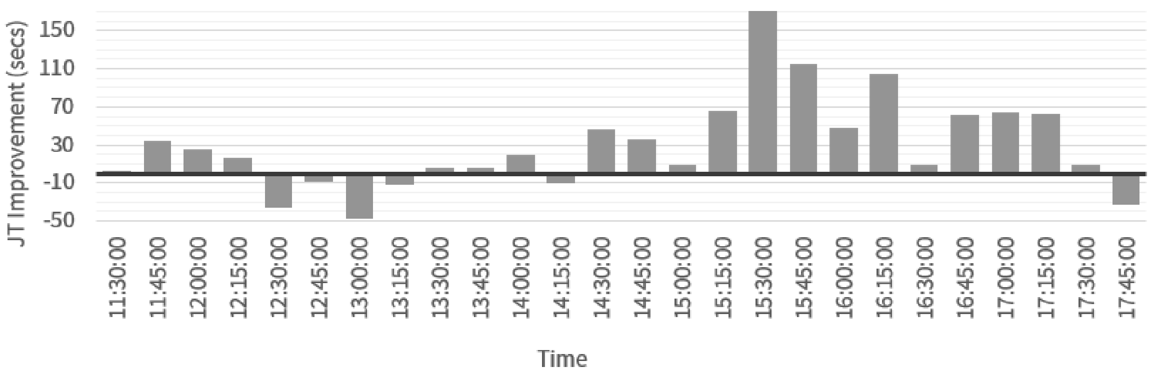


Figure 14: Absolute Difference in Northbound Journey Times at Dover Trial Site in VA versus AutoGreen

The captured data demonstrates that AutoGreen provided useful improvements in journey times in heavy traffic. Even more striking is the significant improvement in journey times achieved during the most congested periods. Also, in the example shown above, AutoGreen ran completely autonomously whereas VA required manual intervention on two occasions at 15:43 and 16:30.

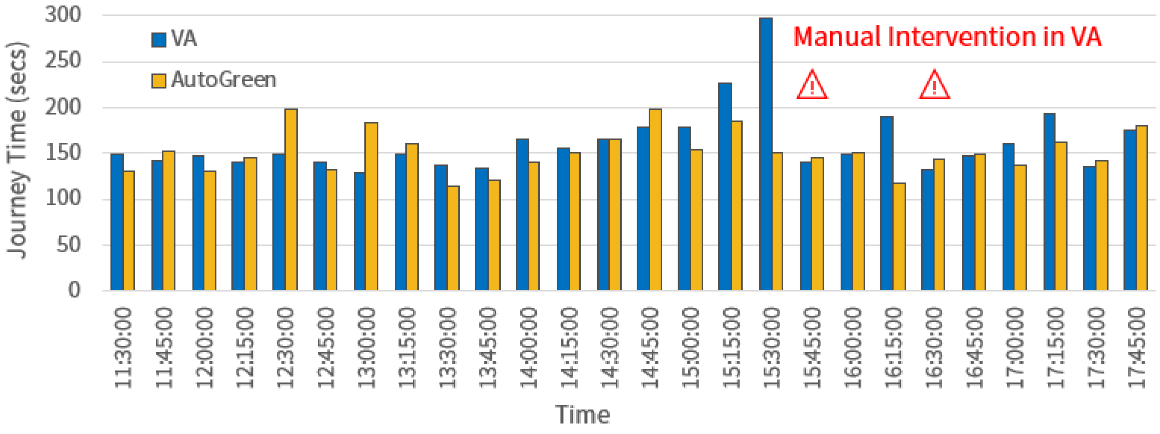


Figure 15: Southbound Journey Times at Dover Trial Site in VA versus AutoGreen

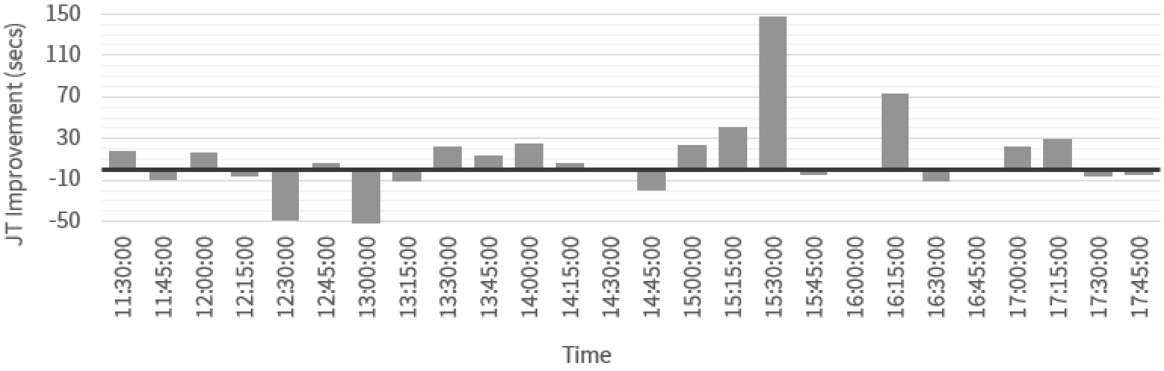


Figure 16: Absolute Difference in Southbound Journey Times at Dover Trial Site in VA versus AutoGreen

Note that around 15:30, AutoGreen is operating with a 50% shorter journey time compared with VA on both phases.

The plots usefully illustrate periods of significant and moderate improvements in journey times by AutoGreen along with a small number of periods where AutoGreen journeys are slightly longer than was the case under VA operation.

AutoGreen takes an intentionally cautious approach when increasing green times in order to manage the associated risk of in-site congestion. This represents a trade-off where we prefer to minimise risk of congestion rather than respond instantly to a brief peak in demand.

VA on the other hand, takes all decisions within the cycle and can therefore instantly employ its configured maximum green setting. This occurs at 12:30 and 14:45 in Figure 16 above. These are both periods where traffic levels are increasing. Notice that following the brief transition period to higher traffic levels, AutoGreen quickly starts to outperform VA again and sustains this.

Results Summary

An easier to digest summary of results is achieved by showing the overall improvement in journey times that is achieved during different traffic conditions. This data is provided below for the two trial sites covered in this paper.

Whilst it would have been interesting to see just how VA would have performed without any operator input, it became necessary to intervene with manual control for brief periods, so as ensure that the trial did not have an unacceptable adverse impact on local traffic.

Dover Northbound	SCENARIO	From	To	Journey Time VA	Journey Time AutoGreen	Relative Improvement
	Moderate	11:30	14:30	142s	142s	0%
	Heavy	14:30	15:15	201s	171s	15%
		16:15	18:00			
	Congested	15:15	16:15	⚠ 267s	158s	41%

Dover Southbound	SCENARIO	From	To	Journey Time VA	Journey Time AutoGreen	Relative Improvement
	Moderate	11:30	15:15	151s	152s	-1%
	Heavy	15:45	18:00	160s	147s	8%
	Congested	15:15	15:45	⚠ 263s	169s	36%

Maidstone Eastbound	SCENARIO	From	To	Journey Time VA	Journey Time AutoGreen	Relative Improvement
	Moderate	06:40	08:10	194s	189s	3%
		09:20	09:50			
	Heavy	08:40	09:20	218s	198s	9%
	Congested	08:10	08:40	⚠ 318s	225s	29%

Maidstone Westbound	SCENARIO	From	To	Journey Time VA	Journey Time AutoGreen	Relative Improvement
	Moderate	06:30	07:30	188s	184s	2%
		09:00	09:50			
	Heavy	08:00	09:00	⚠ 288s	256s	11%
	Congested	07:30	08:00	300s	218s	27%

⚠ = Manual Intervention Required

Table 1: Journey times improvements by scenario.

CONCLUSION

A new scenario-based operating mode has been developed for portable signals which is capable of handling both high-flow and high-complexity sites. The system achieves significantly improved journey times, especially in congested conditions, and provides a viable alternative to manual control at locations where VA would be unable to operate effectively.

In heavy traffic conditions, reductions in journey time ranging between 8% and 15% have been achieved. In congested conditions, improvements span between 27% and 41%, with some 15-minute periods showing up to a 50% reduction in journey times.

The success of the system derives from the use of a high-fidelity FMCW radar together with a scenario-based operating mode. This allows the system to automatically determine green times, and other operating parameters, that are well-matched with current traffic flows. Longer green times are used only when they are required, and the risk associated with extending green times is carefully managed through the ability of the FMCW radar to detect and respond to the presence of congestion.

It is not the intention to remove the presence of Traffic Management Operatives (TMO) from sites completely. There will still be some locations at which full manual control or UTC operation is the most appropriate option. Equally, at some locations, a TMO on site may be required to perform other important site maintenance or safety tasks, even where the lights remain operating in AutoGreen mode. However, the removal of non-essential Man-on-Site conditions from permits has a number of benefits including minimising exposure of TMO's to risk and challenging working conditions whilst also reducing the costs incurred by statutory undertakers.

The Dover trial covered in this paper is particularly useful in highlighting the broad capability of the system, operating as it did just 130m from a signal-controlled junction. Traffic Group Signals are currently encouraging highway authorities and Traffic Management companies to deploy the technology, especially in perceived difficult locations where manual control would have otherwise always been mandated on permits.

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About The Traffic Group

The Traffic Group has a portfolio of businesses focused on product solutions designed to help create safer, greener and more efficient traffic and transport environments.

The group has two core offerings; advanced low-power radar, electro-optical sensors and ANPR cameras for Intelligent Traffic Systems which are used for traffic and pedestrian control, highways monitoring, and enforcement along with a comprehensive range of portable traffic signals suitable for applications ranging from simple two-way deployment through to complex, UTC-integrated temporary junction schemes.

With a strong focus on engineering excellence, the group has achieved three Queen's Awards for Innovation in the last 12 years. TTG invests extensively in new product development and advanced production test facilities to ensure the highest standards of quality, reliability and regulatory compliance.

The group has a strong customer base within the UK and overseas, including major systems integrators, Highways England, local authorities, utilities and many leading traffic management companies. It also has an extensive distributor network.

TTG's current portfolio of companies comprise of AGD Systems Ltd, MAV Systems Ltd, Pike Signals Ltd, Hollco Ltd, AGD Systems Pty Ltd (Australia) and Arkon Services Ltd. A privately owned business, TTG employs over 100 staff located across six sites in the UK and Australia, and is headquartered in Gloucestershire, UK.

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