Transport Research Laboratory

Traffic Management Techniques for Cyclists: Final Report

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PPRO 04/45/04

FINAL PROJECT REPORT

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Traffic Management Techniques for Cyclists: Final Report

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	INVESTIGATION OF OPTIONS FOR TRAFFIC MANAGEMENT TECHNIQUES FOR CYCLISTS AT SIGNALISED JUNCTIONS IN THE URBAN ENVIRONMENT
Client:	**DfT**
	(SukuPhull)

This Report has been prepared for DfT.

The views expressed are those of the author(s) and not necessarily those of DfT.

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Project Manager	E Gould	05/10/2011
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Executive summary

This document reports on a project undertaken for the Department for Transport (Traffic Management Division) in March 2011 entitled *Investigation of Options forTraffic Management Techniques for Cyclists at Signallised Junctions in the Urban Environment.* It describes the outcome of a desktop study that investigates the techniques that are in common usage both in the UK and overseas for cyclist provision at traffic signals.

The objectives of this study were to:

1) Identify the issues relating to movement of cyclists at the approaches to and through signalised junctions, with particular attention to cyclist, junction capacity and impact on safety of all road users, including pedestrians and cyclists;

2) Develop proposals in light of any issues identified and recommend solutions to identified problems.

The project involved a detailed literature review of more than 60 publications written in the English language, sourced from both the UK and overseas. These documents were made up of policy guidance, technical papers, local authority guidelines and journal articles.

The literature review was supported by a consultation process with industry specialists and cycling groups. This was undertaken using TRL's existing contacts within the industry as well as identifying key figures from the literature review. To gain specific experience and feedback from a wider audience online forums and professional networking websites were used as a mean of making contact.

Following the literature review and consultation process a list of 48 different techniques were identified that could assist cyclists when negotiating traffic signal controlled intersections. These techniques ranged from relatively small design amendments that could be employed during the design stage or retrofitted, to more involved strategic plans that need to be incorporated in the design stage or would require a junction redesign.

An assessment scoring methodology was used to critically assess each of the 48 techniques against a range of criteria. This assessment investigated the advantages and disadvantages of each technique from a number of different viewpoints, for example cyclists, pedestrians and all motorised vehicle users. In addition to this the practical challenges raised by implementing these techniques were also rated. These included policy and legislation changes needed, cost of the technique, and highway disruption during implementation etc. The scoring system used was based on a Red Amber Green rating system using a range of five different scores (-2 through to +2).

Recommendations were made based on this assessment; this highlighted those techniques which struck a balance between offering increased benefits for cyclists whilst keeping the negative impacts experienced by other road users to a minimum, and keeping value for money in mind. The recommendations picked up on further development of existing practises, as well as the implementation of more innovative solutions. It was found during the assessment stage of the project that there were no techniques that were without compromise, therefore one of the key recommendations relates to ensuring that the selection of any individual technique is carried out taking full account of the individual circumstances of the location concerned. Factors would include

the level of cycle use (both current and potential) and an understanding of the characteristics of the users; traffic flows and speeds, and vehicle types; the extent and nature of existing cycling infrastructure that feeds the junction, e.g. whether on carriageway or fully off-road. Clearly the costs of many type of infrastructure will be greater if implemented onto existing road infrastructure than if included into new schemes from the start. The implications of loss of capacity for other vehicles will be less significant at locations where cycling has a large modal share (or the potential to become so); similarly measures that lead to reduce traffic speeds will be considered differently on roads whose primary purpose is the movement of traffic than on roads where it is desirable to reduce traffic speeds to improve road safety and for other community benefits.

The techniques highlighted in the recommendations as showing greatest promise for development and implementation on the UK road network are shown in the table below. This table summarises the scores for each of the six key themes investigated, these scores themselves aggregated from 48 individual criteria.

	Technique	Total Cyclist Score	Total Pedestrian Score	Total Other Road User Score	Total Cost Implication Score	Total Regulation and Legislation Score	Total Other Score	Aggregate Total
1	Intergreens designed for cyclist speed	10	0	-3	12	4	14	37
2	Intergreens extended using detection	11	0	-3	7	2	12	29
3	Separate cycle phases with cyclist signal aspects	15	-2	-6	-4	1	2	6
8	Pre signal for cyclists for early start (cycle aspect only)	11	-1	-5	-1	-6	7	5
9	Pre signal for cyclist for early start (separate red amber green signal head)	12	-1	-3	-1	-6	6	7
10	Advanced cycle stop lines	16	1	-2	11	8	13	47
11	Staggered advanced cycle stop lines	5	1	2	11	-4	13	28
12	Cycle by-pass lane for left turning cyclists (signal controlled)	18	-6	3	-7	3	5	16
14	Cycle by- pass lane for straight ahead movement cyclists at T-junction (onto footway)	13	-5	3	-3	-1	6	13
15	Cycle by- pass lane for straight ahead movement cyclists at T-junction (within carriageway)	22	-9	6	-6	-1	3	15
18	Coloured cycle lanes through intersections (one)	14	1	4	11	1	10	41
21	Coordination of signals for cyclists progression "green wave"	16	0	-2	3	0	5	22
26	Road markings to highlight loop detectors	9	0	0	12	-8	9	22
30	Dwell on green for bikes (reverse priority) (cycle track or cycle phases only)	18	7	-3	11	-3	9	39
43	Priority for cyclists during inclement weather	14	-1	-2	-6	2	3	10
44	Straightening staggered Toucans, and make a single phase	16	8	-3	6	0	13	40
45	Pre-timed maximum timer on Toucans	13	3	-4	12	0	10	34
47	Two green periods per cycle for cyclists (to be used with separate cycle phases)	10	-1	-4	9	-1	10	23
48	Conversion to continental style roundabout (vehicle flows under 10 - 15,000)	10	-4	3	-8	0	0	1

Each of these techniques is at a different stage of development, with some being widely used whereas others have only been implemented in a limited number of locations.

In conclusion, the techniques listed above have been shown to perform the best when considering a wide range of criteria. However, it is recommended that these techniques are taken forward for consideration for further trials. In some instances the effects of these techniques could be simulated to keep cost and disruption to a minimum; however it should be noted that the impacts on other road users will differ on a site by site basis.

1 Introduction

The Department for Transport (DfT) commissioned a desk-based research project in early 2011 to explore the range of existing traffic management techniques for cyclists at urban signalised junctions in Great Britain, Europe and around the world, and to understand their potential applicability to the UK.

The purpose of the project was to gather the evidence necessary to make informed decisions about the future of cyclist provision at signalised junctions in Great Britain, understanding the relevant factors which need to be considered and to develop a series of indicators which will be used to recommend and prioritise identified options.

This document forms the key deliverable for the project, and reports on project findings.

1.1 Project Objectives

The objectives of this project were to:

1) Identify the issues relating to movement of cyclists at the approaches to and through signalised junctions, with particular attention to cyclist, junction capacity and impact on safety of all road users, including pedestrians and cyclists;

2) Develop proposals in light of any issues identified and recommend solutions to identified problems.

1.2 Project Context

It is important to understand the wider policy context in which this study was undertaken. In recent years, in particular since the launch of the National Cycling Strategy in 1996, government and local transport policies have been supportive of cycling to meet congestion, accessibility, climate change and health policy objectives.

Through Cycling England, DfT has funded the Cycling Demonstration Towns which have achieved demonstrable success in increasing cycle use, cycle links to schools, and the programme of Bikeability cycle training. In London, TfL has recently launched a programme of Superhighways and the bike hire scheme. Other initiatives have included the National Cycle Network and many local authority supported schemes. DfT has also recently funded a large project to look at cycling safety, which was led by TRL.

Guidance on cycling infrastructure, for example DfT's Cycle Infrastructure Design, LTN 2/08, sets out some core principles of good cycling infrastructure if it is to meet the needs of cyclists: Convenience, Accessibility, Safety, Comfort and Attractiveness. To encourage cycling, junctions and crossings need to facilitate safe passage while avoiding undue delay and interruptions to progress such as having to dismount.

A key finding in the DfT cycling safety study is that a disproportionate number of cycling accidents- nearly two thirds- occur at or near junctions. This was presented in Knowles et al, 2009. The main collision configurations involving a bicycle and car were where a car turns right or left while the cyclist was going straight ahead and conversely where the cyclist makes a right turn while the car was going straight ahead. Furthermore, a disproportionate number of serious accidents involve left-turning lorries at junctions.This evidence is summarised in Reid and Adams (2010). Cycling infrastructure guidance advises that signalised crossings are usually preferable for cyclists in comparison with other forms of junction. Whilst UK guidance documents identify a number of standard approaches which are used routinely across the UK, there are others such as ‘cycle bypasses’ and separate lanes and markings to guide the cyclist through the junction which are used less frequently.

Clearly, changes to the layout or timing of signals will have impacts on other road users, with potential consequences for traffic management of the wider road network. Potential adverse impacts which have been considered in this study include:

- Additional conflicts created through creating new or unexpected movements for cyclists, or dangerous positioning
- Confusion caused by additional cycle signal phases
- Conflicts with pedestrians, as well as loss of pedestrian space and capacity
- Loss of traffic capacity, increased delay and queuing and a greater quantity of lost time
- Interactions with buses, especially where there is also bus priority
- Reduced saturation flow of traffic as a result of cyclists being ahead of other vehicles at the stop line.

Different approaches to date have been used to find solutions to these problems, including in other countries, providing a body of experience from which useful lessons for the UK can be learnt. This project includes a thorough review of guidance and practice both in the UK and elsewhere, taking full account of differences in context that affect the transferability of such experience in the UK.

Issues considered include:

- Differences in road traffic law and regulation, e.g. different legal priorities in different countries;
- Differences in approaches to highway design and signal control; and
- Differences in levels of cycling: e.g. adverse impacts on motorised traffic flow may be considered less of a problem where cyclists comprise a large proportion of traffic

To gain a full understanding of these issues it was necessary not only to carry out a comprehensive review of published guidance and research, but also to take account of the experience of many different stakeholders and their viewpoints. This includes practitioners such as local authority officers responsible both for cycling and traffic management and more generally cycling organisations, lobby groups and academics.

The project methodology is outlined in more detail in the next section of this document.

2 Overview of Project Methodology

This Final Project Report describes the outcomes of the completed project which has included an Assessment Phase, which involved the following tasks:

- A literature review of research literature, official documents and other published information on practice, both UK and internationally;
- Consultation with experts in academia, stakeholder organisations and highway authorities;
- Identification and selection of control methods for detailed investigation;
- Developmentof assessment methodology;
- Review of selected methods using assessment criteria; and
- Development of Recommendations.

Literature review

A review was undertaken using the KnowledgeBase system provided by TRL's Library and Information Centre. Search terms were defined to identify publications relevant to:

- Separate cycle phase
- Signal timings designed to give cyclists priority over other vehicles, such as early start
- Cycle crossings at signalled junctions
- Advance cycle signals
- Special cycle signals at junctions

Searches covered over 60 published guidance documents, conference papers and articles in English language highway research literature as well as other sources including publications from professional bodies and government organisations.

Key publications were also identified from personal knowledge of team members. Information for more detailed analysis was loosely classified under three strands:

- Signal control techniques and their impacts on traffic management;
- The road safety aspects of junction design; and
- Cyclists' behaviour and needs at junctions.

Information collated in this review was then fed into the assessment process. The findings of the literature review are detailed in Section 3 of this document.

Consultation with experts and stakeholders

To supplement information obtained from the literature review the project team contacted a number of experts, stakeholders and practitioners. There were two aims of this: the first being to ensure that no significant publications were overlooked in the literature review; the second to identify examples of practices, trial schemes and even aspirational approaches that have not been reported in the published literature. An initial list of over 30 organisations and individuals was drawn up at the start of the project, in discussion with the client, which was later supplemented by additional contacts suggested by respondents to the consultation. The list included academics known to have particular expertise in cycling infrastructure, experts from NGOs associated with cycling, Cycling England and local authorities identified as having done work in this area. Organisations outside the UK were also contacted, so as to provide an insight into practices in other countries.

Consultees were contacted by email, with an attached summary of the key publications identified by the literature review, and were invited to:

- comment on the list;
- identify any omissions including other key literature sources; and
- Suggest any additional information they considered to be relevant.

A full list of organisations contacted is shown in alphabetical order below.

- Aurecon
- Bike Victoria, Australia
- Cambridge City Council
- Cambridgeshire County Council
- City of Odense, Denmark
- City of London
- CTC
- Cycling Demonstration Towns – Exeter, Darlington, Derby and Lancaster
- Cycling England
- Danish Cycling Embassy
- Department for Transport
- DHV
- JMP
- Leeds University Institute for Transport Studies
- London Borough Officers' Cycling Group
- Low Carbon West England
- MRC (MMM Group)
- Oxford University
- Oxfordshire Council
- South Bank University
- Sustrans
- Trafitec
- Transport for London
- Transport Initiatives

Those who have provided significant input to the study have been acknowledged later in this document.

To provide an opportunity for additional input from practitioners not directly known to the project team, professional networking groups on LinkedIn and on TSG (Traffic Signals Group) were also contacted.

Messages for input were posted on the following LinkedIn groups, representing a variety of stakeholder types at various levels:

- Bike Commuters
- Biking Enthusiasts
- Modal Shift
- Sustainable Transport (UK)
- Sustainable Urban Transport and Mobility Management
- Traffic Engineer and Transportation Planner Network
- Traffic Engineering- Innovative Solutions
- Traffic Light Experts Worldwide
- Urban Planning Professionals
- World Cycling Industry

Development of assessment methodology

In parallel with the information gathering, a set of criteria were developed against which each technique selected for review could be assessed.

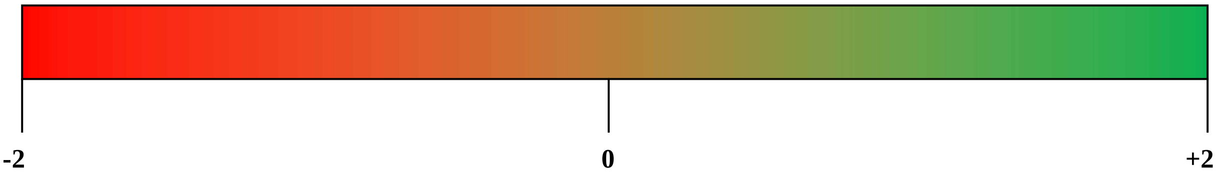
Assessment criteria were developed to cover the implications of each technique under the following top level categories:

- Implications for cyclists (e.g. safety, delay, convenience and attractiveness)
- Other road users(e.g. impacts on pedestrians, public transport users, drivers of motorised vehicles)
- Traffic management (impacts on junction capacity, queue lengths etc)
- Costs of implementation (e.g. cost of equipment, installation costs, ongoing maintenance)
- Land-take and streetscape (the extent to which additional space is required and its impact on the street environment)
- Regulatory implications and transferability to UK
- The strength of evidence supporting the technique

A set of 48 detailed criteria were developed along with a 5 point scoring system. For each of the criterion, a detailed description was developed to define the requirements for each score.

A score of -2 denotes that the technique has negative impacts on that criterion. A neutral score of 0 means that the technique has no impact on the specific criterion and a score of +2 is awarded where a technique has significant benefits. Intermediate scores of +1 and -1 were also developed to distinguish between small positive and marginal negative impacts respectively.

These scores were assigned a colour from red to green, to visually highlight negative and positive effects, as shown below.



A more detailed description of the scoring system and its application to the identified techniques is given in Section 5 of this report.

Following the development of the assessment criteria and scoring system, each of the identified techniques highlighted by the literature review were assessed. This resulted in each technique being awarded an aggregated scores for specific themes (grouped criteria relating to e.g. cyclists or to other road users) as well as across all 55 criteria.

The quantitative scoring system provided a basis for making comparisons between different techniques, and the colour coded scoring system allowed differences in scores to be easily identified. An analysis of the results then provided the basis to describe and discuss the opportunities and drawbacks of different techniques. Finally, various recommendations were made, particularly highlighting techniques which are likely to bring about benefits for cyclists without adversely affecting other road users. For the relevant recommended techniques, simple capacity analysis using TRANSYT was undertaken to show indicative effects on the capacity of a theoretical junction as a result of the technique.

3 Literature Review

This literature review covers research relating to cyclists at signal controlled junctions.

There has been much research into techniques for assisting and giving priority to cyclists at traffic signal controlled junctions. Despite this it would be true to say that many junctions are still designed with the motorist in mind rather than cyclists. The exception to this is for junctions located on strategic cycle routes where greater consideration is often given to bicycle traffic.

The latest National Travel Survey (DfT, 2010) illustrates a significant proportion of journeys made by car which are under one mile in length; 20percent in 2009. Whilst distance travelled by bicycle is increasing, cycling still only accounted for 2percent of trips of less than five miles in the same period (op. cit).

With carefully designed cycle infrastructure, there is a growing body of evidence to suggest that many of these short car trips could be replaced by cycle trips. Whilst the UK road network does provide dedicated facilities for cycling traffic, for example toucan crossings and the Advanced Cycle Stopline (ASLs), the UK's cycle utilisation still remains much lower than our mainland European counterparts. It is believed by many that more can be done to generate a safer, more efficient and more encouraging network of cycling infrastructure, particularly when focussing on junctions.

Junctions can be intimidating and unfriendly to cyclists. When considering the cycling demographic in urban areas, it is worth bearing in mind that encouraging short trips by bicycle can lead to inexperienced cyclists taking to the road, and providing friendlier infrastructure can improve the experience of all cyclists, including experienced riders.

At junctions, not only is space contested between different road users, they can also be complicated to comprehend and the behaviour of road users can be more unpredictable than along stretches of carriageway. Almost two-thirds of KSI (killed or seriously injured) accidents involving cyclists occur at junctions (Knowles et al, 2009). To make cycling the mode of choice for short journeys, the importance of delay and route continuity must also feature in the provision for cyclists. As cyclists generate their own power, signalised junctions are more likely to have a greater interruption impact on journeys by bikes. This is confirmed by Peck (2011), who states that braking to a stop, and starting up again, loses the equivalent energy to travelling 100m. Thus, he states, a 5km journey with 10 stops (e.g. for traffic lights) takes at least 20% more energy to complete.

This literature review presents the current provisions made for cyclists on the UK road system, as well as investigating proven, and more innovative techniques from overseas.

3.1 Cycle facilities currently implemented on UK roads

Advanced Stop Line (ASLs) – ASLs are widely used at signal controlled junctions in the UK. The purpose of the Advance Stop Line is to allow cyclists to progress to the front of the traffic queue during the red period, helping them to position themselves safely for right turns and to assist with making cyclists more visible to drivers of motor vehicles.

In essence, the ASL provides cyclists with visible and practical priority over other vehicles upon departing the signals (Cycling England, 2009).

According to the same research documented by Cycling England (op.cit), 44percent more cyclists are able to position themselves in front of and in sight of waiting motor vehicles when an ASL is provided. Several documents highlight the safety benefits of an ASL with a general reduction of cycle accidents between 25 percent and 35 percent with the introduction of an ASL.

Russell and Carr (2010) suggest that ASLs have little or no effect on capacity if the number of general traffic lanes remains unaltered. A study by Wall (2003)recorded that for junctions with ASLs and nearside cycle lanes the saturation flow for that stop line experienced a small increase, whereas for junctions where ASLs are provided with a central cycle lane the saturation flow of the stop line could experience a small reduction. The project concluded that for the studied junctions the addition of ASLs did not reduce the junction capacity provided that there was not a loss of a lane as a result of the ASL cycle lead in lane.

Advanced stop lines minimise conflict between cyclists and motor vehicles by allowing the cyclist to pull ahead of queued traffic and thereby position themselves more easily for a right-turn, rather than having to change lanes in moving traffic (Cycling England, 2009). Where there are multiple traffic lanes on the approach to an intersection and heavy cyclist right-turn flows a central advisory lane is more advantageous than a nearside lane where vehicle flows are greater than 200 to 300 vehicles per lane per hour (Sustrans, 2007). Another advantage of the central approach lane is where there is a nearside left-turn lane for traffic, the presence of the lane will aid in making the presence of cyclists more obvious to drivers.

London Cycling Design Standards (TfL, 2005) covers the use of part-width ASLs i.e. not covering the whole width of the carriageway with a staggered stop line. These may be better where there is no right-turn for cyclists or the right-turn is undertaken in two stages. It is important to note that the use of partial ASLs are not covered by current legislation and would require authorisation for implementation. Lingwood (2011) notes that a partial ASL may particularly help with reducing encroachment.
Where arms of an intersection have a short red period or high percentage of green time, ASLs may not be suitable as there will be a reduced chance of cyclists reaching the intersection at red, particularly for cyclists wishing to perform a right-turn. In these circumstances, the installation of an ASL would not be beneficial to cyclists, as ASLs can only provide a benefit to riders when the red phase allows a cyclist to progress to the head of the traffic queue. The same effect can happen when there are quick changes between phases (op. cit).

Elephants feet – Where cycle facilities pass through large intersections which could be confusing or intimidating to cyclists, elephants feet road markings could be used to delineate the cyclist route through the intersection. These markings do not form part of the current Traffic Signs Regulations and General Directions (TSRGD) and as such any local authority wishing use the marking must obtain site specific authorisation from the DfT.

TfL's *London Cycling Design Standards* (2005)recommends that to aid cyclist movements the cycle lane can be continued through a signalised intersection using TSRGD diagram numbers 1004 (warning line) or 1010 (boundary line).

Consultation with Lingwood (2011) revealed that a number of authorities have continued mandatory cycle lanes through a T-intersection from directly in front of the ASL, although this is technically in breach of current UK legislation. A similar example in Oxford was provided by Mann (2011).

Cycle by-passes – Cycle by-pass systems can be introduced at traffic signal installations within the United Kingdom under current regulations. The by-pass can be either signalised or 'free entry' with give-way priority when joining the main carriageway. The by-pass system can be split into two categories, one where an on-road cycle lane remains within the confines of the carriageway, the second method where the cyclist is diverted off the carriageway onto a short off-road cycle-track and subsequently rejoins the carriageway after the signalised intersection.

Cycling England Design Checklist A.08 (2011) states that the left-turn on red is one of the main movements cyclists make due to the frustration of waiting at signalised intersections. The other major movement where "jumping the red light" occurs is the straight ahead at T-intersections when there are no conflicting movements. The use of by-pass systems will invariably reduce these occurrences and *LTN 2/08* states that the bypass can reduce delay to cyclists by enabling cyclist to clear the junction ahead of other traffic and so potentially reduce conflict.

The use of an on-carriageway left-turn by-pass does require consideration and additional land use. If this cannot be accommodated from within the carriageway then the space may need to be taken from the adjacent pedestrian realm. The "free entry" left-turn by-pass also raises concerns with regard to possible conflict with pedestrians if there is a specific pedestrian phase on that arm. This is especially the case with regard to partially sighted and blind pedestrians. If governed by signals the by-pass may have its own set of signals or its own separate phase.

Both the off-carriageway left-turn by-pass and the straight ahead off-road by-pass also require careful consideration in the design process with regard to the interaction with pedestrians, especially where cycle phases are included within the design of intersection.

The straight ahead by-pass can be designed to still be within the confines of the carriageway but separated from the traffic signals by the use of a splitter island from straight ahead motorised traffic lanes. This layout is still problematic if there is a need to incorporate pedestrian stages within the signalised intersection, particularly relating to the question of who has priority if cyclists are not governed by the intersection signal control. Such systems can be operated via a push-button method but this will require DfT authorisation.

Where off-carriageway by-pass systems are in place consideration must also be given to how the cyclists rejoin the carriageway. An option to minimise conflict is the introduction of a build-out, however this could act as hazard to cyclists who remain in the carriageway and may have to leave the kerbside into vehicular paths if a suitable by-pass through the island is not provided.

Right-turn facilities – To aid right-turn movements a number of measures have been used in the UK. One method is the two-stage movement in which cyclists will make the manoeuvre in two separate stages and do not have to leave the nearside lane when approaching an intersection with two or more lanes (London Cycle Network, 1994). This arrangement generally works best when where the two movements are phased in order to reduce delay. A disadvantage of the method is the requirement for additional signal equipment and layout requirements (op. cit).

Another method for aiding the right-turn movement is the use of a G-turn which allows cyclists to cross the carriageway directly rather than make a right-turn (op.cit). The final method is by the use of a "jug-handle" approach, where the cyclist is diverted on a short length of cycle track from the carriageway to a toucan crossing. This may mean that the cyclist will have to negotiate two crossings and add further delay to the journey.

Toucan crossings – A toucan crossing is a signal controlled crossing that can be used by both pedestrians and cyclists and can be implemented when a shared route joins a signalised intersection. If the footway and cycle track on the approach are segregated then segregation has to stop short of the waiting area as this has to be shared use (*LTN 2/08*). Where there are high pedestrian or cycle flows, parallel crossing should be introduced to remove potential conflict (*LTN 2/08*). An article by Russell and Carr (2010) makes reference to a diagonal crossing for cyclists when there is an all red phase, which is preferable to completing the manoeuvre in two stages.

Staggered or split crossings are not recommended for cyclists because they cause delay and gives rise to potential for conflict with pedestrians (*LTN 2 /08*).

Staggered crossings offer a number of benefits with regard to minimising lost time to traffic at junctions as pedestrian to traffic intergreens are kept low. Likewise, splitting the crossing into two movements can offer greater flexibility when considering running pedestrian crossings with non–conflicting traffic phases. Conversely, cyclists experience greater delay when using staggered toucan facilities, and Russell suggests that there are an increasing number of examples where single crossings have been used over wide stretches of road, and offer satisfactory performance.

An alternative to toucan crossings was investigated by Greenshields et al in their *Shared Zebra Crossing Study* (2006). This investigation focussed on the use of zebra crossings as a shared use pedestrian and cyclist crossing, termed a “tiger” crossing.

The key benefits offered by the shared use zebra crossing (“tiger”) are the reductions in delay for both pedestrians *and* cyclists in comparison to toucan crossings. The CTC (via Peck, 2011) would “prefer there to be the flexibility to allow zebra crossings to be used by cyclists” [as an alternative to a toucan crossing], noting the financial benefits of this approach over signalisation. However there is still a necessity for the pedestrian or rider to approach the crossing with caution to ensure that road users come to a halt before the cyclist or pedestrian progresses across the crossing.

This study showed that at “tiger” crossings (currently only informal in nature, for example where this is the typical user behaviour at a specific site where the existing zebra crossing links two separated sections of shared footway) there were few conflicts between cyclists and other cyclists and few conflicts between cyclists and pedestrians.

However, the study identified that cyclists crossing a zebra crossing whilst mounted were at 1.85 times more risk of conflict than pedestrians. As zebra crossings are not used alongside signal control this has not been considered as a technique under the scope of this project.

Uncontrolled cycle crossing –The article by Russell and Carr (2010) makes reference to situations where operational considerations make it difficult to justify a separately controlled crossing for cyclists. In this instance it may be appropriate to use an uncontrolled crossing of an arm with cycle track approaches marked as give way. This has an advantage of cyclists not facing a full red signal when it is safe to cross.

Exemptions from traffic orders - Cyclists should be exempt from restrictions within TROs, including banned turns and road closures, unless there are proven safety reasons for not doing so (Cycling England, 2009).

Cyclist detection – Throughout this literature review it has been noted that for many of the schemes offering improved service and comfort for cyclists at traffic signals, successful and reliable cyclist detection is critical. There are many methods noted in the literature, most of which are already implemented on the UK road network for both cyclist and other traffic detection.

Clark and Page (2000) give a thorough evaluation of inductive loop technology in their paper *Cycling and Urban Traffic Management and Control Systems*. The paper explains that inductive loops are a well used detection strategy consisting of a buried loop of wire set into the carriageway surface. Detection is triggered by the magnetic field of this coil of wire being interrupted by a ferrous object. The key detection issue presented by inductive loops when detecting cyclists arises from a limited volume of ferrous material (very little in some bikes) and a smaller cross-sectional area in comparison to a motorised vehicle, meaning it is often difficult to obtain accurate and reliable cyclist detection. Finely tuning the loop equipment and calibrating the sensitivity has been proven to improve their accuracy. Clark and Page continue by reporting on a study carried out to identify the optimum loop shape and size for accurate bicycle detection. From a range of four configurations tested, the half chevron shaped loop was found to be most reliable, returning a success rate of at least 90 percent of detections by all cycle types travelling in the middle 80 percent of the loop, using both high and low sensitivity settings (op.cit).

Green Lights for Bikes (SKM, 2010) notes that inductive loops can either be used to call or extend a bicycle phase at traffic signals, in the same way as they could for vehicular traffic. This paper also highlights the importance of ensure that there are no false calls for the cycle loop by other vehicles in close proximity, and that ideally an advanced loop should be positioned on the approach to the stop line so that there is adequate cruise time left for the cyclist to give the signals a chance to change prior to their arrival. This is important to minimise the cyclist delay at the signals, and assist with encouraging compliance of the traffic signals by cyclists. Fietsberaad (unknown) suggests that this distance should be approximately 20 metres from the stop line for both demanding and extending the cycle phase.

Lingwood (2011) confirms the use of inductive loops in a draft version of Cycle Design Guide(via personal communication), however goes on to suggest that to avoid the instance where a cyclist might not be detected by the loop, a dedicated push button demand unit should be provided at or near to the stop line so that cyclists can manually enter their demand.Lingwood (op.cit) suggests that this should be positioned at a height of 1.2 metres above ground level. Wilke and Eady (2010) present similar benefits for the inclusion of a cyclist push button, but highlight that by including this facility planners are forcing cyclists to stop and wait, which is not conducive to reducing cyclist delay. An alternative to the cyclist push button can be offered by the installation of an infra-red stop line detector, although the use of this technique to address this challenge is not widely reported in literature.

An alternative to loop based detection is above ground detection; specifically video detection. Video detection offers solutions to many of the inherent drawbacks to loop based systems. As mentioned previously, inductive loops need to be tuned to ensure a sufficient sensitivity to detect bicycles, but not so high so that they detect passing vehicles.

Sherman (2007) also reports on this limitation, and also concludes that the loops must be carefully placed so that cyclists cannot, or will not, bypass them. In addition to this there is much anecdotal evidence from traffic engineers, citing examples of carriageway maintenance works resulting in loops being damaged (or even removed), thereby giving rise to false or missed detections.

Video detectors allow an engineer to set a “virtual” loop on the camera view which will register detection when traffic passes through or stops within it. Sherman (op. cit) continues by citing research carried out by Santa Clara County, which concluded that video detectors had difficulty detecting bicycles in darkness resulting in occasional false calls due to vehicle shadows appearing on the bicycle lane.

Naturally the technologies within these systems are progressing continually and different manufacturers typically have subtly different product offerings, as highlighted by a research paper by Kimley Horn Associates (2003). In their independent study four competing video detection units were tested under the same conditions to establish their accuracy for detection of cyclists. The tests were undertaken over a two day period, in both daylight and darkness. Results showed that both Peek and Iteris products were capable of 100 percent success rates of detection. It should however be noted that as vision based products, any video detectors requires a certain level of ambient light, either provided naturally or by street lighting.

3.2 Cycling facilities with the potential to be implemented on UK roads

Staggered stop lines – In *Collection of Cycle Concepts* by the Danish Road Directorate (2000) the staggered stop line system is described. In essence this is a part-width ASL with an advanced stop line for cyclists, but does not encroach in front of the adjacent vehicle lanes. This is in part due to the fact that the equivalent of the UK right-turn movement in Denmark is not allowed on a vehicular green arrow aspect and as such a full advanced stop line is not necessary. There should be a 5 metre stagger to make cyclists and pedestrians more visible to motorists. An accident study showed there to be a 35 percent reduction in the number of accidents between motor vehicles turning right (UK left) and cyclists continuing straight ahead.

Marking where cyclists need pass over or to wait for detectors – In the USA it is relatively common practice to apply a road marking for the optimal position that cyclists need to travel or rest upon to ensure detection by inductive loops. The marking is used to reduce the likelihood of cyclists not being detected and subsequently experiencing long wait periods and to decrease the likelihood of non-compliance at signals.

Cycle symbol, from the Traffic Control Bicycle Part 9 (2009 Edition)

Traffic calming and plateaus –The 2008 document by SWOV, (the Dutch Institute for Road Safety Research) recommends that additional facilities are required to reduce speed differentials between cyclists and other traffic and this can be achieved via the use of speed bumps and plateaus. This recommendation is reflected in SafetyNet'slater (2009)document *Pedestrians and Cyclists.*

Markings through the junction – as discussed previously,elephants feet can be used in the UK to delineate a cyclist's route through a signalised intersection, however these need to be authorised by DfT. Many European countries, specifically Denmark, Germany and the Netherlands provide highly visible, distinctively coloured bike lane crossings through intersections. These are one of a few treatments that are focussed through the intersection rather than at the approach or leaving the stop line. The coloured section is for the crossing area itself as well as conflict points, but is not used on the approach or after the intersection.

The *Collection of Cycle Concepts* (Danish Road Directorate,2000) details the use of three types of crossing. One is blue, while the two others are marked by variations of white broken edge lines. Bicycle symbols are always marked. A study of cycle-crossing accidents through intersections showed that the presence of the cycle crossing led to a 36 percent reduction in the number of bicycle accidents and as much as 57 percent in the number of severely injured. There was a recorded increase in pedestrian accidents however this was attributed to motorists particularly focussing their attention on cyclists, to the detriment of other road users.

A further study was undertaken by Jensen (2007) which attempted to assess the impact of using this blue crossing colouring technique on multiple arms of the same junction. The study found that with a single instance of coloured treatment through an intersection there is a 10 percent reduction in accidents and a 19 percent reduction in injuries. Corresponding figures for using the technique at two arms of the same junction found a 23 percent increase in accidents and 48percentincrease in injuries. Using the same coloured treatment across four arms increases the rate of accidents by 60 percent and injuries by 189 percent.Jensen(op.cit) goes on to suggest that these results show that the effects of the blue cycle crossings are influencedby the size of the intersection, the number of arms for which the treatment is applied and also traffic volumes. The safety flaws recorded at two and four arm setups (where the technique is applied) is reported to be a result of an increase in rear-end shunt style collisionsbetween motor vehicles and motorists disobeying red signals.

The Pedestrian and Bicyclist Safety and Mobility in Europe (International Technology Scanning Program, 2010) details an additional study undertaken on crossings in Portland, USA of coloured bike crossings. This shows that significantly more motorists yielded to cyclists and slowed or stopped before entering the blue marking area, more cyclists followed the coloured bike path and fewer cyclists turned their heads to scan for traffic or used hand signals.

Channelisation of cyclists - The Danish Road Directorate (2000) publication details the technique of channelisation,Where there is a high proportion of different movements of cyclists, riders are channelled into separate lanes for example to travel left and straight ahead. This places cyclists in the optimal position for the desired movement before entering the junction and helps minimise any potential cyclist to cyclist conflict. The lanes should be wide enough to allow side by side running on the approach to the intersection. Where there is a left-turn stage, these should always be channelised.

Cyclists not allowed to use motor vehicle left (right)-turn arrow signal - The *Collection of Cycle Concepts* (op. cit) states that the Danish traffic regulations prohibit cyclists undertaking a left-turn (UK right-turn) where there is a left-turn arrow traffic signal. Instead they are required to undertake the turning manoeuvre as a two stage process; they firstly have to go to the opposite side of the intersection and wait at a secondary stop line before they can make proceed in the required direction.

This is implemented to reduce the inconvenience to other road traffic and reduce conflicting collisions with opposing traffic flows where there are multiple lanes. In such instances where this is used, the second movement should be incorporated in the next phase to reduce delay.

Signal offsets designed for cycle progression(Green Wave) – In many urban areas, consecutive traffic signal controlled junctions are timed so that they offer progression when travelling along the major route. In the case of SCOOT controlled junctions this progression is altered to reflect prevailing traffic conditions. The offset from one junction to the next requires the average cruise speed to be known from one stop line to the next. Papers by Taylor and Mahmassani (2000) and Clark (2000)propose that this cruise time could be set to positively benefit cyclists rather than a mixed traffic profile.

In these papers, it is stated that this coordination for cyclists might even offer cyclists a greater advantage than motorists, because stopping at a red signal has a physical as well as a psychological effect for cyclists. This is noted by Peck (2011) who states that braking to a stop and restarting loses the equivalent energy to travelling 100m.

Taylor and Mahmassani (2000) recognise that there is greater variability in cyclist cruise times than there is in vehicular traffic cruise times, partly due to factors including differences in skill and physical fitness, but also because platooning is unlikely to make bicycle cruise speeds more uniform due to the relatively low numbers of cyclists. This is echoed by Peck (2011), who suggests that the maximum speed of a cyclist is around 25mph, with mean speeds around 10-15mph – much lower than that of a vehicle.

Anecdotal evidence exists which suggests that many cyclists routinely adjust their speeds to allow for progression throughsignals on streets where they have learned the signal timing pattern through repeated journeys by bike (op.cit). As a result of this, they suggest that the best way to provide some uniformity to cyclist cruise time would be to inform cyclists of the designed progression speed. Additionally they suggest that posting a progression speed slightly higher than the designed progression speed would offer further benefits.

Pucher and Buehler (2007) explain that many Dutch, Danish and German city planners have implemented signal timings designed with cyclist progression in mind. Their paper suggests that a cycling cruise speed of 14-22km/hr is generally assumed to provide the “green wave” for cyclists. The *Design Checklist* (Cycling England, 2011) even suggests that having adjacent signals timed to provide a green wave at 30 mph (most suitable for vehicular cruise speed) may lead to significant delays for cyclists. Naturally the impact of this needs to be considered on a site by site basis, however a common suggestion by all papers is that steps can be taken when designing for progression between signals to consider cycling traffic in addition to those driving motor vehicles.

Ryding (2007) provides the results of a study undertaken in 2004 comprising a green wave covering 13 linked signalised intersections with a cruise speed of 20km/hr. The results showed that there was:

- A reduction in stops and travel for cyclist travel;
- The maximum number of stops saved was six stops; and
- A saving of 2 minutes and 29 seconds was made,based on a previous journey time of 8 minutes 54 seconds.
- An average increase in the speed of cyclists of 5km/hr was recorded following implementation of the green wave.

The same study also assessed motor vehicle progression and this showed for the same period and direction of travel that the number of stops experienced by vehicular traffic showed a reduction of one stop, the average travel time along the network showed a minor increase of 4 seconds and there was a very small average vehicular speed increase of 0.02km/hr.

The route assessed was 2.2km long and prior to the green wave study had a daily flow of 30,000 cyclists and 17,000 cars along with heavy public transport flows equivalent to 1 bus every minute. Finally, the document states that the progression of cyclists can be affected by buses stopping, delivery lorries and congestion in the cycle lane.

A trial scheme is currently being undertaken between Transport for London and the London Borough of Camden to provide traffic signal progression designed for a speed suitable for cycling traffic. Once ended, the results of this trial would be most useful in providing evidence from the UKaround this topic.

Certainly there is a role of speed reduction in urban (and also residential areas) where physical measures are not required, which could be achieved by this technique. This would have wider community benefits which should also be exploited, particularly where there is an existing desire to bring in a 20mph speed limit.

To address one of the issues raised in Taylor and Mahmassani's (2000) paper regarding the variability of cyclist cruise times, the city of Odense in Denmark have installed **roadside progression indicating LEDs.** These LEDs come on in sequence prior to the approach receiving a green signal, such that if an approaching cyclist keeps pace with the LEDs that are lit, then they will reach the downstream signals as they turn green (Russell*,* 2009)

As discussed earlier in this literature review, **toucan crossings** are widely used on the UK roads where a significant number of cyclists need to cross a major road. In Russell's (2009) paper a number of modifications are suggested that could be made to the design and control of toucan crossings. Some of these suggestions require a philosophy change to move cyclists higher up the order of priority when considering capacity at a junction.

Russell (op.cit) continues by proposing where staggered toucan facilities are the only suitable solution that they should be linked, so that a demand for the first half of the crossing automatically inputs a demand for the second half of the crossing. This would give cyclists better progression through the facility and would reduce cyclist delay. Likewise, delays can be minimised for cyclists if the staggered facility is controlled by SCOOT with each half of the crossing set up as an individual SCOOT node. Optimisation is likely to then provide greater benefit to cyclists, but potentially at the cost of vehicle throughput.

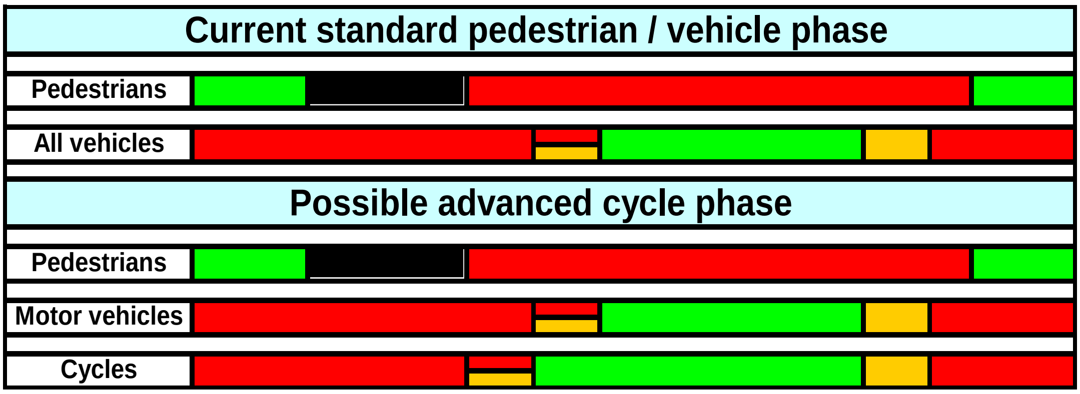
In the UK, **pre-timed maximum** is occasionally applied to a pedestrian or toucan crossing to reduce the waiting time for non-road traffic. Pre-timed maximum works by starting a maximum timer when the vehicle phase gains right of way, if this pre-timed maximum timer is not set the timer is started when the pedestrian or cyclist presses the push button. Typically this timer will be set to run for approximately 30 seconds (site dependant), therefore if not used, and there is no break in the traffic, the pedestrian or cyclist waiting to cross will be required to wait this period of time before right of way is changed. When pre-timed maximum is switched on, in most cases where pedestrian or cyclist demand is low, this timer will have elapsed prior to the pedestrian or cyclist making the demand. As a result the toucan crossing will give right of way to the pedestrian or cyclists almost immediately - thus minimising their delay. This function can have a dramatic effect on vehicle capacity along the stretch of road so should only be utilised where this impact is minimal. This point is emphasised by Lingwood(2011), who also advises that toucan crossings should not be linked to the UTMCas it will lead to an increase in delay to cyclists and pedestrians.

There are number of suggestions put forward by the papers reviewed as part of this literature review that require separate signalisation of the cyclist traffic. Provision is already made within the Traffic Signs Regulations and General Directions (2002) for highway authorities to use a cycle specific traffic signal aspect. Schedule 8 shows diagram 3000.2, which comprises a full red signal as well as amber and green cycle signals. This literature review has not revealed any publications specifically relating to this current signal aspect; however it is understood to be used on numerous junctions across the UK.

Separate signalling for cyclists – Alta Planning and Design (2009) state that in some cases the signal phases for motorists should be completely separated from bicycle phases. Many European countries are already using these separate phases for cyclists and this practice is also being taken up in other continents including within North America and Australasia. The three key benefits for such a system are summarised in Sinclair Knight Merz consultants (SKM) (2010) document *Green Lights for Bikes*:

- Provides a greater degree of control of bike riders independently of other modes;
- The ability to offer cyclists an early start to minimise conflict; and
- Can be retrofitted to existing infrastructure.

The CTC, via Peck (2011) suggests that an advance phase for cyclists could be provided by making "better use of the period in which no green or red pedestrian signal is displayed" [the blackout period]. This is displayed below, although there is a risk that moves towards reducing the all-red clearance time on junctions could result in less available time to release cyclists early, particularly at crossings with heavy pedestrian flows where pedestrians may dwell on the crossing area into the blackout period, potentially increasing conflict between pedestrians and cyclists.



Providing an advance cycle phase without the removal of time from vehicles (Peck, 2011)

The document *Safety of Pedestrians and Cyclists in Urban Areas* (European Safety Council, 1999) states that a separate signal phase can reduce crash risk to children by up to 90 percent, calling upon work undertaken by Leden (1988). Whilst the authors of the 1999 report do not explicitly state that this benefit is specifically for child cyclists, this is the natural interpretation of the text.

In addition to separate phases, it is also possible to have a separately controlled cycle phase which provides the opportunity to have a separate cycle stage, whereby all potential conflicts with motorised vehicles are removed. Another benefit of the separate stage is to ease the movement of right-turning vehicles (op.cit).

The *Pedestrian and Bicyclist Mobility of Europe* publication (International Technology Scanning Program, 2010) notes anecdotal experiences that show cyclists comprehend and adhere to bicycle traffic signals. The document provides additional confirmation as to the three possible uses of separate signals, these being:

- An advanced green for bicyclists that proceeds the motorists green by several seconds;
- An exclusive green stage for bicyclists to make right-turns; and,
- A red stage while left-turn exclusive stage for motor vehicles.

Early start for cyclists – According to Wilke and Eady (2010) there are three key benefits to supplying cyclists with an early start facility, these being:

- Reduced “rat-running” by motor vehicles;
- To make cyclists more visible; and
- To support the priority of non-motorised users.

Likewise they provide two key disadvantages:

- Reduced green time for traffic; and
- More information to process (also results in additional street clutter).

All green cyclist stage (Bike scramble) –Weighland (2008) describes an alternative use for separate signalled control for cyclists. The bike scramble stage was installed in the City of Portland, USA to improve traffic conditions and improve safety for cyclists by allowing a protected movement for all cyclist movements at an intersection.

Bicycle Scramble on Green in the Netherlands
With thanks to C. Peck, CTC for photograph

A before and after study was undertaken on the trial site in 2004which found that the volume of cyclists using the intersection increased and the amount of illegal crossings significantly decreased after the scramble stage was installed (op.cit). However, this technique is not without its disadvantages and Wilke and Koorey (2005) state that including a dedicated bicycle stage at an intersection may result in a loss of time to traffic or longer cycle.

The *York Region [*Canada*] Pedestrian and Cycling Masterplan* (MMM Group, 2008) states that such systems should only be considered in “extreme” circumstances. This could include where the intersection layout is not considered to be standard and the route for cyclists is not obvious. SKM’s(2010) *Green Lights for Bikes* states that the potential application for a scramble stage is most beneficial where there is a strong demand for cyclists to make a diagonal movement. However, they reiterate that this strategy has limited application as it can significantly reduce the green time available for other vehicular movements.

Traffic and Legal Aspects of AFTG [All green cyclist stage] (Fietsberaad, 2003)references similar advantages as described above but states that the scramble phase should be run twice in a cycle, and provides details of example timings. A double-cycle with relatively short green for cyclists (5 to 8 seconds) will lead to 10 seconds less time for traffic per cycle. The document also states that incorporating the system where there is an existing pedestrian demand can be difficult. However,there are three main conditions outlined when the system can be introduced successfully; these are that:

- The intersection must be compact preferably with cycle lanes on the approach
- There is a two or three stages for traffic; and
- The volumes of motor vehicles should be below a threshold of 25,000 per day.

Korve and Niemeier (2002) claim that incorporating a new bicycle-only signal phase at an existing intersection in the U.S. had never been analysed before their study. They examined the effects of a bicycle-only signal phase at a high-volume intersection for both cyclists and vehicles in Davis, California and found increased rates of bicycle safety due to lower number of bicycle-vehicle conflicts. Applying a cost-benefit analysis to both vehicle delay and emissions, they found that benefits of the technique in this particular context outweighed the costs and disadvantages.

Two green periods per cycle for cyclists – two greens per cycle is only possible with separate cycle phases. In *Fietsverkeer 24* (Fietsberaad, 2010) a case study was provided of this method, implemented on the basis of reducing cyclist waiting time. The study showed that having two green stages at the intersection was not viable for all modes of traffic - with large delays experienced by motorised vehicles. The second period wassubsequently removed.

The Fietsberaad publication (date unknown) *The bicycle-friendly traffic light*citesan additional example of this technique, from Tilburg in the Netherlands where two periods per cycle was implemented. As a result the average waiting time for cyclists was reduced by 50percent and the maximum waiting time by 30 percent. However, the cycle time had to be lengthened by 10 seconds causing the average waiting time for motor vehicles to increase by approximately 15 percent.

Cycle countdown signals – this can be a countdown to green for cyclists, to help them prepare to set off. As cyclists accelerate more slowly than motor vehicles, this can be beneficial so that they can get ready to move off, and will anticipate accelerating traffic around them. This may have a reduction in the impact on the saturated flow.

Countdown signals can also countdown to red, which can help prevent cyclists having insufficient time to clear the junction. A 2009 report published by Alta Planning and Design suggests that cycle countdown signals would give adequate information to allow cyclists to prepare for the green signal, and under green conditions, plan if they have time left to cross a wide intersection prior to conflicting traffic being given right of way. Countdown units particularly help where there are less experienced riders, cyclists who require additional time or where there is a wide intersection to clear. Wiersma's (2006) document *Evaluation of Waiting Time Predictor* states that these systems can only be used at fixed time (or in some instances semi-fixed light regimes) and that evidence showed there to be a reduction in red light running by cyclists.

Dwell on green – SKM (2010)suggest a technique where the default signal is green to cyclists and pedestrians until a vehicle is detected. This is generally opposite to conventional practice where signals change to green to vehicles after the end of a pedestrian phase. Dwell on green will allow cyclists to arrive on green and reduce time spent slowing, waiting and restarting. This system is best used where there are high cycle flows and low traffic flows, but is likely to cause delays to vehicles.

Cycle time to be kept to a minimum –*The Bicycle Friendliness of Traffic Control Systems* (Jongenotter and Akkerman, 2003) states that the waiting time at intersections is a good indicator of bicycle friendliness and this is strongly related to system cycle time. They suggest that keeping cycle times to 90 seconds or less is most beneficial to cyclists. If feasible, reducing the size of the intersection so that cycle and wait times can be reduced should also be considered. This 90 second period is validated in various other documents, including CROW Manual (2007).

The *Green Waves for Cyclists in Copenhagen Best Practice Guidelines*(Ryding,2007) states that the cycle time in Copenhagen is typically 80 to 100 seconds during peak times but reduced to 60 to 70 seconds during off-peak periods to minimise cyclist waiting time.

Cyclists passing through a red signal– Where there are no conflicting vehicular movements, there can be increased temptation for cyclists to disobey signals, particularly when turning left or going straight ahead at a T-junction. The use of left-turn on red can allow cyclists to legally make these manoeuvres where safe to do so. This has been applied in Europe where one cycle lane leads to another.

This idea has been mooted by the Mayor of London, but the CTC (via Peck, 2011) suggests that this proposal would require "a fundamental review of the way priority and cyclists is arranged". Peck continues by stating that the Highway Code (paragraph 170) states that pedestrians have priority over side turning traffic if they have started to cross, yet this rule is "routinely abused" by other road users. A clear priority system would need to be re-established to ensure the safety of all users.

*Best practice to promote walking(*Danish Road Directorate, 1998) makes reference to where this technique has been usedin the Netherlands. In this document they suggest that this measure should only be taken if the possible conflicts between cyclists and other road users are thought to be acceptable (e.g. where speeds and vehicular volumes are both low and the roadway cross section is wide). Dutch cities require the installation of a special sign at intersections where this is a legal manoeuvre.

The straight ahead on red for major road cyclists at T junctions is another application of allowing cyclists through a red light. Separate bicycle lights could be installed and the signal reprogrammed to allow cyclists to go whenever other traffic is held back. Either of these options are complicated when there are pedestrian phases at intersections and would require the use of a separate signal. In Germany, cycle symbols are placed within the marked cycle lane facing the side road to provide additional warning to emerging drivers. Lastly, this strategy could raise safety concerns if there are heavy flows of right-turning large vehicles from a side road as their swept path may encroach upon the cycle lane.

In an attempt to warn motorists of the presence of cyclists on the nearside cycle lane at traffic signals the Danish city Grenå has installed a system that uses **RFID tags on bicycles** to trigger an illuminated warning sign below the red, amber and green traffic light. This illumination is specifically designed to warn traffic turning right (left in the UK) who could cut across the path of cyclists wanting to travel straight ahead.

The trial of the 'See-mi' RFID tag was undertaken by 280 cyclists (Kilde Consult, 2008). In general the participants were positive about the system and its potential to make drivers of larger vehicles (e.g. goods vehicles) and other motorists more aware of cyclists in the traffic.

In addition to the RFID scheme making cyclists feel more comfortable at signals, a Dutch trial (evaluated by Harms, 2008) has looked at **giving cyclists greater priority, shorter waiting times and additional green periods during adverse weather conditions or when the temperature is low**. The benefits for cyclists aim to make cycling in poor weather less of a burden and more attractive, and hopefully remove the temptation for cyclists to disobey traffic signals to save waiting in the rain or cold. The trial revealed that waiting times for cyclists during this operation were sharply reduced, whilst there was no adverse impact on the waiting times for motorised traffic. The report noted that the performance could be variable however, and is very dependent on the traffic flows at the junctions where this could be used. The results of this trial also showed that the numbers of occurrences where cyclists disobeyed the red signals were reduced, and the number of occurrences where motorised traffic disobeyed the red signals did not show any noticeable change.

3.3 Collision Data and Safety Observations

Fietsverkeer(2004) concludes that there is rather limited knowledge concerning this topic and that the body of research is presently too limited to draw comprehensive conclusions or practical solutions a sustainable safe approach. Knowledge is poor where bicycle provisions are concerned and there is certainly room for improvement in this area.

Research into the causes of cyclist collisions has been documented in recent years, and there is evidence to suggest that junctions are a significant factor when investigating the provision for cyclists. A study undertaken by TRL (Knowles et al, 2009) found that:

- Almost two-thirds of cyclists killed or seriously injured (KSI) were at or near junctions;
- 38 percent of all cyclist KSI involved a car/ taxi in an urban area at a junction;
- Collisions involving a large vehicle such as an HGV were more likely to result in a fatality because of their size. A cited study by Robinson (2005) found that most of the collisions occur when large goods vehicles are travelling at less than 10mph. This was because most collisions occurred during manoeuvres, in particular left turns and at roundabouts. When an HGV was involved, the main collision configuration was the HGV driver making a left turn while the cyclist was going ahead;
- The main collision configurations involving a bicycle and car were the car turning right or left while the cyclist was going straight ahead and the cyclist making a right turn while the car was going straight ahead; and
- In collisions involving a bicycle and another vehicle, 'failed to look properly' was found to be a key contributory factor at junctions for drivers and riders (reported in 60 percent of serious collisions at junctions). 'Failed to look properly' was

attributed to the car driver in 57 percent of serious collisions Available sources fail to show whether drivers are looking but failing to see the cyclist or failing to look for them. Equally, the strategies adopted by cyclists at junctions are also not well understood; 'cyclist failed to look properly' was attributed to the cyclist in 43 percent of all serious collisions.

The TRL study listed some engineering measures, including those specific to junctions, which are seen to be beneficial to cyclists, many of which have already been highlighted in the literature review process.

The 2009*SafetyNet* document *Pedestrians and Cyclists* confirms these findings, stating that most cyclist collisions occur in urban areas. Many of these occur frequently at facilities designed for cyclists such as tracks and lanes. The factors found to contribute to these collisions are:

- The speed of motorised vehicles,
- The weight and design of these vehicles,
- The lack of protections for cyclists,
- Cyclist visibility and
- Degree of vehicle control; and
- The level of alcohol consumed.

One of the issues for cyclists is their lack of visibility and this appears to be a major contributory factor in the rates of collisions whether approaching from rear or to the side. The recommendations for improving cyclist safety are facilities to reduce the speed differential. In addition some countries including Germany and Netherlands have measures specifically aimed at improving the visibility of cyclists, with vehicle regulations requiring additional reflectors and other items for road going bikes.

Whilst this study has focussed on the study of cyclists at junctions and measures to improve the provision for cyclists at this specific location, due consideration must be given to the wider network within which junctions fit. For facility continuity, an important determinant of appropriate provision at junctions must be the nature of the facilities leading to and from the junction. In particular, this would include understanding the role of on and off carriageway facilities before and after the junction.

Whilst segregation is an extremely contentious subject, it is worth noting that research does exist which links the provision on approach to junctions with safety, and is worth briefly considering.

Jensen has written a number of papers on cyclist safety including *Road Safety and perceived risk of cycle facilities in Copenhagen* (2007) and *Bicycle Tracks and Lanes: a Before-After Study* (2007). These studies have provided an insight into the safety of cycle tracks (adjacent to road) in that there is an increase in accidents and injuries between:

- Cyclist and other cyclists;
- Cyclist and right-turn vehicles;
- Cyclist and pedestrians; and
- Cyclist and bus passengers.

At intersections the accident and injury rates increase by about 10percent in urban areas.

Three important gains are provided by cycle tracks;

- Fewer accidents in which cars hit cyclists from the rear;
- Fewer accidents with cyclists turning left (UK right) ;and
- Fewer accidents involving parked vehicles.

Where tracks were converted to cycle lanes on the approach to signalised intersections the number of accidents fell by 30 percent, however the number of injuries increased by 19 percent. This is owing to the change in the nature of collisions, from those with pedestrians or other cyclists to those with vehicles which result in more injuries (and injuries that are more severe). It was found that an advanced stop line with a turn lane for vehicles is considered best with regards to cyclists.

With regard to cycle lanes, there is 5 percent increase in accidents and 15 percent more injuries but this increase appears to be attributed to accidents at junctions. The introduction of cycle lanes did not result in a fall of vehicles rear-ending bikes or involving left-turning bikes (UK right). Furthermore, there was no increase in collisions with pedestrians or between left-turning motor vehicles. There was an increase of 73 percent with right-turning vehicles and bike to bike rear end collisions.

As part of the study into blue-crossings, detailed earlier, interviews with cyclists showed that the perceived risk is greater in mixed traffic when compared to lanes and tracks. Cyclists feel safest at signalised intersection with blue highlighted crossings, even though when this treatment is applied to more than one arm of a junction, there is likely to be an increase in the number of injury accidents.

In 1999 Coates undertook a study and presented the paper *Safety Benefits of Cycle Lanes*. In the paper he stated that if cycle lanes are not carried across a junction it is likely that accidents involving cyclists will increase. In a study where cycle lanes were marked on the approach to an intersection it showed that at all but two sites there was an increase in accidents through the intersection. After the introduction of lanes through the intersection, nine intersections showed a reduction in the number of accidents.

Fietsverkeer (2004) Where speed reducers (traffic calming measures) are applied there is a reduction of 15 percent to 26 percent in the number of casualties. In the case of signalised intersections, the number of accidents increases with the flow of motor vehicles. It seems 20,000 vehicles per 24 hour period is the threshold after which a noticeable increase of the number of accidentsoccurs. The note references a SWOV report undertaken in the 1980s that demonstrated that bike tracks alongside local and urban roads are safer than bike lanes, whereas on-road bike lanes are more dangerous to cyclists than no bike facilities at all. The note goes on to say that a bike path crossing an intersection on local roads should be elevated or converted into a bike lane on the approach and through an intersection.

The (2008) SWOVfact sheetconfirms the statements made in *Fietsverkeer Note 9*. This states that bicycle facilities that separate motorised traffic from cyclists are necessary and that road segments with adjacent separated bicycle facilities are safer than road segments without such facilities. The number of collisions can be reduced by the addition of additional measures at intersections such as priority regulations, speed bumps and plateaus. The fact sheet continues, stating that there are twice as many fatalities or injuries requiring in-patient care at intersections when compared to road segments and that where possible the intersection of two distributor roads should be of a roundabout design (continental design if possible) or the introduction of the measures already listed.

The same research refers to statistics for collisions at through intersections. Tracks were worse than lanes (50 percent more injury crashes per passing cyclists) or no facilities (32 percent more injury crashes per passing cyclist) and this led to the recommendation to terminate or truncate paths some distance from the intersection. The *SWOV* note also makes reference to German research which showed that it is preferable to mix cyclists with motorised traffic just before the intersection, especially where right-turn on red (left-turn in the UK) movements are likely.

Section 4 of this document contains the full list of techniques which have been identified to take forward into the assessment phase of the project.

4 Identified Techniques

The following 48 techniques have been identified during the literature review and have been considered during the assessment phase of the project. More detailed information on these techniques can be found in Section 6.9.

The techniques have been split into three categories:

- Those used commonly in the UK
- Those not commonly applied in the UK
- Those applied internationally

A short description of each technique is also provided, alongside a unique ID code which is carried forward throughout this document.

4.1 Techniques commonly used within the UK

Technique	Short Description	ID Ref
Intergreen extension for slow cyclists	Designed to ensure cyclists clear the intersection before conflicting traffic is given right of way	1
Advanced Stop Lines	Provides a dedicated waiting area for cyclists ahead of other traffic	10
Cycle by-pass lane for left turning cyclists (giveway priority)	Dedicated turning cycle track exit onto the carriageway controlled by priority rules	13
Cycle by-pass lane for ahead cyclists at T-junction (within carriageway)	Extension of the carriageway to take cycles around the traffic signals to prevent them from having to stop	15
Elephants feet markings through junction	Delineation of cycle route through a junction using rectangular markings either side	17
	Allow cyclists to undertake banned moves in certain situations where their movement does not conflict with other traffic or pose additional safety hazards	20
Inductive loops to request cycle demand or priority (for separate phase or early green)		28
Video detectors to request cycle demand or priority (for separate phase or early green)		29
	To raise the height of the carriageway where cyclists are crossing from kerb to kerb	41

4.2 Techniques not commonly applied in the UK

Technique	Short Description	ID Ref
Intergreens extended using detection	Extension of intergreens as a reaction to the presence of a slow moving bicycle	2
Cycle by-pass lane for left turning cyclists (signal controlled)	Dedicated turning cycle track exit onto the carriageway controlled by traffic signals	12
Cycle by-pass lane for ahead cyclists at T-junction (onto footway)	Delay reduction by allowing cycles to miss the traffic signals via an off street cycle track	14
Cycle tunnels	Delay free conflict free means for cyclists to cross a major road	16
Push buttons to request cycle demand or priority (for separate phase or early green)		27
	Allow cyclists to by-pass the traffic signals and cross side roads uncontrolled, via gap acceptance	40
Pre-timed maximum timer on Toucans	Aimed at reducing delay to cyclists	45

4.3 Techniques currently only used overseas

Technique	Short Description	ID Ref
Separate cycle phases with cyclist signal aspects	Separating cyclists from other vehicles by providing dedicated phase for their movement	3
Incorporation of cycle countdown units into cycle traffic signals (countdown to green and red)	To communicate waiting times to cyclists when on red, and communicate remaining green time when on green.	4
All round cycle stages (red to traffic)	"Bike scramble" on-street with cyclists waiting in dedicated cycle lanes	5
	Bike scramble" off-street with cyclists waiting in dedicated areas on the footway	6
All round cycle and pedestrian stage (red to traffic)	Cyclists remaining on street and giving way to pedestrians on crossings	7
Pre signal for cyclists for early start (cycle aspect only)	Cyclists given an illuminated green cycle symbol signal when they have right of way	8
Pre signal for cyclists for early start (separate signal head)	Cyclists controlled by a separate red, amber, green signal	9
	Cyclists wait in a part width advanced stop area	11

Coloured cycle lanes through junctions (one)	Coloured lane delineating the route through the junction for cyclists	18
Coloured cycle lanes through junctions (two or more)	Coloured lanes delineating the routes through the junction for cyclists on more than one arm	19
Coordination of signals for cyclists progression "green wave"	Allows cyclists travelling at cruise speed to pass through successive green signals	21
LED indication to communicate the progression speed to cyclists	Allows cyclists to adjust their speed to meet the next green	22
Selected vehicle priority for cyclists (similar to bus priority)	Priority at the intersection given to the arms or movements with greatest cycle demand	23
	Cyclists turn right by remaining in the left lane and waiting at an advanced stop line in the intersection for the next stage to be given right of way, at which point they progress to their destination arm of the junction	24
	As above but with a mandatory traffic order preventing cyclists from turning in one movement alongside other traffic	25
Road markings to highlight loop detectors	Communication of where cyclists need to position themselves to ensure improved detection rate	26
Dwell on green for bikes (reverse priority) (cycle track or cycle phases only	Similar to a toucan crossing, but the signals rest on cycle and pedestrian right of way in the absence of other demand	30
Cyclists allowed to turn left on red at any intersection (no green)	Change of law to allow cyclists exemption from having to stop at red lights when turning left	31
Cyclists allowed to turn left on red at specific intersection (cycle symbol green / red light during pedestrian phase)	As above, but in selected locations, site by site exemption	32
Cyclist allowed to turn left on red where designated lane present (on both arms) (cycle symbol green / red light during pedestrian phase)		33
	Change of law to allow cyclists exemption from having to stop at red lights when travelling ahead at a T junction when they are not crossing a side road	34
Straight ahead for cyclists on red (cycle symbol green / red light during pedestrian phase) at T intersection		35

Straight ahead for cyclists on red with route through junction marked (cycle symbol green / red light during pedestrian phase) at intersection		36
Junction cycle time reduction (90 second maximum)	Cycle time kept low to minimise the waiting time for cyclists and pedestrians	37
Channelization of left, right and ahead cyclists	This technique helps prevent conflicts from cyclists and other vehicles making turns across the paths of others	38
	Keeping cyclists on the footway until they approach signals, once there they can be given right of way rather than gap accepting and crossing uncontrolled	39
RFID tags on bikes and warning indicator on signals	Detection of cyclists in the nearside lane warns motorists of their presence	42
	By use of a weather station, cyclist delay and chance of having to stop is reduced during periods of rain, or low temperatures	43
Straightening staggered Toucans, and make a single phase	Reducing delay to cyclists by allowing them to cross roads in one movement rather than two	44
	Convex mirrors positioned on the existing street furniture to allow motorists (especially large vehicles) a better view of any cyclists in the nearside cycle lane	46
	Repeating the green period for cyclists or the dominant cycle movement to reduce delay and increase their level of service	47
Conversion to continental style roundabout (vehicle flows under 10 - 15,000 per day)	Roundabout designed to have compact geometry and slow speeds	48

5 Assessment Methodology

A spreadsheet based scoring system was developed against which each of the 48 techniques could be assigned a score on a 5-point scale for each of 55 criteria divided into the following themes:

- Cyclists
- Pedestrians
- Vehicles (traffic management)
- Cost Implications
- Regulation and Legislation
- Other.

As previously described, the scores range from 2, where the technique was considered to have a significant positive impact on a particular criterion through 0, for no expected impact, to -2 for significant negative impacts.

Each of these scores was assigned a coloured category (based on a RAG scale, representing **R**ed, **A**mber and **G**reen) as follows, to provide a visual indication of score.

Score	Effect	RAG Status
-2	Major negative effect	
-1	Minor negative effect	
0	Neutral	
1	Minor positive effect	
2	Major positive effect	

Aggregated scores for each theme were also developed, as well as an overall score for each technique.

Please note we have assumed a base scenario of a standard width cycle lane on the approach to an intersection under signal control with standard red / amber / green traffic signals.

Cyclists

In total, 14 criteria have been identified for assessment within this theme.

These criteria for assessing impacts on cyclists were derived in part from the requirements for cycling infrastructure originally set out in DfT's publication *Cycle Audit and Review* and now reflected in *Cycling Infrastructure Design*. This is based upon five headings:

- Coherence
- Directness
- Attractiveness
- Safety
- Comfort

These were broken down in further detail to provide criteria specifically relating to junctions, in particular concerning delay, legibility and conflicting turning movements.

Additional criteria were chosen to consider how the junction would perform under different levels of cycle use.The full list of criteria considered for this theme is shown below, along with a description of the types of factors considered.

Theme Criteria	Description
Deviation	Deviation looked at whether cyclists were forced to deviate from their desired route
Legibility	Legibility suggested how legible the technique would be to cyclists
Safety	Safety looked at to what extent safety was improved for cyclists
Capacity	Capacity investigated how the technique altered the cyclist capacity through the junction
Delay: waiting time	Focuses on how long cyclists have to wait before they receive a green signal
Delay: chance of stopping	focuses on how likely it is that cyclists will have to stop as a result of the proposed technique
Attractiveness	Would the technique encourage people to cycle
Comfort	How comfortable would cyclists feel with the inclusion of a technique.
LOS: Existing Flows Low	How does this technique perform when cyclist flow is low
LOS: Existing Flows Medium	How does this technique perform when cyclist flow is medium
LOS: Existing Flows High	How does this technique perform when cyclist flow is high
LOS: Predicted Growth	How does this technique perform when considering future growth of cyclist demand
Behaviour and Compliance	What influence do techniques have on the behaviour of cyclists and their compliance to the traffic signals
Priority over others	Does the technique award priority to cyclists over other road users

Pedestrians

In total, 8 criteria have been identified for assessment within this theme.

We have sought to understand how a scheme would impact on:

- Capacity for pedestrians
- Protection of pedestrians
- Behaviour at the crossing, to include Deviation and Distance to cross
- Delay incurred
- Legibility for all users, including those with visual impairments

The full list of criteria considered for this theme is shown below, along with a description of the types of factors considered.

Theme Criteria	Description
Deviation	Deviation looked at whether pedestrians were forced to deviate from their desired route
Legibility	How legible the technique would be to pedestrians
Legibility: Sensory Impaired Pedestrians	How legible the technique would be to sensory impaired pedestrians
Safety	Safety looked at to what extent safety is improved for pedestrians
Capacity	Capacity investigated how the technique altered the pedestrian capacity through the junction
Delay	What influence the technique has on pedestrian delay
Distance to Cross	Does the technique require pedestrians to cross a greater distance
Attractiveness	Does the technique have any influence on how attractive the environment is for pedestrians

Vehicles (traffic management)

In total, 8 criteria have been identified for assessment within this theme.

In terms of criteria for assessing the relative performance of signals, the following factors were considered to be critical:

- Capacity
- Delay
- Effect on saturation flow of other traffic
- Dispersion factors
- Context
- Potential for alternative configuration (and operational impact).

Whilst many of these metrics would be traditionally measured through involved analysis of traffic models, this would not have been practicable within the timescale and scope of the current study. Additional criteria were also chosen to reflect the need to reflect legibility, safety and behavioural impacts in the assessment.

The full list of criteria considered for this theme is shown below, along with a description of the types of factors considered.

Theme Criteria	Description
Legibility	How legible the technique would be to other road users
Safety	To what extent the level of safety is changed for other road users
Capacity	How the technique alters the other road user capacity through the junction
Delay: Public Transport	What influence the technique has on public transport delay
Delay: Private Vehicles	What influence the technique has on the delay of private vehicles
Saturation Flow Effect	How the saturation flow of traffic is influenced by each technique
Upstream and downstream factors	How the upstream and downstream flow of traffic is altered by each technique
Behaviour and Compliance	What influence does the technique have on the behaviour of other road users and their compliance to the traffic signals

Cost Implications

In total, 6 criteria have been identified for assessment within this theme:

- Planning and Design Costs
- Land Costs
- Equipment Costs
- Installation Costs
- Costs for Trials
- Ongoing Costs e.g. Maintenance

UK Planning Framework

In total, 4 criteria have been identified for assessment within this theme.

We have considered whether any scheme identified (particularly those identified by international sources) would be compatible with UK regulations and highway engineering practices.

The following criteria have been developed:

- Compatibility with TSRGD
- Compatibility with DMRB
- The provision of UK guidance on the technique
- The coverage of the Highway Code relevant to the technique

The main legislation is the Traffic Signs Regulations and General Directions (TSRGD). The Design Manual for Roads and Bridges (DMRB) provide official standards, advice notes and other documents for trunk roads and motorways. It is recognised that the DMRB is primarily designed to providestandards and specifications for trunk roads, which are unlikely to carry a high proportion of cyclist traffic. However, it has been included in this theme as it is understood that where specific local guidance does not exist then local authorities will use the DMRB for guidance.

Other Considerations

In total, 8 criteria have been identified for assessment within this theme.

These factors do not fall into the above categories, but nevertheless require consideration.

The following criteria have been developed:

- The amount of land required for a particular scheme
- Timescale for installation
- The reliability of equipment used
- Compatibility with existing infrastructure
- Feasibility for trial
- Existing up-take, to distinguish in-use solutions from ideas
- Strength of available evidence
- Impact on streetscape.

The list of criteria considered for this theme is shown below, along with a description of the types of factors considered.

Theme Criteria	Description
Land / Size	Considers the amount of space and any additional land required for each technique
Timescale for Installation	Estimated time for implementation
Reliability of Equipment	Whether the equipment has a proven track record or is it new
Compatibility with existing setup	Whether the new technique work with existing equipment
Feasibility for trial	Whether the technique suitable for trial, taking into account cost and disruption on the highway
In Use	How well adopted is the technique, either in the UK or internationally
Source of Technique	What is the origin of the technique with regard to the literature review and consultation phase
Streetscape (clutter)	Whether each technique adds additional street clutter

6 Assessment Results

6.1 Total Scores

The table on the next page shows all results which have been developed following the assessment phase. Whilst this contains a lot of detail, the value of the coloured scoring system can be seen.

The table below has been replicated from Section 5, showing the link between score received and colour rating.

Score	Effect	RAG Status
-2	Major negative effect	
-1	Minor negative effect	
0	Neutral	
1	Minor positive effect	
2	Major positive effect	

For ease of reading, the large assessment table has been broken down into theme tables which follow, and include the aggregated scores for each technique.

Please note that weightings have not been applied to the developed criteria, to reflect the greater importance of some criteria over others. Care should therefore be taken when considering overall scores of individual techniques as negative scores could potentially override positive scores received, regardless of their relative importance.

	Cyclists															Pedestrians								
Technique	Deviation	Legibility	Safety	Capacity	Delay: waiting time	Delay: chance of stopping	Attractiveness	Comfort	LOS: Existing Flows Low	LOS: Existing Flows Medium	LOS: Existing Flows High	LOS: Predicted Growth	Behaviour and Compliance	Priority over others	**Total Cyclist Score**	Deviation	Legibility	Legibility: Sensory Impaired Pedestrians	Safety	Capacity	Delay	Distance to Cross	Attractiveness	**Total Pedestrian Score**
Intergreens designed for cyclist speed	0	1	1	0	0	0	0	1	2	1	1	2	1	0	**10**	0	0	0	1	0	-1	0	0	**0**
Intergreens extended using detection	0	1	1	0	0	0	1	1	2	1	1	2	1	0	**11**	0	0	0	1	0	-1	0	0	**0**
Separate cycle phases with cyclist signal aspects	0	2	2	0	0	0	2	2	-1	1	2	2	2	1	**15**	0	0	0	1	0	-2	-1	0	**-2**
Incorporation of cycle countdown units into cycle signal aspects (for use where a separate cycle phase is installed)	0	1	1	0	0	0	1	0	1	1	1	1	2	0	**9**	0	0	0	0	0	0	0	0	**0**
All round cycle stages (red to traffic) "bike scramble" with cyclists on street. (for use where a separate cycle phase is installed)	2	1	1	1	-1	0	2	2	2	1	1	1	1	0	**14**	0	0	0	0	0	-1	-1	0	**-2**
All round cycle stages (red to traffic) "bike scramble" with cyclists off street (for use where a separate cycle phase is installed)	1	1	1	1	-1	0	2	2	2	1	1	1	1	0	**13**	0	-1	0	-1	0	-1	-1	0	**-4**
All round cycle and pedestrian stage (red to traffic) "bike scramble" (for use where a separate cycle phase is installed)	1	-1	1	1	-1	0	1	1	2	1	1	1	1	0	**9**	0	-1	-2	-1	0	0	0	-1	**-5**
Pre signal for cyclists for early start (cycle aspect only)	0	1	1	1	0	0	1	1	2	1	1	0	1	1	**11**	0	0	0	0	0	-1	0	0	**-1**
Pre signal for cyclist for early start (separate red amber green signal head)	0	2	1	1	0	0	1	1	2	1	1	0	1	1	**12**	0	0	0	0	0	-1	0	0	**-1**
Advanced cycle stop lines	0	2	2	1	1	0	1	1	2	2	1	1	1	1	**16**	0	0	0	1	0	0	0	0	**1**
Staggered advanced cycle stop lines	0	2	1	0	0	0	0	1	2	0	-1	-1	0	1	**5**	0	0	0	1	0	0	0	0	**1**
Cycle by-pass lane for left turning cyclists (signal controlled)	1	1	2	1	0	0	1	2	2	2	2	2	1	1	**18**	-1	-1	-1	0	0	-1	-1	-1	**-6**
Cycle by-pass lane for left turning cyclists (giveway priority)	1	1	1	1	1	1	1	1	2	2	1	0	-1	-1	**11**	-1	-1	-2	-1	0	-1	-1	-1	**-8**
Cycle by- pass lane for straight ahead movement cyclists at T-junction (onto footway)	-1	1	1	0	2	2	1	2	2	1	-1	-1	2	2	**13**	0	-1	-2	-1	0	0	0	-1	**-5**
Cycle by- pass lane for straight ahead movement cyclists at T-junction (within carriageway)	2	1	1	0	2	2	1	1	2	2	2	2	2	2	**22**	0	-1	-2	-2	0	-1	-2	-1	**-9**
Cycle tunnels	-2	1	1	0	2	2	0	2	0	1	2	2	0	0	**11**	-2	1	1	2	0	2	0	0	**4**
Elephants feet markings through intersection	0	2	1	0	0	0	1	1	2	2	2	2	1	-1	**13**	0	1	0	0	0	0	0	0	**1**
Coloured cycle lanes through intersections (one)	0	2	2	0	0	0	1	1	2	2	2	2	1	-1	**14**	0	1	0	0	0	0	0	0	**1**
Coloured cycle lanes through intersections (two or more)	0	1	1	0	0	0	1	1	2	2	2	2	1	-1	**12**	0	1	0	0	0	0	0	0	**1**
Exemption of cyclists from banned turn traffic orders	1	1	0	1	1	1	2	0	2	1	-1	-1	1	1	**10**	0	0	0	0	0	0	0	0	**0**
Coordination of signals for cyclists progression "green wave"	0	1	1	0	2	2	1	1	2	2	1	1	1	1	**16**	0	0	0	1	0	-1	0	0	**0**
LED indication to communicate the progression speed to cyclists	0	2	0	0	0	0	2	2	2	1	1	1	1	0	**12**	0	0	0	0	0	0	0	0	**0**
Selected vehicle priority for cyclists (similar to bus priority)	0	0	0	1	1	0	1	0	2	0	-1	-1	1	1	**5**	0	0	0	0	0	-1	0	0	**-1**
Two stage right-turn (major / complicated intersections)	-1	-1	1	0	-1	-2	1	1	1	1	0	0	-1	-1	**-2**	0	0	0	0	0	0	0	0	**0**
Two stage right-turn - cyclists banned from right traffic lane	-1	-1	2	0	-1	-2	1	1	1	1	0	0	-1	-1	**-1**	0	0	0	0	0	0	0	0	**0**
Road markings to highlight loop detectors	0	1	1	0	1	1	0	0	2	1	1	0	1	0	**9**	0	0	0	0	0	0	0	0	**0**
Push buttons to demand cycle demand or priority (for separate phase or early green)	-1	0	1	0	1	-2	0	0	2	1	-1	-1	1	0	**1**	0	-1	-1	0	0	0	0	0	**-2**
Inductive loops to demand cycle demand or priority (for separate phase or early green)	0	0	1	1	1	1	0	0	2	2	2	2	1	0	**13**	0	0	0	1	0	0	0	0	**1**
Video detectors to demand cycle demand or priority (for separate phase or early green)	0	0	1	1	1	1	0	0	2	2	2	2	1	0	**13**	0	0	0	1	0	0	0	0	**1**
Dwell on green for bikes (reverse priority) (cycle track or cycle phases only)	0	0	1	2	2	2	2	1	0	1	2	2	1	2	**18**	0	1	0	1	1	2	0	2	**7**
Cyclists allowed to turn left on red at any intersection (UK wide change in law)	0	0	-2	1	1	1	1	-1	2	1	-1	-2	-1	1	**1**	0	-1	-2	-1	0	0	0	-1	**-5**
Cyclists allowed to turn left on red at specific intersection (cycle symbol green / red light during pedestrian phase)	0	2	-2	1	1	1	1	-1	2	1	-1	-2	-1	1	**3**	0	0	0	0	0	0	0	0	**0**
Cyclist allowed to turn left on red at specific intersections where designated lane present (on both arms) (cycle symbol green / red light during pedestrian phase)	0	2	-1	1	1	1	1	0	2	1	1	1	0	1	**11**	0	0	0	0	0	0	0	0	**0**
Straight ahead for cyclists on red (no green) at any 3 arm intersection (on main opposite minor road) (UK wide change in law)	0	0	-2	1	1	1	1	-1	2	1	-1	-2	-1	1	**1**	0	-1	-2	-1	0	0	0	-1	**-5**
Straight ahead for cyclists on red (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersection	0	2	-2	1	1	1	1	-1	2	1	-1	-2	-1	1	**3**	0	0	0	0	0	0	0	0	**0**
Straight ahead for cyclists on red with route through intersection marked (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersections	0	2	-1	1	1	1	1	0	2	1	1	1	0	1	**11**	0	0	0	0	0	0	0	0	**0**
Junction cycle time reduction (90 second maximum)	0	0	0	0	1	-1	0	0	1	1	1	1	1	0	**5**	0	0	0	0	0	1	0	0	**1**
Channelization of left, right and ahead cyclists	0	2	1	0	0	0	0	0	0	1	2	2	0	0	**8**	0	0	0	0	0	0	-1	0	**-1**
Cycle tracks converted to lanes on final approach to intersections	1	1	1	0	0	0	-1	-1	1	1	1	1	1	0	**6**	0	1	1	1	0	0	0	1	**4**
Uncontrolled cycle crossing at junctions	0	0	-2	1	0	0	1	-1	1	0	-2	-2	0	-1	**-5**	0	-1	-2	-1	0	-1	0	-1	**-6**
Speed bumps and plateaus	0	1	1	0	0	0	0	-1	1	1	1	1	0	0	**5**	0	0	0	1	0	0	0	1	**2**
RFID tags on bikes and warning indicator on signals	0	0	1	0	0	0	1	1	2	2	2	2	0	0	**11**	0	0	0	0	0	0	0	0	**0**
Priority for cyclists during inclement weather	0	0	0	0	1	1	1	1	2	2	2	2	1	1	**14**	0	0	0	0	0	-1	0	0	**-1**
Straightening staggered Toucans, and make a single phase	1	2	0	1	1	2	1	1	1	1	2	2	1	0	**16**	1	2	2	0	1	1	1	0	**8**
Pre-timed maximum timer on Toucans	0	0	0	0	2	1	1	1	2	1	1	1	2	1	**13**	0	0	0	0	0	2	0	1	**3**
Trixi mirrors	0	0	1	0	0	0	0	0	2	2	1	1	0	0	**7**	0	0	0	0	0	0	0	0	**0**
Two green periods per cycle for cyclists (to be used with separate cycle phases)	0	0	0	1	1	0	1	0	1	1	2	2	1	0	**10**	0	0	0	0	0	-1	0	0	**-1**
Conversion to continental style roundabout (vehicle flows under 10 - 15,000)	0	2	1	1	0	0	1	1	2	1	1	1	0	-1	**10**	-1	1	-1	-1	-1	0	0	-1	**-4**

	Other Road Users									Cost Implications							Regulation and Legislation					Other										
Technique	Legibility	Safety	Capacity	Delay: Public Transport	Delay: Private Vehicles	Saturation Flow Effect	Upstream and downstream Factors	Behaviour and Compliance	**Total Other Road User Score**	Planning and Design Costs	Land Costs	Equipment Costs	Installation Costs	Costs for Trials	Ongoing Costs e.g. Maintenance	**Total Cost Implication Score**	TSRGD	DMRB	Guidance	Highway Code	**Total Regulation and Legislation Score**	Land / Size	Timescale for Installation	Reliability of Equipment	Compatibility with existing setup	Feasibility for trial	In Use	Source of Technique	Streetscape (clutter)	**Total Other Score**	**Aggregate Total**	
Intergreens designed for cyclist speed	0	1	-1	-1	-1	0	-1	0	**-3**	2	2	2	2	2	2	**12**	2	0	0	2	**4**	2	2	2	2	2	2	2	0	**14**	**37**	1
Intergreens extended using detection	0	1	-1	-1	-1	0	-1	0	**-3**	1	2	1	1	1	1	**7**	2	-1	-1	2	**2**	2	2	1	2	2	2	2	-1	**12**	**29**	2
Separate cycle phases with cyclist signal aspects	1	1	-2	-2	-2	-1	-1	0	**-6**	-1	-1	-1	-1	-1	1	**-4**	2	0	-1	0	**1**	-1	-1	2	2	1	1	0	-2	**2**	**6**	3
Incorporation of cycle countdown units into cycle signal aspects (for use where a separate cycle phase is installed)	1	-1	0	0	0	0	0	-1	**-1**	1	0	1	0	0	1	**3**	-2	-2	-2	-2	**-8**	2	-1	1	1	2	-1	0	0	**4**	**7**	4
All round cycle stages (red to traffic) "bike scramble" with cyclists on street. (for use where a separate cycle phase is installed)	-1	0	-1	-1	-1	1	0	0	**-3**	-2	-1	1	1	-2	1	**-2**	-2	-2	-2	-2	**-8**	-1	1	2	2	-1	-1	0	-1	**1**	**0**	5
All round cycle stages (red to traffic) "bike scramble" with cyclists off street (for use where a separate cycle phase is installed)	1	0	-1	-1	-1	1	0	0	**-1**	-2	-1	-2	-2	-2	1	**-8**	-2	-2	-2	-2	**-8**	-1	1	2	2	-1	-1	0	-2	**0**	**-8**	6
All round cycle and pedestrian stage (red to traffic) "bike scramble" (for use where a separate cycle phase is installed)	-1	1	-1	-1	-1	1	0	0	**-2**	-2	-1	-1	1	-2	1	**-4**	-2	-2	-2	-2	**-8**	-1	1	2	2	-1	-2	0	-1	**0**	**-10**	7
Pre signal for cyclists for early start (cycle aspect only)	-1	0	-1	-1	-1	1	-1	-1	**-5**	-1	2	-1	-1	-1	1	**-1**	-1	-1	-2	-2	**-6**	2	-1	2	2	2	0	0	0	**7**	**5**	8
Pre signal for cyclist for early start (separate red amber green signal head)	0	0	-1	-1	-1	1	-1	0	**-3**	-1	2	-1	-1	-1	1	**-1**	-1	-1	-2	-2	**-6**	2	-1	2	2	2	0	0	-1	**6**	**7**	9
Advanced cycle stop lines	1	1	0	-1	-1	0	-1	-1	**-2**	2	2	2	2	2	1	**11**	2	2	2	2	**8**	2	2	2	2	2	2	2	-1	**13**	**47**	10
Staggered advanced cycle stop lines	1	1	0	0	0	0	-1	1	**2**	2	2	2	2	2	1	**11**	-1	-1	-1	-1	**-4**	2	2	2	2	2	1	2	0	**13**	**28**	11
Cycle by-pass lane for left turning cyclists (signal controlled)	1	1	0	0	0	0	1	0	**3**	-1	-1	-1	-1	-2	-1	**-7**	2	0	0	1	**3**	-1	-1	2	2	2	1	2	-2	**5**	**16**	12
Cycle by-pass lane for left turning cyclists (giveway priority)	1	0	0	0	0	0	0	0	**1**	-1	-1	0	-1	-1	-1	**-5**	2	0	0	1	**3**	-1	-1	2	2	2	2	2	-2	**6**	**8**	13
Cycle by- pass lane for straight ahead movement cyclists at T-junction (onto footway)	1	0	1	1	1	0	-1	0	**3**	1	-1	-1	-1	-1	0	**-3**	0	0	-1	0	**-1**	-1	0	2	2	2	1	2	-2	**6**	**13**	14
Cycle by- pass lane for straight ahead movement cyclists at T-junction (within carriageway)	1	0	1	1	1	1	1	0	**6**	-1	-1	-1	-1	-1	-1	**-6**	0	0	-1	0	**-1**	-1	-1	2	2	2	1	0	-2	**3**	**15**	15
Cycle tunnels	1	1	1	1	1	1	-1	0	**5**	-2	-2	-2	-2	-2	-2	**-12**	0	-1	-1	0	**-2**	-2	-2	1	-1	-2	-1	2	-2	**-7**	**-1**	16
Elephants feet markings through intersection	1	1	0	0	0	0	0	1	**3**	2	2	2	1	2	2	**11**	-2	-2	-1	-2	**-7**	2	2	2	2	2	1	0	-1	**10**	**31**	17
Coloured cycle lanes through intersections (one)	2	1	0	0	0	0	0	1	**4**	2	2	2	1	2	2	**11**	2	2	-2	-1	**1**	2	2	2	2	2	1	0	-1	**10**	**41**	18
Coloured cycle lanes through intersections (two or more)	-1	-2	0	0	0	0	0	0	**-3**	1	2	2	-1	2	-1	**5**	2	2	-2	-1	**1**	2	2	2	2	2	1	0	-2	**9**	**25**	19
Exemption of cyclists from banned turn traffic orders	0	0	0	0	0	0	0	-1	**-1**	-1	2	-1	1	1	1	**3**	2	2	-1	2	**5**	2	-1	2	2	2	2	2	0	**11**	**28**	20
Coordination of signals for cyclists progression "green wave"	1	1	-2	-1	-1	0	0	0	**-2**	-2	2	2	1	-2	2	**3**	2	-2	-2	2	**0**	2	-2	2	2	2	-1	0	0	**5**	**22**	21
LED indication to communicate the progression speed to cyclists	1	1	0	0	0	0	0	1	**3**	1	2	-2	-2	-2	-1	**-4**	2	-2	-2	-1	**-3**	1	-2	-1	-1	-1	-1	0	-1	**-6**	**2**	22
Selected vehicle priority for cyclists (similar to bus priority)	0	0	-1	0	-1	0	0	0	**-2**	-1	2	-1	-1	-1	-1	**-3**	2	-2	-2	0	**-2**	2	-2	-1	2	1	-2	-2	0	**-2**	**-5**	23
Two stage right-turn (major / complicated intersections)	0	0	0	-1	-1	-1	-1	0	**-4**	1	2	2	2	1	2	**10**	-2	-2	-2	-1	**-7**	2	2	2	2	2	1	2	-1	**12**	**9**	24
Two stage right-turn - cyclists banned from right traffic lane	0	0	0	-1	-1	-1	-1	0	**-4**	1	2	2	2	1	1	**9**	-2	-2	-2	-1	**-7**	2	2	2	2	2	0	0	-1	**9**	**6**	25
Road markings to highlight loop detectors	0	0	0	0	0	0	0	0	**0**	2	2	2	2	2	2	**12**	-2	-2	-2	-2	**-8**	2	2	2	2	2	0	0	-1	**9**	**22**	26
Push buttons to demand cycle demand or priority (for separate phase or early green)	0	0	0	0	0	0	0	0	**0**	2	2	1	1	2	2	**10**	-1	-1	-2	-1	**-5**	2	1	2	2	2	1	2	-1	**11**	**15**	27
Inductive loops to demand cycle demand or priority (for separate phase or early green)	0	0	0	0	0	0	0	0	**0**	1	2	1	-1	2	1	**6**	0	0	-1	0	**-1**	2	1	1	2	2	2	2	-1	**11**	**30**	28
Video detectors to demand cycle demand or priority (for separate phase or early green)	0	0	0	0	0	0	0	0	**0**	-1	2	1	1	2	2	**7**	0	0	-1	0	**-1**	2	2	1	2	2	1	2	-1	**11**	**31**	29
Dwell on green for bikes (reverse priority) (cycle track or cycle phases only)	0	1	-1	-1	-1	0	0	-1	**-3**	2	2	1	2	2	2	**11**	0	-1	-1	-1	**-3**	2	2	2	2	2	-1	0	0	**9**	**39**	30
Cyclists allowed to turn left on red at any intersection (UK wide change in law)	0	-1	0	0	0	0	0	-1	**-2**	-2	2	2	2	-2	2	**4**	-1	-2	-2	-2	**-7**	2	-2	2	1	-1	-1	0	0	**1**	**-8**	31
Cyclists allowed to turn left on red at specific intersection (cycle symbol green / red light during pedestrian phase)	0	-1	0	0	0	0	0	-1	**-2**	-2	2	-1	-1	-2	2	**-2**	-2	-2	-2	-2	**-8**	2	-2	2	1	-1	0	0	-1	**1**	**-8**	32
Cyclist allowed to turn left on red at specific intersections where designated lane present (on both arms) (cycle symbol green / red light during pedestrian phase)	0	-1	0	0	0	0	0	-1	**-2**	-2	2	-1	-1	-2	2	**-2**	-2	-2	-2	-2	**-8**	2	-2	2	1	-1	0	0	-1	**1**	**0**	33
Straight ahead for cyclists on red (no green) at any 3 arm intersection (on main opposite minor road) (UK wide change in law)	0	-1	0	0	0	0	0	-1	**-2**	-2	2	2	2	-2	2	**4**	-1	-2	-2	-2	**-7**	2	-2	2	1	-1	-1	0	0	**1**	**-8**	34
Straight ahead for cyclists on red (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersection	0	-1	0	0	0	0	0	-1	**-2**	-2	2	-1	-1	-2	2	**-2**	-2	-2	-2	-2	**-8**	2	-2	2	1	-1	-1	0	-1	**0**	**-9**	35
Straight ahead for cyclists on red with route through intersection marked (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersections	0	-1	0	0	0	0	0	-1	**-2**	-2	2	-1	-1	-2	2	**-2**	-2	-2	-2	-2	**-8**	2	-2	2	1	-1	-1	0	-1	**0**	**-1**	36
Junction cycle time reduction (90 second maximum)	0	0	-1	-1	-1	0	-1	0	**-4**	-1	2	2	2	2	2	**9**	2	2	-1	2	**5**	2	2	2	2	2	2	2	0	**14**	**30**	37
Channelization of left, right and ahead cyclists	-1	-1	-1	-1	-1	-1	-1	0	**-7**	-1	-1	2	-2	-1	2	**-1**	2	-1	-1	-1	**-1**	-1	-1	2	2	1	1	2	-1	**5**	**3**	38
Cycle tracks converted to lanes on final approach to intersections	1	1	-1	-1	-1	-1	-1	0	**-3**	-1	2	-1	-2	-2	1	**-3**	2	-1	-1	-1	**-1**	2	-1	2	2	1	1	0	-1	**6**	**9**	39
Uncontrolled cycle crossing at junctions	0	-1	1	1	1	1	-1	0	**2**	-1	2	-1	-1	-1	1	**-1**	2	-1	-1	-1	**-1**	2	-1	2	2	2	0	-2	-1	**4**	**-7**	40
Speed bumps and plateaus	1	1	0	0	0	-1	0	0	**1**	-1	2	-2	-2	-2	1	**-4**	2	1	-1	-1	**1**	2	-2	2	1	-1	1	0	-2	**1**	**6**	41
RFID tags on bikes and warning indicator on signals	1	1	0	0	0	0	0	1	**3**	-1	0	-2	-1	-1	-1	**-6**	-2	-2	-2	-2	**-8**	2	1	0	1	1	-1		-1	**3**	**3**	42
Priority for cyclists during inclement weather	0	0	0	-1	-1	0	0	0	**-2**	-1	2	-2	-1	-2	-2	**-6**	2	-1	-1	2	**2**	2	1	0	1	1	-1	0	-1	**3**	**10**	43
Straightening staggered Toucans, and make a single phase	0	0	-1	-1	-1	0	0	0	**-3**	1	2	2	1	-2	2	**6**	2	-1	-1	0	**0**	2	1	2	2	1	2	2	1	**13**	**40**	44
Pre-timed maximum timer on Toucans	0	0	-1	-1	-1	0	0	-1	**-4**	2	2	2	2	2	2	**12**	2	-1	-1	0	**0**	2	2	2	2	2	2	-2	0	**10**	**34**	45
Trixi mirrors	1	1	0	0	0	0	0	0	**2**	2	2	2	2	2	1	**11**	0	-2	-2	-2	**-6**	2	2	1	2	2	1	0	-1	**9**	**23**	46
Two green periods per cycle for cyclists (to be used with separate cycle phases)	0	0	-1	-1	-1	0	0	-1	**-4**	-1	2	2	2	2	2	**9**	0	0	-1	0	**-1**	2	2	2	2	2	0	0	0	**10**	**23**	47
Conversion to continental style roundabout (vehicle flows under 10 - 15,000)	1	1	1	0	0	0	0	0	**3**	-2	-2	-1	-2	-2	1	**-8**	2	0	-1	-1	**0**	-2	-2	2	0	-1	1	0	2	**0**	**1**	48

For ease of reading, this large table has been broken down into theme tables which follow, and include the aggregated scores for each technique.

6.2 Theme Tables

The theme tables form the following sections:

- Section 6.3: Cyclists
- Section 6.4: Pedestrians
- Section 6.5: Vehicles
- Section 6.6: Cost Implications
- Section 6.7: Regulation and Legislation
- Section 6.8: Other

In Section 6.9 the advantages and disadvantages of each of the techniques are outlined.

6.3 Theme Table: Cyclists

	Technique	Deviation	Legibility	Safety	Capacity	Delay: waiting time	Delay: chance of stopping	Attractiveness	Comfort	LOS: Existing Flows Low	LOS: Existing Flows Medium	LOS: Existing Flows High	LOS: Predicted Growth	Behaviour and Compliance	Priority over others	Total Cyclist Score
		Cyclists														
1	Intergreens designed for cyclist speed	0	1	1	0	0	0	0	1	2	1	1	2	1	0	10
2	Intergreens extended using detection	0	1	1	0	0	0	1	1	2	1	1	2	1	0	11
3	Separate cycle phases with cyclist signal aspects	0	2	2	0	0	0	2	2	-1	1	2	2	2	1	15
4	Incorporation of cycle countdown units into cycle signal aspects (for use where a separate cycle phase is installed)	0	1	1	0	0	0	1	0	1	1	1	1	2	0	9
5	All round cycle stages (red to traffic) "bike scramble" with cyclists on street. (for use where a separate cycle phase is installed)	2	1	1	1	-1	0	2	2	2	1	1	1	1	0	14
6	All round cycle stages (red to traffic) "bike scramble" with cyclists off street (for use where a separate cycle phase is installed)	1	1	1	1	-1	0	2	2	2	1	1	1	1	0	13
7	All round cycle and pedestrian stage (red to traffic) "bike scramble" (for use where a separate cycle phase is installed)	1	-1	1	1	-1	0	1	1	2	1	1	1	1	0	9
8	Pre signal for cyclists for early start (cycle aspect only)	0	1	1	1	0	0	1	1	2	1	1	0	1	1	11
9	Pre signal for cyclist for early start (separate red amber green signal head)	0	2	1	1	0	0	1	1	2	1	1	0	1	1	12
10	Advanced cycle stop lines	0	2	2	1	1	0	1	1	2	2	1	1	1	1	16
11	Staggered advanced cycle stop lines	0	2	1	0	0	0	0	1	2	0	-1	-1	0	1	5
12	Cycle by-pass lane for left turning cyclists (signal controlled)	1	1	2	1	0	0	1	2	2	2	2	2	1	1	18
13	Cycle by-pass lane for left turning cyclists (giveway priority)	1	1	1	1	1	1	1	1	2	2	1	0	-1	-1	11
14	Cycle by- pass lane for straight ahead movement cyclists at T-junction (onto footway)	-1	1	1	0	2	2	1	2	2	1	-1	-1	2	2	13
15	Cycle by- pass lane for straight ahead movement cyclists at T-junction (within carriageway)	2	1	1	0	2	2	1	1	2	2	2	2	2	2	22
16	Cycle tunnels	-2	1	1	0	2	2	0	2	0	1	2	2	0	0	11
17	Elephants feet markings through intersection	0	2	1	0	0	0	1	1	2	2	2	2	1	-1	13
18	Coloured cycle lanes through intersections (one)	0	2	2	0	0	0	1	1	2	2	2	2	1	-1	14
19	Coloured cycle lanes through intersections (two or more)	0	1	1	0	0	0	1	1	2	2	2	2	1	-1	12
20	Exemption of cyclists from banned turn traffic orders	1	1	0	1	1	1	2	0	2	1	-1	-1	1	1	10
21	Coordination of signals for cyclists progression "green wave"	0	1	1	0	2	2	1	1	2	2	1	1	1	1	16
22	LED indication to communicate the progression speed to cyclists	0	2	0	0	0	0	2	2	2	1	1	1	1	0	12
23	Selected vehicle priority for cyclists (similar to bus priority)	0	0	0	1	1	0	1	0	2	0	-1	-1	1	1	5
24	Two stage right-turn (major / complicated intersections)	-1	-1	1	0	-1	-2	1	1	1	1	0	0	-1	-1	-2
25	Two stage right-turn - cyclists banned from right traffic lane	-1	-1	2	0	-1	-2	1	1	1	1	0	0	-1	-1	-1
26	Road markings to highlight loop detectors	0	1	1	0	1	1	0	0	2	1	1	0	1	0	9
27	Push buttons to demand cycle demand or priority (for separate phase or early green)	-1	0	1	0	1	-2	0	0	2	1	-1	-1	1	0	1
28	Inductive loops to demand cycle demand or priority (for separate phase or early green)	0	0	1	1	1	1	0	0	2	2	2	2	1	0	13
29	Video detectors to demand cycle demand or priority (for separate phase or early green)	0	0	1	1	1	1	0	0	2	2	2	2	1	0	13
30	Dwell on green for bikes (reverse priority) (cycle track or cycle phases only)	0	0	1	2	2	2	2	1	0	1	2	2	1	2	18
31	Cyclists allowed to turn left on red at any intersection (UK wide change in law)	0	0	-2	1	1	1	1	-1	2	1	-1	-2	-1	1	1
32	Cyclists allowed to turn left on red at specific intersection (cycle symbol green / red light during pedestrian phase)	0	2	-2	1	1	1	1	-1	2	1	-1	-2	-1	1	3
33	Cyclist allowed to turn left on red at specific intersections where designated lane present (on both arms) (cycle symbol green / red light during pedestrian phase)	0	2	-1	1	1	1	1	0	2	1	1	1	0	1	11
34	Straight ahead for cyclists on red (no green) at any 3 arm intersection (on main opposite minor road) (UK wide change in law)	0	0	-2	1	1	1	1	-1	2	1	-1	-2	-1	1	1
35	Straight ahead for cyclists on red (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersection	0	2	-2	1	1	1	1	-1	2	1	-1	-2	-1	1	3
36	Straight ahead for cyclists on red with route through intersection marked (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersections	0	2	-1	1	1	1	1	0	2	1	1	1	0	1	11
37	Junction cycle time reduction (90 second maximum)	0	0	0	0	1	-1	0	0	1	1	1	1	1	0	5
38	Channelization of left, right and ahead cyclists	0	2	1	0	0	0	0	0	0	1	2	2	0	0	8
39	Cycle tracks converted to lanes on final approach to intersections	1	1	1	0	0	0	-1	-1	1	1	1	1	1	0	6
40	Uncontrolled cycle crossing at junctions	0	0	-2	1	0	0	1	-1	1	0	-2	-2	0	-1	-5
41	Speed bumps and plateaus	0	1	1	0	0	0	0	-1	1	1	1	1	0	0	5
42	RFID tags on bikes and warning indicator on signals	0	0	1	0	0	0	1	1	2	2	2	2	0	0	11
43	Priority for cyclists during inclement weather	0	0	0	0	1	1	1	1	2	2	2	2	1	1	14
44	Straightening staggered Toucans, and make a single phase	1	2	0	1	1	2	1	1	1	1	2	2	1	0	16
45	Pre-timed maximum timer on Toucans	0	0	0	0	2	1	1	1	2	1	1	1	2	1	13
46	Trixi mirrors	0	0	1	0	0	0	0	0	2	2	1	1	0	0	7
47	Two green periods per cycle for cyclists (to be used with separate cycle phases)	0	0	0	1	1	0	1	0	1	1	2	2	1	0	10
48	Conversion to continental style roundabout (vehicle flows under 10 - 15,000)	0	2	1	1	0	0	1	1	2	1	1	1	0	-1	10

6.4 Theme Table: Pedestrians

	Technique	Pedestrians								
		Deviation	Legibility	Legibility: Sensory Impaired Pedestrians	Safety	Capacity	Delay	Distance to Cross	Attractiveness	**Total Pedestrian Score**
1	Intergreens designed for cyclist speed	0	0	0	1	0	-1	0	0	**0**
2	Intergreens extended using detection	0	0	0	1	0	-1	0	0	**0**
3	Separate cycle phases with cyclist signal aspects	0	0	0	1	0	-2	-1	0	**-2**
4	Incorporation of cycle countdown units into cycle signal aspects (for use where a separate cycle phase is installed)	0	0	0	0	0	0	0	0	**0**
5	All round cycle stages (red to traffic) "bike scramble" with cyclists on street. (for use where a separate cycle phase is installed)	0	0	0	0	0	-1	-1	0	**-2**
6	All round cycle stages (red to traffic) "bike scramble" with cyclists off street (for use where a separate cycle phase is installed)	0	-1	0	-1	0	-1	-1	0	**-4**
7	All round cycle and pedestrian stage (red to traffic) "bike scramble" (for use where a separate cycle phase is installed)	0	-1	-2	-1	0	0	0	-1	**-5**
8	Pre signal for cyclists for early start (cycle aspect only)	0	0	0	0	0	-1	0	0	**-1**
9	Pre signal for cyclist for early start (separate red amber green signal head)	0	0	0	0	0	-1	0	0	**-1**
10	Advanced cycle stop lines	0	0	0	1	0	0	0	0	**1**
11	Staggered advanced cycle stop lines	0	0	0	1	0	0	0	0	**1**
12	Cycle by-pass lane for left turning cyclists (signal controlled)	-1	-1	-1	0	0	-1	-1	-1	**-6**
13	Cycle by-pass lane for left turning cyclists (giveway priority)	-1	-1	-2	-1	0	-1	-1	-1	**-8**
14	Cycle by- pass lane for straight ahead movement cyclists at T-junction (onto footway)	0	-1	-2	-1	0	0	0	-1	**-5**
15	Cycle by- pass lane for straight ahead movement cyclists at T-junction (within carriageway)	0	-1	-2	-2	0	-1	-2	-1	**-9**
16	Cycle tunnels	-2	1	1	2	0	2	0	0	**4**
17	Elephants feet markings through intersection	0	1	0	0	0	0	0	0	**1**
18	Coloured cycle lanes through intersections (one)	0	1	0	0	0	0	0	0	**1**
19	Coloured cycle lanes through intersections (two or more)	0	1	0	0	0	0	0	0	**1**
20	Exemption of cyclists from banned turn traffic orders	0	0	0	0	0	0	0	0	**0**
21	Coordination of signals for cyclists progression "green wave"	0	0	0	1	0	-1	0	0	**0**
22	LED indication to communicate the progression speed to cyclists	0	0	0	0	0	0	0	0	**0**
23	Selected vehicle priority for cyclists (similar to bus priority)	0	0	0	0	0	-1	0	0	**-1**
24	Two stage right-turn (major / complicated intersections)	0	0	0	0	0	0	0	0	**0**
25	Two stage right-turn - cyclists banned from right traffic lane	0	0	0	0	0	0	0	0	**0**
26	Road markings to highlight loop detectors	0	0	0	0	0	0	0	0	**0**
27	Push buttons to demand cycle demand or priority (for separate phase or early green)	0	-1	-1	0	0	0	0	0	**-2**
28	Inductive loops to demand cycle demand or priority (for separate phase or early green)	0	0	0	1	0	0	0	0	**1**
29	Video detectors to demand cycle demand or priority (for separate phase or early green)	0	0	0	1	0	0	0	0	**1**
30	Dwell on green for bikes (reverse priority) (cycle track or cycle phases only)	0	1	0	1	1	2	0	2	**7**
31	Cyclists allowed to turn left on red at any intersection (UK wide change in law)	0	-1	-2	-1	0	0	0	-1	**-5**
32	Cyclists allowed to turn left on red at specific intersection (cycle symbol green / red light during pedestrian phase)	0	0	0	0	0	0	0	0	**0**
33	Cyclist allowed to turn left on red at specific intersections where designated lane present (on both arms) (cycle symbol green / red light during pedestrian phase)	0	0	0	0	0	0	0	0	**0**
34	Straight ahead for cyclists on red (no green) at any 3 arm intersection (on main opposite minor road) (UK wide change in law)	0	-1	-2	-1	0	0	0	-1	**-5**
35	Straight ahead for cyclists on red (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersection	0	0	0	0	0	0	0	0	**0**
36	Straight ahead for cyclists on red with route through intersection marked (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersections	0	0	0	0	0	0	0	0	**0**
37	Junction cycle time reduction (90 second maximum)	0	0	0	0	0	1	0	0	**1**
38	Channelization of left, right and ahead cyclists	0	0	0	0	0	0	-1	0	**-1**
39	Cycle tracks converted to lanes on final approach to intersections	0	1	1	1	0	0	0	1	**4**
40	Uncontrolled cycle crossing at junctions	0	-1	-2	-1	0	-1	0	-1	**-6**
41	Speed bumps and plateaus	0	0	0	1	0	0	0	1	**2**
42	RFID tags on bikes and warning indicator on signals	0	0	0	0	0	0	0	0	**0**
43	Priority for cyclists during inclement weather	0	0	0	0	0	-1	0	0	**-1**
44	Straightening staggered Toucans, and make a single phase	1	2	2	0	1	1	1	0	**8**
45	Pre-timed maximum timer on Toucans	0	0	0	0	0	2	0	1	**3**
46	Trixi mirrors	0	0	0	0	0	0	0	0	**0**
47	Two green periods per cycle for cyclists (to be used with separate cycle phases)	0	0	0	0	0	-1	0	0	**-1**
48	Conversion to continental style roundabout (vehicle flows under 10 - 15,000)	-1	1	-1	-1	-1	0	0	-1	**-4**

6.5 Theme Table: Vehicles (traffic management)

	Technique	Other Road Users: Legibility	Safety	Capacity	Delay: Public Transport	Delay: Private Vehicles	Saturation Flow Effect	Upstream and downstream Factors	Behaviour and Compliance	Total Other Road User Score
1	Intergreens designed for cyclist speed	0	1	-1	-1	-1	0	-1	0	-3
2	Intergreens extended using detection	0	1	-1	-1	-1	0	-1	0	-3
3	Separate cycle phases with cyclist signal aspects	1	1	-2	-2	-2	-1	-1	0	-6
4	Incorporation of cycle countdown units into cycle signal aspects (for use where a separate cycle phase is installed)	1	-1	0	0	0	0	0	-1	-1
5	All round cycle stages (red to traffic) "bike scramble" with cyclists on street. (for use where a separate cycle phase is installed)	-1	0	-1	-1	-1	1	0	0	-3
6	All round cycle stages (red to traffic) "bike scramble" with cyclists off street (for use where a separate cycle phase is installed)	1	0	-1	-1	-1	1	0	0	-1
7	All round cycle and pedestrian stage (red to traffic) "bike scramble" (for use where a separate cycle phase is installed)	-1	1	-1	-1	-1	1	0	0	-2
8	Pre signal for cyclists for early start (cycle aspect only)	-1	0	-1	-1	-1	1	-1	-1	-5
9	Pre signal for cyclist for early start (separate red amber green signal head)	0	0	-1	-1	-1	1	-1	0	-3
10	Advanced cycle stop lines	1	1	0	-1	-1	0	-1	-1	-2
11	Staggered advanced cycle stop lines	1	1	0	0	0	0	-1	1	2
12	Cycle by-pass lane for left turning cyclists (signal controlled)	1	1	0	0	0	0	1	0	3
13	Cycle by-pass lane for left turning cyclists (giveway priority)	1	0	0	0	0	0	0	0	1
14	Cycle by- pass lane for straight ahead movement cyclists at T-junction (onto footway)	1	0	1	1	1	0	-1	0	3
15	Cycle by- pass lane for straight ahead movement cyclists at T-junction (within carriageway)	1	0	1	1	1	1	1	0	6
16	Cycle tunnels	1	1	1	1	1	1	-1	0	5
17	Elephants feet markings through intersection	1	1	0	0	0	0	0	1	3
18	Coloured cycle lanes through intersections (one)	2	1	0	0	0	0	0	1	4
19	Coloured cycle lanes through intersections (two or more)	-1	-2	0	0	0	0	0	0	-3
20	Exemption of cyclists from banned turn traffic orders	0	0	0	0	0	0	0	-1	-1
21	Coordination of signals for cyclists progression "green wave"	1	1	-2	-1	-1	0	0	0	-2
22	LED indication to communicate the progression speed to cyclists	1	1	0	0	0	0	0	1	3
23	Selected vehicle priority for cyclists (similar to bus priority)	0	0	-1	0	-1	0	0	0	-2
24	Two stage right-turn (major / complicated intersections)	0	0	0	-1	-1	-1	-1	0	-4
25	Two stage right-turn - cyclists banned from right traffic lane	0	0	0	-1	-1	-1	-1	0	-4
26	Road markings to highlight loop detectors	0	0	0	0	0	0	0	0	0
27	Push buttons to demand cycle demand or priority (for separate phase or early green)	0	0	0	0	0	0	0	0	0
28	Inductive loops to demand cycle demand or priority (for separate phase or early green)	0	0	0	0	0	0	0	0	0
29	Video detectors to demand cycle demand or priority (for separate phase or early green)	0	0	0	0	0	0	0	0	0
30	Dwell on green for bikes (reverse priority) (cycle track or cycle phases only)	0	1	-1	-1	-1	0	0	-1	-3
31	Cyclists allowed to turn left on red at any intersection (UK wide change in law)	0	-1	0	0	0	0	0	-1	-2
32	Cyclists allowed to turn left on red at specific intersection (cycle symbol green / red light during pedestrian phase)	0	-1	0	0	0	0	0	-1	-2
33	Cyclist allowed to turn left on red at specific intersections where designated lane present (on both arms) (cycle symbol green / red light during pedestrian phase)	0	-1	0	0	0	0	0	-1	-2
34	Straight ahead for cyclists on red (no green) at any 3 arm intersection (on main opposite minor road) (UK wide change in law)	0	-1	0	0	0	0	0	-1	-2
35	Straight ahead for cyclists on red (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersection	0	-1	0	0	0	0	0	-1	-2
36	Straight ahead for cyclists on red with route through intersection marked (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersections	0	-1	0	0	0	0	0	-1	-2
37	Junction cycle time reduction (90 second maximum)	0	0	-1	-1	-1	0	-1	0	-4
38	Channelization of left, right and ahead cyclists	-1	-1	-1	-1	-1	-1	-1	0	-7
39	Cycle tracks converted to lanes on final approach to intersections	1	1	-1	-1	-1	-1	-1	0	-3
40	Uncontrolled cycle crossing at junctions	0	-1	1	1	1	1	-1	0	2
41	Speed bumps and plateaus	1	1	0	0	0	-1	0	0	1
42	RFID tags on bikes and warning indicator on signals	1	1	0	0	0	0	0	1	3
43	Priority for cyclists during inclement weather	0	0	0	-1	-1	0	0	0	-2
44	Straightening staggered Toucans, and make a single phase	0	0	-1	-1	-1	0	0	0	-3
45	Pre-timed maximum timer on Toucans	0	0	-1	-1	-1	0	0	-1	-4
46	Trixi mirrors	1	1	0	0	0	0	0	0	2
47	Two green periods per cycle for cyclists (to be used with separate cycle phases)	0	0	-1	-1	-1	0	0	-1	-4
48	Conversion to continental style roundabout (vehicle flows under 10 - 15,000)	1	1	1	0	0	0	0	0	3

6.6 Theme Table: Cost Implications

	Technique	Cost Implications: Planning and Design Costs	Land Costs	Equipment Costs	Installation Costs	Costs for Trials	Ongoing Costs e.g. Maintenance	Total Cost Implication Score
1	Intergreens designed for cyclist speed	2	2	2	2	2	2	**12**
2	Intergreens extended using detection	1	2	1	1	1	1	**7**
3	Separate cycle phases with cyclist signal aspects	-1	-1	-1	-1	-1	1	**-4**
4	Incorporation of cycle countdown units into cycle signal aspects (for use where a separate cycle phase is installed)	1	0	1	0	0	1	**3**
5	All round cycle stages (red to traffic) "bike scramble" with cyclists on street. (for use where a separate cycle phase is installed)	-2	-1	1	1	-2	1	**-2**
6	All round cycle stages (red to traffic) "bike scramble" with cyclists off street (for use where a separate cycle phase is installed)	-2	-1	-2	-2	-2	1	**-8**
7	All round cycle and pedestrian stage (red to traffic) "bike scramble" (for use where a separate cycle phase is installed)	-2	-1	-1	1	-2	1	**-4**
8	Pre signal for cyclists for early start (cycle aspect only)	-1	2	-1	-1	-1	1	**-1**
9	Pre signal for cyclist for early start (separate red amber green signal head)	-1	2	-1	-1	-1	1	**-1**
10	Advanced cycle stop lines	2	2	2	2	2	1	**11**
11	Staggered advanced cycle stop lines	2	2	2	2	2	1	**11**
12	Cycle by-pass lane for left turning cyclists (signal controlled)	-1	-1	-1	-1	-2	-1	**-7**
13	Cycle by-pass lane for left turning cyclists (giveway priority)	-1	-1	0	-1	-1	-1	**-5**
14	Cycle by- pass lane for straight ahead movement cyclists at T-junction (onto footway)	1	-1	-1	-1	-1	0	**-3**
15	Cycle by- pass lane for straight ahead movement cyclists at T-junction (within carriageway)	-1	-1	-1	-1	-1	-1	**-6**
16	Cycle tunnels	-2	-2	-2	-2	-2	-2	**-12**
17	Elephants feet markings through intersection	2	2	2	1	2	2	**11**
18	Coloured cycle lanes through intersections (one)	2	2	2	1	2	2	**11**
19	Coloured cycle lanes through intersections (two or more)	1	2	2	-1	2	-1	**5**
20	Exemption of cyclists from banned turn traffic orders	-1	2	-1	1	1	1	**3**
21	Coordination of signals for cyclists progression "green wave"	-2	2	2	1	-2	2	**3**
22	LED indication to communicate the progression speed to cyclists	1	2	-2	-2	-2	-1	**-4**
23	Selected vehicle priority for cyclists (similar to bus priority)	-1	2	-1	-1	-1	-1	**-3**
24	Two stage right-turn (major / complicated intersections)	1	2	2	2	1	2	**10**
25	Two stage right-turn - cyclists banned from right traffic lane	1	2	2	2	1	1	**9**
26	Road markings to highlight loop detectors	2	2	2	2	2	2	**12**
27	Push buttons to demand cycle demand or priority (for separate phase or early green)	2	2	1	1	2	2	**10**
28	Inductive loops to demand cycle demand or priority (for separate phase or early green)	1	2	1	-1	2	1	**6**
29	Video detectors to demand cycle demand or priority (for separate phase or early green)	-1	2	1	1	2	2	**7**
30	Dwell on green for bikes (reverse priority) (cycle track or cycle phases only)	2	2	1	2	2	2	**11**
31	Cyclists allowed to turn left on red at any intersection (UK wide change in law)	-2	2	2	2	-2	2	**4**
32	Cyclists allowed to turn left on red at specific intersection (cycle symbol green / red light during pedestrian phase)	-2	2	-1	-1	-2	2	**-2**
33	Cyclist allowed to turn left on red at specific intersections where designated lane present (on both arms) (cycle symbol green / red light during pedestrian phase)	-2	2	-1	-1	-2	2	**-2**
34	Straight ahead for cyclists on red (no green) at any 3 arm intersection (on main opposite minor road) (UK wide change in law)	-2	2	2	2	-2	2	**4**
35	Straight ahead for cyclists on red (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersection	-2	2	-1	-1	-2	2	**-2**
36	Straight ahead for cyclists on red with route through intersection marked (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersections	-2	2	-1	-1	-2	2	**-2**
37	Junction cycle time reduction (90 second maximum)	-1	2	2	2	2	2	**9**
38	Channelization of left, right and ahead cyclists	-1	-1	2	-2	-1	2	**-1**
39	Cycle tracks converted to lanes on final approach to intersections	-1	2	-1	-2	-2	1	**-3**
40	Uncontrolled cycle crossing at junctions	-1	2	-1	-1	-1	1	**-1**
41	Speed bumps and plateaus	-1	2	-2	-2	-2	1	**-4**
42	RFID tags on bikes and warning indicator on signals	-1	0	-2	-1	-1	-1	**-6**
43	Priority for cyclists during inclement weather	-1	2	-2	-1	-2	-2	**-6**
44	Straightening staggered Toucans, and make a single phase	1	2	2	1	-2	2	**6**
45	Pre-timed maximum timer on Toucans	2	2	2	2	2	2	**12**
46	Trixi mirrors	2	2	2	2	2	1	**11**
47	Two green periods per cycle for cyclists (to be used with separate cycle phases)	-1	2	2	2	2	2	**9**
48	Conversion to continental style roundabout (vehicle flows under 10 - 15,000)	-2	-2	-1	-2	-2	1	**-8**

6.7 Theme Table: Regulation and Legislation

	Technique	Regulation and Legislation: TSRGD	DMRB	Guidance	Highway Code	Total Regulation and Legislation Score
1	Intergreens designed for cyclist speed	2	0	0	2	4
2	Intergreens extended using detection	2	-1	-1	2	2
3	Separate cycle phases with cyclist signal aspects	2	0	-1	0	1
4	Incorporation of cycle countdown units into cycle signal aspects (for use where a separate cycle phase is installed)	-2	-2	-2	-2	-8
5	All round cycle stages (red to traffic) "bike scramble" with cyclists on street. (for use where a separate cycle phase is installed)	-2	-2	-2	-2	-8
6	All round cycle stages (red to traffic) "bike scramble" with cyclists off street (for use where a separate cycle phase is installed)	-2	-2	-2	-2	-8
7	All round cycle and pedestrian stage (red to traffic) "bike scramble" (for use where a separate cycle phase is installed)	-2	-2	-2	-2	-8
8	Pre signal for cyclists for early start (cycle aspect only)	-1	-1	-2	-2	-6
9	Pre signal for cyclist for early start (separate red amber green signal head)	-1	-1	-2	-2	-6
10	Advanced cycle stop lines	2	2	2	2	8
11	Staggered advanced cycle stop lines	-1	-1	-1	-1	-4
12	Cycle by-pass lane for left turning cyclists (signal controlled)	2	0	0	1	3
13	Cycle by-pass lane for left turning cyclists (giveway priority)	2	0	0	1	3
14	Cycle by- pass lane for straight ahead movement cyclists at T-junction (onto footway)	0	0	-1	0	-1
15	Cycle by- pass lane for straight ahead movement cyclists at T-junction (within carriageway)	0	0	-1	0	-1
16	Cycle tunnels	0	-1	-1	0	-2
17	Elephants feet markings through intersection	-2	-2	-1	-2	-7
18	Coloured cycle lanes through intersections (one)	2	2	-2	-1	1
19	Coloured cycle lanes through intersections (two or more)	2	2	-2	-1	1
20	Exemption of cyclists from banned turn traffic orders	2	2	-1	2	5
21	Coordination of signals for cyclists progression "green wave"	2	-2	-2	2	0
22	LED indication to communicate the progression speed to cyclists	2	-2	-2	-1	-3
23	Selected vehicle priority for cyclists (similar to bus priority)	2	-2	-2	0	-2
24	Two stage right-turn (major / complicated intersections)	-2	-2	-2	-1	-7
25	Two stage right-turn - cyclists banned from right traffic lane	-2	-2	-2	-1	-7
26	Road markings to highlight loop detectors	-2	-2	-2	-2	-8
27	Push buttons to demand cycle demand or priority (for separate phase or early green)	-1	-1	-2	-1	-5
28	Inductive loops to demand cycle demand or priority (for separate phase or early green)	0	0	-1	0	-1
29	Video detectors to demand cycle demand or priority (for separate phase or early green)	0	0	-1	0	-1
30	Dwell on green for bikes (reverse priority) (cycle track or cycle phases only)	0	-1	-1	-1	-3
31	Cyclists allowed to turn left on red at any intersection (UK wide change in law)	-1	-2	-2	-2	-7
32	Cyclists allowed to turn left on red at specific intersection (cycle symbol green / red light during pedestrian phase)	-2	-2	-2	-2	-8
33	Cyclist allowed to turn left on red at specific intersections where designated lane present (on both arms) (cycle symbol green / red light during pedestrian phase)	-2	-2	-2	-2	-8
34	Straight ahead for cyclists on red (no green) at any 3 arm intersection (on main opposite minor road) (UK wide change in law)	-1	-2	-2	-2	-7
35	Straight ahead for cyclists on red (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersection	-2	-2	-2	-2	-8
36	Straight ahead for cyclists on red with route through intersection marked (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersections	-2	-2	-2	-2	-8
37	Junction cycle time reduction (90 second maximum)	2	2	-1	2	5
38	Channelization of left, right and ahead cyclists	2	-1	-1	-1	-1
39	Cycle tracks converted to lanes on final approach to intersections	2	-1	-1	-1	-1
40	Uncontrolled cycle crossing at junctions	2	-1	-1	-1	-1
41	Speed bumps and plateaus	2	1	-1	-1	1
42	RFID tags on bikes and warning indicator on signals	-2	-2	-2	-2	-8
43	Priority for cyclists during inclement weather	2	-1	-1	2	2
44	Straightening staggered Toucans, and make a single phase	2	-1	-1	0	0
45	Pre-timed maximum timer on Toucans	2	-1	-1	0	0
46	Trixi mirrors	0	-2	-2	-2	-6
47	Two green periods per cycle for cyclists (to be used with separate cycle phases)	0	0	-1	0	-1
48	Conversion to continental style roundabout (vehicle flows under 10 - 15,000)	2	0	-1	-1	0

6.8 Theme Table: Other

	Technique	Land / Size	Timescale for Installation	Reliability of Equipment	Compatibility with existing setup	Feasibility for trial	In Use	Source of Technique	Streetscape (clutter)	Total Other Score
1	Intergreens designed for cyclist speed	2	2	2	2	2	2	2	0	14
2	Intergreens extended using detection	2	2	1	2	2	2	2	-1	12
3	Separate cycle phases with cyclist signal aspects	-1	-1	2	2	1	1	0	-2	2
4	Incorporation of cycle countdown units into cycle signal aspects (for use where a separate cycle phase is installed)	2	-1	1	1	2	-1	0	0	4
5	All round cycle stages (red to traffic) "bike scramble" with cyclists on street. (for use where a separate cycle phase is installed)	-1	1	2	2	-1	-1	0	-1	1
6	All round cycle stages (red to traffic) "bike scramble" with cyclists off street (for use where a separate cycle phase is installed)	-1	1	2	2	-1	-1	0	-2	0
7	All round cycle and pedestrian stage (red to traffic) "bike scramble" (for use where a separate cycle phase is installed)	-1	1	2	2	-1	-2	0	-1	0
8	Pre signal for cyclists for early start (cycle aspect only)	2	-1	2	2	2	0	0	0	7
9	Pre signal for cyclist for early start (separate red amber green signal head)	2	-1	2	2	2	0	0	-1	6
10	Advanced cycle stop lines	2	2	2	2	2	2	2	-1	13
11	Staggered advanced cycle stop lines	2	2	2	2	2	1	2	0	13
12	Cycle by-pass lane for left turning cyclists (signal controlled)	-1	-1	2	2	2	1	2	-2	5
13	Cycle by-pass lane for left turning cyclists (giveway priority)	-1	-1	2	2	2	2	2	-2	6
14	Cycle by- pass lane for straight ahead movement cyclists at T-junction (onto footway)	-1	0	2	2	2	1	2	-2	6
15	Cycle by- pass lane for straight ahead movement cyclists at T-junction (within carriageway)	-1	-1	2	2	2	1	0	-2	3
16	Cycle tunnels	-2	-2	1	-1	-2	-1	2	-2	-7
17	Elephants feet markings through intersection	2	2	2	2	2	1	0	-1	10
18	Coloured cycle lanes through intersections (one)	2	2	2	2	2	1	0	-1	10
19	Coloured cycle lanes through intersections (two or more)	2	2	2	2	2	1	0	-2	9
20	Exemption of cyclists from banned turn traffic orders	2	-1	2	2	2	2	2	0	11
21	Coordination of signals for cyclists progression "green wave"	2	-2	2	2	2	-1	0	0	5
22	LED indication to communicate the progression speed to cyclists	1	-2	-1	-1	-1	-1	0	-1	-6
23	Selected vehicle priority for cyclists (similar to bus priority)	2	-2	-1	2	1	-2	-2	0	-2
24	Two stage right-turn (major / complicated intersections)	2	2	2	2	2	1	2	-1	12
25	Two stage right-turn - cyclists banned from right traffic lane	2	2	2	2	2	0	0	-1	9
26	Road markings to highlight loop detectors	2	2	2	2	2	0	0	-1	9
27	Push buttons to demand cycle demand or priority (for separate phase or early green)	2	1	2	2	2	1	2	-1	11
28	Inductive loops to demand cycle demand or priority (for separate phase or early green)	2	1	1	2	2	2	2	-1	11
29	Video detectors to demand cycle demand or priority (for separate phase or early green)	2	2	1	2	2	1	2	-1	11
30	Dwell on green for bikes (reverse priority) (cycle track or cycle phases only)	2	2	2	2	2	-1	0	0	9
31	Cyclists allowed to turn left on red at any intersection (UK wide change in law)	2	-2	2	1	-1	-1	0	0	1
32	Cyclists allowed to turn left on red at specific intersection (cycle symbol green / red light during pedestrian phase)	2	-2	2	1	-1	0	0	-1	1
33	Cyclist allowed to turn left on red at specific intersections where designated lane present (on both arms) (cycle symbol green / red light during pedestrian phase)	2	-2	2	1	-1	0	0	-1	1
34	Straight ahead for cyclists on red (no green) at any 3 arm intersection (on main opposite minor road) (UK wide change in law)	2	-2	2	1	-1	-1	0	0	1
35	Straight ahead for cyclists on red (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersection	2	-2	2	1	-1	-1	0	-1	0
36	Straight ahead for cyclists on red with route through intersection marked (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersections	2	-2	2	1	-1	-1	0	-1	0
37	Junction cycle time reduction (90 second maximum)	2	2	2	2	2	2	2	0	14
38	Channelization of left, right and ahead cyclists	-1	-1	2	2	1	1	2	-1	5
39	Cycle tracks converted to lanes on final approach to intersections	2	-1	2	2	1	1	0	-1	6
40	Uncontrolled cycle crossing at junctions	2	-1	2	2	2	0	-2	-1	4
41	Speed bumps and plateaus	2	-2	2	1	-1	1	0	-2	1
42	RFID tags on bikes and warning indicator on signals	2	1	0	1	1	-1		-1	3
43	Priority for cyclists during inclement weather	2	1	0	1	1	-1	0	-1	3
44	Straightening staggered Toucans, and make a single phase	2	1	2	2	1	2	2	1	13
45	Pre-timed maximum timer on Toucans	2	2	2	2	2	2	-2	0	10
46	Trixi mirrors	2	2	1	2	2	1	0	-1	9
47	Two green periods per cycle for cyclists (to be used with separate cycle phases)	2	2	2	2	2	0	0	0	10
48	Conversion to continental style roundabout (vehicle flows under 10 - 15,000)	-2	-2	2	0	-1	1	0	2	0

6.9 Individual Technique Tables

For each of the techniques we have identified in Section 4 of this document, a summary table has been produced which describes the technique, outlines the advantages and disadvantages of its use, and highlights aggregated scores for each theme. For ease, the same colours as the previous tables have been used.

The following table demonstrates how each of the technique tables is structured.

<table>
<tr><td rowspan="6">Ref</td><td colspan="2">Scheme / Technique</td><td colspan="4">Name of Scheme / Technique</td></tr>
<tr><td colspan="2">Description</td><td colspan="4">A short description of the scheme is here</td></tr>
<tr><td colspan="2">Pros</td><td colspan="4">Outline of the advantages of technique</td></tr>
<tr><td colspan="2">Cons</td><td colspan="4">Outline of the disadvantages of technique</td></tr>
<tr><td>Cyclist</td><td>Pedestrian</td><td>Other Road User</td><td>Cost Implication</td><td>Regulation and Legislation</td><td>Other</td></tr>
<tr><td>Score</td><td>Score</td><td>Score</td><td>Score</td><td>Score</td><td>Score</td></tr>
</table>

For ease of reading, aggregated scores have beenreplicated fromthe relevant theme tables shown in Sections 6.3-6.8.

The theme scores are a result of simple aggregation of the scores awarded to each criterion within each theme.

Please note the scores are not directly linked to the Pros and Cons listed.

<table>
<tr><td rowspan="7">1</td><td>Scheme / Technique</td><td colspan="5">Intergreens designed for cyclist speed</td></tr>
<tr><td>Description</td><td colspan="5">Intergreen times specifically set for slower cyclists speed on a traffic stage change to ensure cyclists have vacated the intersection,</td></tr>
<tr><td>Pros</td><td colspan="5">Beneficial to cyclists at large intersections and uphill gradients
Reduces potential for conflict between cyclists and motor vehicles
Increased comfort levels for cyclists
Particularly important at sites with low cyclist flow
No legislative changes needed, only minimal guidance changes needed
Cheap to install and trial</td></tr>
<tr><td>Cons</td><td colspan="5">Delay to other road users as a result of the additional clearance time
Increased cycle time
May result in queues due to the additional delay</td></tr>
<tr><td>Cyclist</td><td>Pedestrian</td><td>Other Road User</td><td>Cost Implication</td><td>Regulation and Legislation</td><td>Other</td></tr>
<tr><td>10</td><td>0</td><td>-3</td><td>12</td><td>4</td><td>4</td></tr>
</table>

<table>
<tr><td rowspan="7">2</td><td>Scheme / Technique</td><td colspan="5">Intergreens extended using detection</td></tr>
<tr><td>Description</td><td colspan="5">Intergreens extended when cyclists are detected within the intersection, clearance time held until cyclists have vacated.</td></tr>
<tr><td>Pros</td><td colspan="5">Beneficial to cyclists at large intersections and uphill gradients
Reduces potential for conflict between cyclists and motor vehicles
Increased comfort levels for cyclists
Particularly important at sites with low cyclist flow
No legislative changes needed, only minimal guidance changes needed
Only extends the intergreen when required</td></tr>
<tr><td>Cons</td><td colspan="5">Detection reliability could cause problems
May result in isolated delays and queues where cycle flows are heavy</td></tr>
<tr><td>Cyclist</td><td>Pedestrian</td><td>Other Road User</td><td>Cost Implication</td><td>Regulation and Legislation</td><td>Other</td></tr>
<tr><td>11</td><td>0</td><td>-3</td><td>7</td><td>2</td><td>12</td></tr>
</table>

<table>
<tr><td rowspan="4">3</td><td>Scheme / Technique</td><td>Separate cycle phase with cycle signal aspects</td></tr>
<tr><td>Description</td><td>Technique involves the specification of cyclist only phases separately controlled to vehicular traffic</td></tr>
<tr><td>Pros</td><td>Removes all conflict with moving traffic for cyclists
Improved compliance by cyclists
Improves attractiveness, legibility and comfort for cyclists
Works best with high cyclist flows
Compatible with current signal infrastructure</td></tr>
<tr><td>Cons</td><td>Low cyclist flows do not justify this technique
Delay to pedestrians and delay and capacity of vehicular traffic reduced</td></tr>
</table>

		• Saturation flow could be reduced as a result of road space being needed for the cycle lane (potentially wider cycle lane required) • Not compatible with ASL • Complex control needed when cyclists share road space with buses • Relatively expensive to install and may require additional land • Additional street clutter from additional signal equipment

Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
15	-2	-6	-4	1	2

4		
	Scheme / Technique	Incorporation of cycle countdown units into cycle signal aspects (for use where a separate cycle phase is installed)
	Description	Countdown signals to communicate waiting times to cyclists when on red, and communicate remaining green time when on green.
	Pros	• Improves compliance for cyclists • Improves attractiveness to cyclists, increases cyclists awareness of the traffic signals • Easily trialled
	Cons	• Can only be used at fixed time installations, will cause confusion if utilised with SCOOT • TSRGDchanges required before its use • Dissemination of countdown function to cyclists • May have negative impact on motorist compliance and behaviour (may use countdown times to speed on final approach and through intersection)

Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
9	0	-1	3	-8	4

5		
	Scheme / Technique	All round cycle stages (red to traffic) "bike scramble" with cyclists on street (for use where a separate cycle phase is installed)
	Description	This technique allows protected movements for cyclists from all arms during a separate cycle phase at the same time. Instead of using an ASL this technique requires capacity of cyclists in a wider approach lane.
	Pros	• Removes all conflicts with motor vehicles • Improved cyclist compliance • Shorter route through the junction, reduced deviation • Capacity of cyclists improved • Increased attractiveness and comfort for cyclists • Possible increase in vehicle saturation flow • Compatibility with existing infrastructure good • Offers better service where low cyclist flows are present
	Cons	• Not compatible with ASL • Problematic if cyclists share a bus lane on the approach • Increases the likelihood of cyclist to cyclist conflict

<table>
<tr><td rowspan="3"></td><td></td><td colspan="6">

- Only works where vehicle demand is low (25,000 vehicles per day)
- Works best with compact junction layout
- TSRGD and local guidance both need updating
- Possible increase in delay for other road users including pedestrians
- May require wider cycle lanes to give adequate space due to loss of ASL
- Expensive / awkward to trial
- Planning and design costs may be expensive

</td></tr>
<tr><td>Cyclist</td><td>Pedestrian</td><td>Other Road User</td><td>Cost Implication</td><td>Regulation and Legislation</td><td>Other</td></tr>
<tr><td>14</td><td>-2</td><td>-3</td><td>-2</td><td>-8</td><td>1</td></tr>
</table>

<table>
<tr><td rowspan="6">6</td><td>Scheme / Technique</td><td colspan="6">All round cycle stages (red to traffic) “bike scramble” with cyclists off street
(for use where a separate cycle phase is installed)</td></tr>
<tr><td>Description</td><td colspan="6">This technique allows protected movements for cyclists from all arms during a separate cycle phase at the same time. In this option cyclists wait on the footway rather than on the carriageway. It is necessary to assume that footway has space or land must be taken from the carriageway.</td></tr>
<tr><td>Pros</td><td colspan="6">

- Negates conflicts between cyclists and vehicles
- Shorter route through the junction, reduced deviation
- Increased attractiveness and comfort
- Offers better service where low cyclist flows are present
- Equipment compatible with existing signal equipment
- Improved cyclist compliance
- Capacity of cyclists improved

</td></tr>
<tr><td>Cons</td><td colspan="6">

- Could be confusing to pedestrians, pedestrians may be tempted to cross during the cycle scramble stage.
- Delay to pedestrians
- Reduced capacity for other road users
- TSRGD and local guidance both need updating
- Expensive / awkward to trial
- Additional street clutter
- Planning and design costs may be expensive

</td></tr>
<tr><td>Cyclist</td><td>Pedestrian</td><td>Other Road User</td><td>Cost Implication</td><td>Regulation and Legislation</td><td>Other</td></tr>
<tr><td>13</td><td>-4</td><td>-1</td><td>-8</td><td>-8</td><td>0</td></tr>
</table>

<table>
<tr><td rowspan="2">7</td><td>Scheme / Technique</td><td>All round cycle and pedestrian stage (red to traffic) “bike scramble”
(for use where a separate cycle phase is installed)</td></tr>
<tr><td>Description</td><td>This technique allows protected movements for cyclists from all arms during a separate cycle phase at the same time. The cyclists are run within the same stage as pedestrians, and therefore are running opposed. Instead of using an ASL this technique requires storage of cyclists in a wider approach lane.</td></tr>
</table>

	Pros	• Shorter route through the junction, reduced deviation • Negates conflicts between cyclists and vehicles • Increased attractiveness and comfort • Equipment compatible with existing signal equipment • Improves cyclist compliance
	Cons	• Potential confusion by cyclists and pedestrians sharing the stage • Poor legibility and safety for blind and partially sighted pedestrians • Potential conflict between cyclists and pedestrians • Attractiveness to pedestrians could be decreased • TSRGD and local guidance both need updating • Expensive / awkward to trial • Additional street clutter • Capacity reduction and delay increase on sites where an existing all red stage to traffic does not exist • According to literature review this is a conceptual technique that has yet to be implemented

Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
9	-5	-2	-4	-8	0

8	Scheme / Technique	Pre signal for cyclist for early start (cycle aspect only)
	Description	Cyclists given an early green signal via a green cycle aspect which illuminates while general traffic lanes are still held on red. After a short period of time the vehicle lanes are then given a green signal. In order for this to be beneficial a cycle lane and ASL are required to help cyclists position themselves ahead of the traffic.
	Pros	• Benefit to safety by reducing conflict and allowing cyclists to get a head start • Likely to improve cyclist capacity • Increased attractiveness and comfort for cyclists • Improved cyclist compliance • Supports priority of cyclists over other vehicles • No additional land costs • Compatibility with existing infrastructure • Minimal additional street clutter
	Cons	• May result in slight delay for pedestrians due to additional time needed for pre signal • May be decreased legibility by motor vehicles due to additional cycle signal • Possible poor compliance and behaviour by motorists • Loss of capacity for motor vehicles • Increase in delay for motor vehicles • Will require amendments to TSRGD and guidance documents

Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
11	-1	-5	-1	-6	7

9	Scheme /	Pre signal for cyclist for early start

	Technique	(separate red amber green signal head)				
	Description	Cyclists given an early green signal while general traffic lanes are still held on red. In this option the cyclists are given a full red, amber, green signal specifically for control of the pre-signal. After a short period of time the vehicle lanes are then given a green signal. In order for this to be beneficial a cycle lane and ASL are required to help cyclists position themselves ahead of the traffic.				
	Pros	• Benefit to safety by reducing conflict and allowing cyclists to get a head start • Likely to improve cyclist capacity • Increased attractiveness and comfort for cyclists • Improved cyclist compliance • Supports priority of cyclists over other vehicles • No additional land costs • Compatibility with existing infrastructure				
	Cons	• May result in slight delay for pedestrians due to additional time needed for pre signal • May be decreased legibility by motor vehicles due to additional cycle signals, however improved over the previous option. • Possible poor compliance and behaviour by motorists • Loss of capacity for motor vehicles • Increase in delay for motor vehicles • Will require amendments to TSRGD and guidance documents • Additional street clutter				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	12	-1	-3	-1	-6	6

10	Scheme / Technique	Advanced cycle stop lines
	Description	The purpose of the ASL is to allow cyclists to progress to the front of the traffic queue during the red period. This allows them to position themselves more easily for the required manoeuvre, whilst making them more visible to drivers.
	Pros	• Good legibility for cyclist • Proven safety and collision reduction record • Improved capacity and reduced delay time for cyclists • Increased attractiveness and comfort for cyclists • Works best with low to medium cyclist flows • Improved cyclist compliance • Supports priority of cyclists over other vehicles • Pedestrian safety likely to improve due to reduction in red running • Improved legibility for motor vehicles • Cheap to install • Covered by current legislation and policies
	Cons	• Cyclists still encouraged to pass long vehicles on the nearside, resulting in potential conflict during left turn manoeuvres.

		• High cyclist flows may result in insufficient space for all cyclists • Could lead to minor delays for other motor vehicles • Can suffer encroachment by motor vehicles, intimidation of cyclists				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	16	1	-2	11	8	13

11	Scheme / Technique	Staggered advanced cycle stop lines				
	Description	The purpose of the staggered ASL is to allow cyclists to progress to the front of the traffic queue during the red period. This allows them to position themselves more easily for the required manoeuvre, whilst making them more visible to drivers. These could be implemented at T intersections where there is no right turn for cyclists				
	Pros	• Good legibility for cyclists • Proven safety and collision reduction record • Increased attractiveness and comfort for cyclists • Works best with low to medium cyclist flows • Pedestrian safety likely to improve due to reduction in red running • Improved legibility for motor vehicles • Cheap to install • Segregates cyclists and reduces intimidation by motorists • Minimal street clutter				
	Cons	• Cyclists still encouraged to pass long vehicles on the nearside, resulting in potential conflict during left turn manoeuvres. • Medium to High cyclist flows may result in insufficient capacity for bicycles • Needs alteration to TSRGD and local guidance				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	5	1	2	11	-4	13

12	Scheme / Technique	Cycle by-pass lane for left turning cyclists (signal controlled)
	Description	Cycle by-pass systems can be introduced at traffic signal installations within the United Kingdom under current regulations. The by-pass system can be split into two categories, one where an on-road cycle lane remains within the confines of the carriageway, the second method where the cyclist is diverted of the carriageway onto a short off-road cycle-track and subsequently rejoins the carriageway after the signalised intersection. The by-pass is governed by signal controls.
	Pros	• Negates all conflicts for left-turning cyclists • Additional capacity for left-turning cyclists and likely to be fewer delays • Increased attractiveness and comfort for cyclists • Should work well with all levels of cyclist flow • Behaviour and compliance may improve with fewer left-turns on red • Improved legibility for motor vehicles and possible safety benefits • No amendment required to TSRGD and Highway Code

		• Equipment already used in UK and no issues with reliability and compatibility.				
	Cons	• Possible safety and legibility disbenefitsfor pedestrians, especially blind and partially sighted pedestrians • May result in longer distance to cross for pedestrians and associated delay • Installation and set-up costs may be notable. • Additional land may be required, possibly taken from pedestrian realm. • Extended and possibly disruptive installation time • Additional street clutter with new signal poles and civil works				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	18	-6	3	-7	3	5

13	Scheme / Technique	Cycle by-pass lane for left turning cyclists (giveway priority)				
	Description	Cycle by-pass systems can be introduced at traffic signal installations within the United Kingdom under current regulations. The by-pass system can be split into two categories, one where an on-road cycle lane remains within the confines of the carriageway, the second method where the cyclist is diverted of the carriageway onto a short off-road cycle-track and subsequently rejoins the carriageway after the signalised intersection. The by-pass is 'free entry' and giveway controlled when rejoining the main carriageway.				
	Pros	• Reduces the number of conflict points for left-turning cyclists • Additional capacity for left-turning cyclists and likely to be fewer delays (depends of vehicle flow on main road) • Increased attractiveness and comfort for cyclists • Should work well with low and medium cyclist flows • No amendment required to TSRGD and Highway Code • Equipment already used in UK and no issues with reliability and compatibility				
	Cons	• Safety and legibility disbenefitsfor pedestrians, especially blind and partially sighted pedestrians • May result in longer distance to cross for pedestrians and associated delay • May be issues with high cyclist flows • Behaviour and compliance levels may reduce (cyclists not giving way) • Does not support priority over other road users • Installation and set-up costs may be notable. • Additional land may be required, possibly taken from pedestrian realm • Extended and possibly disruptive installation time • Additional street clutter and civil works				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	11	-8	1	-5	3	6

14	Scheme / Technique	Cycle by- pass lane for straight ahead movement cyclists at T-junction (onto footway)				
	Description	Cycle by-pass systems can be introduced at traffic signal installations within the United Kingdom under current regulations. For this technique the cycle lane is diverted onto the footway to by-pass the traffic signals. The cyclist then rejoins the carriageway upstream of the intersection. This technique is primarily used on the major arm, opposite the minor road.				
	Pros	• Reduces conflict with motor vehicles proceeding straight ahead (no competition for space) • Capacity increased and delay reduced for other road users by relocating cyclists to the footway • No requirement to stop at traffic signals and no delay • Increased attractiveness and comfort for cyclists • Should work well with low and medium cyclist flows • Behaviour and compliance likely to improve, less passing through red and supports priority for cyclists. • No amendment required to TSRGD and Highway Code • Equipment already used in UK and no issues with reliability and compatibility				
	Cons	• Safety and legibility disbenefits for pedestrians, especially blind and partially sighted pedestrians • Possible conflict point where cyclists rejoin the carriageway, this will depend on the design • May be less attractive route for pedestrians due to potential conflict with cyclists • May be issues with high cyclist flows • Not the most direct route for cyclists • Installation and set-up costs may be notable. • Additional land may be required, possibly taken from pedestrian realm • Extended and possibly disruptive installation time • Additional street clutter and civil works				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	13	-5	3	-3	-1	6

15	Scheme / Technique	Cycle by- pass lane for straight ahead movement cyclists at T-junction (within carriageway)
	Description	Cycle by-pass systems can be introduced at traffic signal installations within the United Kingdom under current regulations. For this technique the cycle lane is diverted behind the signals but still at carriageway level to by-pass the traffic signals. This technique is primarily used on the major arm, opposite the minor road.
	Pros	• Reduces conflict with motor vehicles proceeding straight ahead (no competition for space)

		• Capacity increased and delay reduced for other road users by relocating cyclists behind the signals. • Offers direct route with no requirement to stop and no delay • Increased attractiveness and comfort for cyclists • Should work well with all levels of cyclist flows (as long as cycle lane is wide enough) • Behaviour and compliance likely to improve, less passing through red and supports priority for cyclists. • No amendment required to TSRGD and Highway Code • Equipment already used in UK and no issues with reliability and compatibility				
	Cons	• Possible safety and legibility disbenefits for pedestrians, especially blind and partially sighted pedestrians • May result in longer distance to cross for pedestrians and associated delay • May be less attractive route for pedestrians due to potential conflict with cyclists • Installation and set-up costs may be notable. • Additional land may be required, possibly taken from pedestrian realm • Extended and possibly disruptive installation time • Additional street clutter and civil works				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	22	-9	6	-6	-1	3

16	Scheme / Technique	Cycle Tunnels				
	Description	Cycle tunnels are provided to remove the conflict between vehicles and cyclists. They provide a delay free means for cyclist routes to cross major roads.				
	Pros	• Potential safety and legibility benefits for cyclists • Reduced delays and chances of stopping for cyclists • Particular benefits for high cyclist flows • Improved safety and legibility for pedestrians including blind and partially sighted pedestrians • Improved legibility and safety for motorists due to the possible conflict with cyclists having been removed • Reduced delay to motorists				
	Cons	• Can have negative impact on cyclists route, may require cyclists to deviate from desire line • Possible personal security issues felt by cyclists • Poor design can result in poor attractiveness • Impact on pedestrian deviation, possible detraction from desire line • Expensive to build and install • Additional land required with associated costs • Changes may be required to the DMRB and guidance documents • Additional street clutter				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and	Other

					Legislation	
	11	4	5	-12	-2	-7

17	Scheme / Technique	Elephants feet markings through intersection				
	Description	Where cycle facilities pass through large intersections which could be confusing or intimidating to cyclists elephants feet road markings can be used to delineate the cyclists route. These markings do not form part of the current Traffic Signs Regulations and General Directions (TSRGD) and as such any local authority wishing use the marking must obtain site specific authorisation from the DfT.				
	Pros	• Improved legibility through the intersection for cyclists • Aid in highlighting possible cyclist movements to other road users and reduce likelihood for conflict • Increased attractiveness and comfort for cyclists • Should work well with all levels of cyclist flows (as long as area is wide enough) • Behaviour likely to improve • Increased legibility for pedestrians and other road users, highlights area where they may encounter cyclists • Equipment already used in UK and no issues with reliability and compatibility • Minimal cost implications including maintenance				
	Cons	• Not currently allowed in the TSRGD, new entry will be required which could be time consuming and expensive (consultation, staff time etc) • Amendments would be required to local guidance documents and Highway Code • Does not support priority for cyclists as route is predetermined • Will result in additional road markings through the intersection, could be confusing if more than one lane				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	13	1	3	11	-7	10

18	Scheme / Technique	Coloured cycle lanes through intersections (one)
	Description	Many European countries, specifically Denmark, Germany and the Netherlands provide highly visible, distinctively coloured bike lane crossings through intersections, these are one of a few treatments that are focussed through the intersection rather than on at the approach or leaving the stop line. The coloured section is for the crossing area itself and conflict points, it is not used on the approach or after the intersection. Collision studies in Denmark show there to be a reduction in cyclist collisions.
	Pros	• Proven collision reduction measure (overseas) • Improved legibility through the intersection for cyclists • Aid in highlighting possible cyclist movements to other road users

		and reduce likelihood for conflict • Increased attractiveness and comfort for cyclists • Should work well with all levels of cyclist flows (as long as area is wide enough) • Behaviour and compliance likely to improve • Increased legibility for pedestrians and other road users, highlights area where may encounter cyclists • Equipment already used in UK and no issues with reliability and compatibility • Minimal cost implications including maintenance • As only a coloured surface no amendments required to TSRGD • Relatively easy and cost effective to trial
	Cons	• Amendments would be required to guidance documents and possibly Highway Code • Does not support priority for cyclists as route is predetermined • Will result in additional road markings through the intersection adding to clutter

Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
14	1	4	11	1	10

19	Scheme / Technique	Coloured cycle lanes through intersections (two or more)
	Description	Many European countries, specifically Denmark, Germany and the Netherlands provide highly visible, distinctively coloured bike lane crossings through intersections, these are one of a few treatments that are focussed through the intersection rather than on at the approach or leaving the stop line. The coloured section is for the crossing area itself and conflict points, it is not used on the approach or after the intersection. Collision studies in Denmark show there to be an increase in collisions between motor vehicles and this is tied to size of the intersection, number of arms and traffic volumes.
	Pros	• Proven collision reduction measure for cyclists (overseas) • Improved legibility through the intersection for cyclists • Aid in highlighting possible cyclist movements to other road users and reduce likelihood for conflict • Increased attractiveness and comfort for cyclists • Should work well with all levels of cyclist flows (as long as area is wide enough) • Behaviour and compliance likely to improve • Increased legibility for pedestrians, highlights area where may encounter cyclists • Equipment already used in UK and no issues with reliability and compatibility • Minimal design and planning costs • As only a coloured surface no amendments required to TSRGD

		• Relatively easy and cost effective to trial
	Cons	• Collisions between motor vehicles likely to increase (overseas study), possibly due to confusion with more than one marked crossing area • Amendments would be required to guidance documents and possibly Highway Code • Does not support priority for cyclists as route is predetermined • Installation costs may be relatively high as well as ongoing maintenance costs • Will result in additional road markings through the intersection adding to clutter

Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
12	1	-3	5	1	9

20	Scheme / Technique	Exemption of cyclists from banned traffic orders
	Description	This technique is designed to be implemented in isolated instances to assist with making cycle routes more user friendly. Banned traffic movements are often imposed for all classes of vehicles; however exemption of cyclists would cause little or no disbenefits for other road users.
	Pros	• Can give cyclists shorter routes, and more freedom resulting in reduced deviation from their desire line • Potential improvements to cycle capacity and delays • Works best where cyclist flows are low • No additional land required • Compatible with existing signalling equipment • A number of permitted variations already exist but for some others, TSRGD changes may be required.
	Cons	• Does not work as well where cyclist flows are high in some circumstances • Has the potential to introduce safety issues for cyclists if not implemented correctly • Potential to cause temptation for motorists to be less compliant to the traffic orders if they see cyclists undertaking banned moves • Additional planning costs and equipment costs

Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
10	0	-1	3	5	11

21	Scheme / Technique	Coordination of signals for cyclist progression “green wave”
	Description	Typically the progression speed used for calculation of offset times between successive green periods is taken to be the speed of motor vehicles, this technique offers benefits to cycles by specifying the progression speed to be that of cyclists.
	Pros	• Increased safety for cyclists • Reduced delays for cyclists

		• Improved attractiveness and comfort to cyclists • Works best when there are low to medium cyclist flows as higher flows might result in slower cyclists delaying faster cyclists and causing them to fall behind the green wave • Improved behaviour and compliance by cyclists • Encourages reduced cruise speed for vehicles • No land or additional equipment costs • No changes required to the TSRGD • Equipment both reliable and compatible with existing setup
	Cons	• Delay to other road users due to their faster progression speed • Only really works in urban areas with low speeds • Capacity reduction for motorised vehicles • Possible delays for public transport • Expensive to design and set up • Alterations needed to local guidance and design specifications • Installation and modelling could prove a lengthy process

Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
16	0	-2	3	0	5

22	Scheme / Technique	LED indication to communicate the progression speed to cyclists
	Description	This technique requires the implementation of green period offsets based on cyclists progression speed. The additional facilities offered in this option display the “green wave” progression speed to the cyclists whilst they travel along the length of the link. This is done using a series of LED lights installed by the roadside which light and extinguish to display the pace required by the cyclists to arrive at the next intersection during the green period.
	Pros	• Increased legibility for cyclists • Reduces cyclists delay and chance for having to stop • Increased attractiveness and comfort to cyclists • No impact on pedestrians progress • Improved legibility for motorists • Improves cyclist and motorist compliance with the signals • No additional land required
	Cons	• Only works with fixed time signals, i.e. cannot be used with SCOOT • Extensive installation costs to incorporate at all junctions • Extensive time required to install at all junctions • Expensive to trial • Could require changes to TSRGD • Changes required to local guidance • Unknown reliability • Unknown compatibility

Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
12	0	3	-4	-3	-6

<table>
<tr><td rowspan="6">23</td><td>Scheme / Technique</td><td colspan="5">Selected vehicle priority for cyclists (similar to bus priority)</td></tr>
<tr><td>Description</td><td colspan="5">This strategy would give priority to cyclists on the approach to a junction by making stage changes to reduce the cyclists delay, or extending green times to ensure that cyclists are not required to stop.</td></tr>
<tr><td>Pros</td><td colspan="5">• Potential improvement for cyclist delay and increased cyclist capacity
• Improved attractiveness to cyclists
• Works well where there is one major cycling route through the intersection
• Improvements to cyclists behaviour and compliance
• No additional land costs
• No changes needed to TSRGD
• Compatible equipment</td></tr>
<tr><td>Cons</td><td colspan="5">• Performs badly when heavy cyclist flows are experienced on all arms of the junction
• Can add to pedestrian delay
• Can add to other road users delay on opposing arms by the call for cyclist green
• Can add to public transport delay if not incorporated within existing bus priority system
• Additional equipment needed therefore additional costs
• Changes needed to local guidance and design specifications
• Time consuming to install additional detection
• Unknown performance as this is a conceptual system</td></tr>
<tr><td>Cyclist</td><td>Pedestrian</td><td>Other Road User</td><td>Cost Implication</td><td>Regulation and Legislation</td><td>Other</td></tr>
<tr><td>5</td><td>-1</td><td>-2</td><td>-3</td><td>-2</td><td>-2</td></tr>
</table>

<table>
<tr><td rowspan="3">24</td><td>Scheme / Technique</td><td>Two stage right-turn (major / complicated intersections)</td></tr>
<tr><td>Description</td><td>For right-turning cyclists at major or complicated intersection the manoeuvre can be undertaken in two separate stages. An additional stop line is provided on the next arm on the left or protected by a traffic island on the opposing arm. Cyclists therefore do not have to leave the nearside lane when approaching an intersection with two or more lanes This arrangement generally works best when where the two movements are phased in order to reduce delay.
With this arrangement an ASL is not required.</td></tr>
<tr><td>Pros</td><td>• Reduced potential for conflict between right-turning cyclists and other vehicles
• Increased attractiveness and comfort for cyclists
• Should work relatively well for all levels of cyclist flow (as long as secondary stop line has adequate capacity)
• Equipment already used in UK and no issues with reliability and compatibility
• Relatively easy and cost effective to trial</td></tr>
</table>

	Cons	• Will require a deviation for cyclists, not the most direct route • Legibility may be poor for cyclists, difficult to comprehend required movements • Will increase delay and chance of stopping for cyclists • Does not support priority for cyclists as route and may lead to poor behaviour • Secondary stop line on next arm may have detrimental effect on capacity, delay and saturation flow for motor vehicles. • May incur some design and planning costs • Would require amendments to all legislative and guidance documentation				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	-2	0	-4	10	-7	12

25	Scheme / Technique	Two stage right-turn - cyclists banned from right traffic lane				
	Description	In Denmark, road traffic law prohibits cyclists undertaking a left-turn (UK right-turn) where there is a left-turn arrow traffic signal. Instead they are required to undertake the turning manoeuvre as a two stage process; they first have to go to the opposite side of the intersection and wait at a secondary stop line before they can make proceed in the required direction. This is implemented to reduce the inconvenience to other road traffic and reduce conflicting collisions with opposing traffic flows where there are multiple lanes. With this arrangement and ASL is not required.				
	Pros	• Reduces potential for conflict between right-turning cyclists and other vehicles • Increased attractiveness and comfort for cyclists • Should work well relatively well for low and medium levels of cyclists • Equipment already used in UK and no issues with reliability and compatibility • Relatively easy and cost effective to trial				
	Cons	• Will require a deviation for cyclists, not the most direct route • Legibility may be poor for cyclists, difficult to comprehend required movements • Will increase delay and chance of stopping for cyclists • Does not support priority for cyclists as route and may lead to poor behaviour • Secondary stop line on next arm may have detrimental effect on capacity, delay and saturation flow for motor vehicles • May incur some design and planning costs • Would required amendments to all legislative and guidance documentation				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	-1	0	-4	9	-7	9

26	Scheme /	Road markings to highlight loop detectors

<table>
<tr><td rowspan="6"></td><th>Technique</th><th colspan="5"></th></tr>
<tr><td>Description</td><td colspan="5">This technique involves the application a road marking for the optimal position that cyclists need to travel or rest upon to ensure detection by inductive loops. The marking is used to reduce the likelihood of cyclists not being detected and subsequently experiencing long wait periods or leading to running a red light.</td></tr>
<tr><td>Pros</td><td colspan="5">• Slight safety benefit as may lead to better behaviour and compliance and reduction in running a red light
• May reduce delay and chance of stopping if used as an advanced detector
• Works better where there are low cyclist flows
• Equipment already used in UK and no issues with reliability and compatibility
• Relatively easy and cost effective to trial
• Minimal design, planning and maintenance costs
• No effect on pedestrian and motor vehicles</td></tr>
<tr><td>Cons</td><td colspan="5">• New road marking would be required and therefore new diagram entry needed for the TSRGD
• Will be small increase in street clutter</td></tr>
<tr><td>Cyclist</td><td>Pedestrian</td><td>Other Road User</td><td>Cost Implication</td><td>Regulation and Legislation</td><td>Other</td></tr>
<tr><td>9</td><td>0</td><td>0</td><td>12</td><td>-8</td><td>9</td></tr>
</table>

<table>
<tr><td rowspan="6">27</td><th>Scheme / Technique</th><th colspan="5">Push buttons to demand cycle demand or priority
(for separate phase or early green)</th></tr>
<tr><td>Description</td><td colspan="5">This strategy uses a similar push button to standard pelican push buttons for use by cyclists to demand their presence at a signalised intersection. This technique is to be used in collaboration with a separate cycle phase or an early green pre signal.</td></tr>
<tr><td>Pros</td><td colspan="5">• Improved safety for cyclists
• Reduces the delay for cyclists
• Works well where there is a low cyclist flow
• Minimal design and implementation costs
• Existing equipment so known to be reliable and compatible
• No additional land required
• Easy to trial</td></tr>
<tr><td>Cons</td><td colspan="5">• Increases the chances that a cyclist will have to stop at the intersection to register their demand
• Unlikely to provide adequate detection for high flows or future growth as the increased number of cyclists will be required to wait in a queue along the length of the cycle lane
• Possible confusion by pedestrians if the push button is located too close to the waiting area.
• Changes required to TSRGD</td></tr>
<tr><td>Cyclist</td><td>Pedestrian</td><td>Other Road User</td><td>Cost Implication</td><td>Regulation and Legislation</td><td>Other</td></tr>
<tr><td>1</td><td>-2</td><td>0</td><td>10</td><td>-5</td><td>11</td></tr>
</table>

<table>
<tr><td>28</td><th>Scheme / Technique</th><th>Inductive loops to demand cycle demand or priority
(for separate phase or early green)</th></tr>
</table>

	Description	This technique uses conventional inductive loops buried in the carriageway to detect cyclists on the approach to the intersection. These loops can be set to either demand the separate cycle phase or early start or to extend the phase if already on green.
	Pros	• Improved safety for cyclists • Improved capacity for cyclists • Reduced delay for cyclists • Works well regardless of the cyclist numbers • Improves compliance by cyclists • Requires no additional land • Tried and tested method so reliability issue well documented • Compatible with existing infrastructure
	Cons	• Expensive and disruptive to install • Can prove unreliable when not maintained adequately • Can suffer damage as a result of carriageway works • Can miss cycle detections if the bicycle does not cross the loop adequately or if the bike is made of materials such as aluminium or carbon fibre rather than ferrous metals

Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
13	1	0	6	-1	11

29	Scheme / Technique	Video detectors to demand cycle demand or priority (for separate phase or early green)
	Description	This technique uses video technology to detect cyclists on the approach to the intersection. These loops can be set to either demand the separate cycle phase or early start or to extend the phase if already on green.
	Pros	• Capacity for cyclists increased • Delay for cyclists reduced • Reduced change of cyclists having to stop • Works well with all levels of cycle demand • No additional land costs • Cheaper to install than loops • Do not suffer from carriageway work disruption as loops do
	Cons	• Additional equipment costs, more expensive than loops • Additional street clutter • Requires fine tuning to setup detection zone • Requires adequate ambient light to work

Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
13	1	0	7	-1	11

<table>
<tr><td rowspan="5">30</td><td>Scheme / Technique</td><td colspan="5">Dwell on green for bikes (reverse priority)
(cycle track or cycle phases only)</td></tr>
<tr><td>Description</td><td colspan="5">The dwell on green technique reverses the priority where a cyclist route crosses a road. Traditionally the road traffic has priority until there is detection for the cycle crossing. By reversing this priority the cyclists are given the right of way until there is a demand for the road traffic.</td></tr>
<tr><td>Pros</td><td colspan="5">• Capacity for cyclists increased
• Reduced chance of cyclists having to stop
• Switches priority away from motorist and to cyclists
• Increases attractiveness to cyclists and their comfort levels
• Increases capacity for pedestrians and cyclists,can also reduce their delay
• Increased attractiveness to pedestrians
• No additional land costs
• No additional equipment or design costs
• No additional street clutter</td></tr>
<tr><td>Cons</td><td colspan="5">• Is not an effective measure for low cyclist demand
• Potential to encourage cyclists and pedestrians to rush to cross before the green disappears
• Increased delay to motor vehicles and possible longer queues
• Reduced capacity for motor vehicles
• Controller modifications might be required
• Potential policy change</td></tr>
<tr><td>Cyclist
18</td><td>Pedestrian
7</td><td>Other Road User
-3</td><td>Cost Implication
11</td><td>Regulation and Legislation
-3</td><td>Other
9</td></tr>
</table>

#	Scheme / Technique	Cyclists allowed to turn left on red at any intersection (UK wide change in law)
31	Description	This technique would result from a change in the law in that cyclists are allowed to make a left-turn movement at any intersection (no matter the size, layout etc) while under a red light. It is envisioned that the stop line would remain as the current layout and that an exemption is made stating the cyclists can pass over this to perform a left-turn. There would be no additional signs, road markings or alterations to the infrastructure on site. It would be the cyclist's decision on whether it is safe to perform this manoeuvre. Legibility levels for all road users, including cyclists and pedestrians will depend on the change in law and the education and awareness levels
	Pros	• Increased capacity for cyclist movements • Reduction in delay experienced by left-turning cyclists and no requirement to stop (although may have to giveway) • Increased attractiveness for cyclists (experienced cyclists who wish to perform this manoeuvre) • Supports cyclist priority over other users • Would work best with low to medium cyclist flows • No equipment required and therefore no installation or maintenance costs • No additional land required and no additional street clutter
	Cons	• Likelihood for conflict with motor vehicles increased, this is especially the case at unsuitable intersections (small cross section, narrow exit lane increasing potential for conflict) • Likelihood of conflict with pedestrians increased as cyclists could proceed through pedestrian phase, particularly problematic for the visually impaired and blind pedestrians • Reduced levels of comfort for cyclists, merging in with running and conflicting traffic • High cycle flows could increase the potential for conflict with competition or space • May lead to poor behaviour by cyclists (not giving way) or compliance with other movements attempted under red light • May lead to poor behaviour by other road users who may be tempted to turn left, especially moped and motorcyclists • Change in law and amendments to the Road Traffic Act would require extensive planning and may incur large costs. • Education and dissemination of new law may incur large costs • Amendment to TSRGD and associated guidance documents required • Would be beneficial to have off-street trial, cost of which could be expensive

Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
1	-5	-2	4	-7	1

32	Scheme / Technique	Cyclists allowed to turn left on red at specific intersection (cycle symbol green / red light during pedestrian phase)
	Description	This technique would result from a change in the law in that cyclists are allowed to make a left-turn movement at intersection while under a red light. The movement would only be allowed at certain intersections (low speeds, low volumes and wide cross sections) but a separate signal head provided for the cyclist left-turn movement which would show red when a conflicting pedestrian stage is green. The stop line would remain as the current layout and that an exemption is made stating the cyclists can pass over this to perform a left-turn when show a green light via the separate signal head. It would be the cyclist's decision on whether it is safe to perform the left-turn manoeuvre while the separate signal head is green. Legibility levels for all road users, including cyclists and pedestrians will depend on the change in law and the education and awareness levels.
	Pros	• Increased capacity for cyclist movements • Reduction in delay experienced by left-turning cyclists and limited requirement to stop (although may have to giveway) • Increased attractiveness for cyclists (experienced cyclists who wish to perform this manoeuvre) • Supports cyclist priority over other users • Would work best with low to medium cyclist flows • Reliability of equipment is good and compatible with existing infrastructure • No additional land required and minimal addition to street clutter
	Cons	• Likelihood for conflict with motor vehicles increased • Reduced levels of comfort/safety for cyclists, merging in with running and conflicting traffic • High traffic flows could increase the potential for conflict with competition or space • May lead to poor behaviour by cyclists (not giving way) or compliance with other movements attempted under red light • May lead to poor behaviour by other road users who may be tempted to turn on left, especially moped and motorcyclists • Change in law and amendments to the Road Traffic Act would require extensive planning and may incur large costs. • Education and dissemination of new law may incur large costs • Amendment to TSRGDand local guidance documents required • Would be beneficial to have off-street trial, cost of which could be expensive

Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
3	0	-2	-2	-8	1

33	Scheme /	Cyclist allowed to turn left on red at specific intersections where

	Technique	designated lane present (on both arms) (cycle symbol green / red light during pedestrian phase)				
	Description	This technique would result from a change in the law in that cyclists are allowed to make a left-turn movement at an intersection while under a red light. The movement would only be allowed at certain intersections (low speeds, low volumes and wide cross sections) but a separate signal head provided for the cyclist left-turn movement which would show red when a conflicting pedestrian stage is green. The stop line would remain as the current layout and an exemption is made stating the cyclists can pass over this to perform a left-turn when show a green light via the separate signal head. Cycle lanes on both the approach and exit arm would be required and the route through intersection marked in intermittent white lines to designate the area in which movements can take place. It would be the cyclist's decision on whether it is safe to perform the left-turn manoeuvre while the separate signal head is green. Legibility levels for all road users, including cyclists and pedestrians will depend on the change in law and the education and awareness levels.				
	Pros	• Increased capacity for cyclist movements • Reduction in delay experienced by left-turning cyclists and limited requirement to stop (although may have to giveway) • Increased attractiveness for cyclists • Supports cyclist priority over other users • Would work best with low to medium cyclist flows, but may still be suitable for high flows with defined path • Reliability of equipment is good and compatible with existing infrastructure • No additional land required and minimal addition to street clutter				
	Cons	• Likelihood for conflict with motor vehicles increased, although defined road space may reduce the potential when compared to other left-turn on red techniques • May lead to poor behaviour by other road users who may be tempted to turn on left, especially moped and motorcyclists • Change in law and amendments to the Road Traffic Act would require extensive planning and may incur large costs. • Education and dissemination of new guidance may incur large costs • Amendment to TSRGD and local guidance documents required • Would be beneficial to have off-street trial, cost of which could be expensive				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	11	0	-2	-2	-8	1

34	Scheme / Technique	Straight ahead for cyclists on red (no green) at any 3 arm intersection (on main opposite minor road) (UK wide change in law)
	Description	This technique would result from a change in the law in that cyclists are allowed to make a straight-ahead movement at any 3 arm

		intersection (no matter the size, layout etc) while under a red light. It is envisioned that the stop line would remain as the current layout and that an exemption is made stating the cyclists can pass over this to perform a straight-ahead. There would be no additional signs, road markings or alterations to the infrastructure on site. It would be the cyclist's decision on whether it is safe to perform this manoeuvre. Legibility levels for all road users, including cyclists and pedestrians will depend on the change in law and the education and awareness levels					
	Pros	• Increased capacity for cyclist movements • Reduction in delay experienced by straight-ahead movement cyclists and no requirement to stop (although may have to giveway) • Increased attractiveness for cyclists (experienced cyclists who wish to perform this manoeuvre) • Supports cyclist priority over other users • Would work best with low to medium cyclist flows • No equipment required and therefore no installation or maintenance costs • No additional land required and no additional street clutter					
	Cons	• Likelihood for conflict with motor vehicles increased, this is especially the case at possible unsuitable intersections (small cross section, narrow exit lane increasing potential for conflict) • Likelihood of conflict with pedestrians increased as cyclists could proceed through pedestrian phase, particularly problematic for blind and partially sighted pedestrians and could become less attractive for other pedestrians • Reduced levels of comfort for cyclists, merging in with running and conflicting traffic • High traffic flows could increase the potential for conflict with competition or space • May lead to poor behaviour by cyclists (not giving way) or compliance with other movements attempted under red light • May lead to poor behaviour by other road users who may be tempted to turn on left, especially moped and motorcyclists • Change in law and amendments to the Road Act would require extensive planning and may incur large costs. • Education and dissemination of new law may incur large costs • Amendment to TSRGDand associated guidance documents required • Would be beneficial to have off-street trial, cost of which could be expensive					
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	1	-5	-2	4	-7	1

35	Scheme / Technique	Straight ahead for cyclists on red (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersection
	Description	This technique would result from a change in the law in that cyclists are allowed to make a straight-ahead movement at intersections while under a red light. The movement would only be allowed at

		certain intersections (low speeds, low volumes and wide cross sections) but a separate signal head would be provided for the cyclist straight-ahead movement which would show red when a conflicting pedestrian stage is green. The stop line would remain as the current layout and an exemption is made stating the cyclists can pass over this to perform a straight-ahead movement when shown a green light via the separate signal head. It would be the cyclist's decision on whether it is safe to perform the straight-ahead while the separate signal head is green. Legibility levels for all road users, including cyclists and pedestrians will depend on the change in law and the education and awareness levels.
	Pros	• Increased capacity for cyclist movements • Reduction in delay experienced by straight-ahead cyclists and limited requirement to stop (although may have to giveway) • Increased attractiveness for cyclists (experienced cyclists who wish to perform this manoeuvre) • Supports cyclist priority over other users • Would work best with low to medium cyclist flows • Reliability of equipment is good and compatible with existing infrastructure • No additional land required and minimal addition to street clutter
	Cons	• Likelihood for conflict with motor vehicles increased • Reduced levels of comfort for cyclists, merging in with running and conflicting traffic • High traffic flows could increase the potential for conflict with competition or space • May lead to poor behaviour by cyclists (not giving way) or compliance with other movements attempted under red light • May lead to poor behaviour by other road users who may be tempted to turn on left, especially moped and motorcyclists • Change in law and amendments to the Road Traffic Act would require extensive planning and may incur large costs. • Education and dissemination of new law may incur large costs • Amendment to TSRGD associated guidance documents required • Would be beneficial to have off-street trial, cost of which could be expensive • Cost of additional signal equipment

Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
3	0	-2	-2	-8	0

36	Scheme / Technique	Straight ahead for cyclists on red with route through intersection marked (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersections
	Description	This technique would result from a change in the law in that cyclists are allowed to make a straight-ahead movement at intersections while under a red light. The movement would only be allowed at certain intersections (low speeds, low volumes and wide cross

		sections) but a separate signal head would be provided for the cyclist straight-ahead movement which would show red when a conflicting pedestrian stage is green. The stop line would remain as the current layout and an exemption is made stating the cyclists can pass over this to perform a straight-ahead movement when shown a green light via the separate signal head. Cycle lanes would be required on both the approach and exit and marked through the intersection. It would be the cyclist's decision on whether it is safe to perform the straight-ahead while the separate signal head is green. Legibility levels for all road users, including cyclists and pedestrians will depend on the change in law and the education and awareness levels.				
	Pros	• Increased capacity for cyclist movements • Reduction in delay experienced by left-turning cyclists and limited requirement to stop (although may have to giveway) • Increased attractiveness for cyclists • Supports cyclist priority over other users • Would work best with low to medium cyclist flows, but may still be suitable for high flows with defined path • Reliability of equipment is good and compatible with existing infrastructure • No additional land required and minimal addition to street clutter				
	Cons	• Likelihood for conflict with motor vehicles increased, although defined road space may reduce the potential when compared to other straight-ahead on red techniques • May lead to poor behaviour by other road users who may be tempted to proceed on cycle green, especially moped and motorcyclists • Change in law and amendments to the Road Traffic Act would require extensive planning and may incur large costs. • Education and dissemination of new law may incur large costs • Amendment to TSRGDand associated local guidance documents required • Would be beneficial to have off-street trial, cost of which could be expensive				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	11	0	-2	-2	-8	0

37	Scheme / Technique	Junction cycle time reduction (90 second maximum)
	Description	This technique has been referred to by many publications. Keeping the cycle time to a minimum (below 90 seconds) keeps the delay to cyclists to a minimum. This is a well versed method for providing for cycles and pedestrians at traffic signals
	Pros	• Provides reduced delay to cyclists • Works well for all volumes of cyclists • No additional equipment or installation costs

		• No additional land costs • Compatible with existing equipment • Reliable equipment • No changes needed for the TSRGD				
	Cons	• Can result in shorter stage times so might result in cyclists stopping more often • Capacity reduced for other road users • Delay increased for other road users • Possible additional queuing on the upstream links by other road users • Additional planning costs				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	5	1	-4	9	5	14

38	Scheme / Technique	Channelisation of left, right and ahead cyclists				
	Description	This technique is where the approach cycle lanes are divided into separate movement cycle lanes (left and straight ahead for example) to channelise cyclist movements and places them in the optimal position before entering the intersection and minimises any potential cyclist to cyclist conflict. Each channel lane would be marked with the appropriate arrow road marking				
	Pros	• Reduction in likelihood of cycle to cycle conflicts • Good legibility for cyclists on approach • Would work best with medium to high flows, particularly if there are high left-turn flows • Reliability of equipment is good and compatible with existing infrastructure, application of additional road markings • Cost of equipment, road markings, relatively cheap and subsequently future maintenance costs • No amendment required to TSRGD				
	Cons	• May require additional land use for wider lanes, thereby increasing distance to cross • Wider cycle lanes may result in loss of traffic lanes or narrowing of traffic lanes, this may have detrimental effect on the capacity, delay and saturation flow for all motor vehicles • Increase in delay may result in longer queues for motor vehicles • May require amendment to DMRB and associated guidance documents • If additional land required could be costly to install for trial and in practice				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	8	-1	-7	-1	-1	5

39	Scheme / Technique	Cycle tracks converted to lanes on final approach to intersections				
	Description	This technique is where an off-road cycle track is converted to an on-road bicycle lane on the final approach to an intersection.				
	Pros	• Reduction of the likelihood of conflict for cyclists • Reduction in the length of route through intersection, especially for right-turns • Slight improvement to legibility for cyclists and pedestrians • Would work well for all levels of cycle flows • Reduced likelihood of pedestrian to cyclist conflict and therefore may be more attractive for pedestrians • No additional land costs • Reliability of equipment and compatibility with existing infrastructure good • No amendment required to TSRGD				
	Cons	• May be a decrease in attractiveness and comfort for cyclists • May have detrimental effect on the capacity, delay and saturation flow for all motor vehicles if traffic lanes removed or narrowed • Increase in delay may result in longer queues for motor vehicles • Amendments to DMRB and associated guidance documents required • Planning, installation and equipment costs may be high • High costs may mean not suitable for trial				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	6	4	-3	-3	-1	6

40	Scheme / Technique	Uncontrolled cycle crossing at junctions
	Description	This technique is where an off-road cycle track on the approach to signalised intersection is not controlled by traffic signals; instead give way markings are introduced and the cyclist must make the decision on when to cross. Deviation for cyclists is dependent on whether the approach is a cycle track to cycle lane.
	Pros	• Potential capacity increase for cyclists depending on traffic volumes on the road to be crossed • May result in a reduction in waiting times and requirement to stop for cyclists if traffic volumes low • Increase in capacity and saturation flow and decrease in delay for motor vehicles • No additional land costs • Reliability of equipment and compatibility with existing infrastructure good • No amendment required to TSRGD • Feasible for trial

	Cons	• If a cycle lane is diverted onto the footway to access an uncontrolled crossing then this will be have an adverse effect on deviation with a longer route through the intersection • May result in an increase in waiting times and requirement to stop for cyclists if traffic volumes high • Would not work well if there are high cycle flows • Does not support priority over others • Possible poor legibility for pedestrians. May also lead to pedestrians crossing road when not safe to do so when observing cyclists crossing next to them. May make route less attractive to pedestrians • Amendments to local guidance documents required • Planning, installation and equipment costs may be relatively high • Anecdotal source only, no details of use anywhere				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	-5	-6	2	-1	-1	4

41	Scheme / Technique	Speed bumps and plateaus				
	Description	This technique involves the introduction of speed cushions, road humps on the approach to an intersection or the intersection itself located on a raised plateau				
	Pros	• Reduction in likelihood of conflict and severity of collision to all road users due to reduction in vehicular speeds • Would be suitable for all levels of cyclist flow • May make route more attractive to pedestrians • No additional land costs • Reliability of equipment and compatibility with existing infrastructure good • No amendment required to TSRGD				
	Cons	• Reduction in comfort levels for cyclists • Raised plateau may result in reduction of saturation flow • Amendments to cyclist guidance documents required • Planning, installation and equipment costs high				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	5	2	1	-4	1	1

42	Scheme / Technique	RFID tags on bikes and warning indicator on signals
	Description	This technique is aimed at reducing accidents where vehicles (especially large vehicles) turn left across the path of cyclists in the nearside cycle lane. The RFID tag is installed on the bicycle; this tag is then detected by equipment at the traffic signal controlled intersection and results in the illumination of a cycle warning light on

<table>
<tr><td rowspan="6"></td><td></td><td colspan="6">the traffic signal. This tells motorists that there is a bicycle waiting in the nearside bicycle lane, this warning maybe essential as the driver might not be able to see the cyclist in mirrors or through side windows.</td></tr>
<tr><td>Pros</td><td colspan="6">Increased cyclist safety
Increased attractiveness and comfort for cyclists
Works with all volume of cycle demand
Increases legibility and safety for motorists
Potential to improve the compliance and safety by motorists at traffic signals
No additional land required
Equipment compatible with existing infrastructure</td></tr>
<tr><td>Cons</td><td colspan="6">Additional planning costs
Additional equipment costs
Safety disbenefits for cyclists who do not have the RFID tag attached, motorists will assume that no illumination means no cycles on the nearside cycle lane, this could be treated as a substitute for checking mirrors
Changes needed to TSRGD
Unknown reliability of equipment
Additional street clutter</td></tr>
<tr><td>Cyclist</td><td>Pedestrian</td><td>Other Road User</td><td>Cost Implication</td><td>Regulation and Legislation</td><td>Other</td></tr>
<tr><td>14</td><td>-1</td><td>-2</td><td>-6</td><td>2</td><td>3</td></tr>
</table>

<table>
<tr><td rowspan="6">43</td><td>Scheme / Technique</td><td colspan="5">Priority for cyclists during inclement weather</td></tr>
<tr><td>Description</td><td colspan="5">This technique has been used with success in the Netherlands. The system is designed to offer greater priority and reduced delay to cyclists during periods of heavy rain or when the ambient temperature is low</td></tr>
<tr><td>Pros</td><td colspan="5">Decreased delay
Decreased chances for cyclist to have to stop during these periods
Increased attractiveness to cyclists and increased comfort levels
Works with all levels of cyclist demand
Improves cyclist behaviour and compliance
No additional land required
No changes needed for the TSRGD or highway code</td></tr>
<tr><td>Cons</td><td colspan="5">Potentially causes vehicle delay including public transport
Potential delay to pedestrians
Additional planning and design costs
Additional equipment needed (weather station)
Additional ongoing maintenance costs (weather station)
Changes required for local guidance documentation
Unknown reliability of equipment</td></tr>
<tr><td>Cyclist</td><td>Pedestrian</td><td>Other Road User</td><td>Cost Implication</td><td>Regulation and Legislation</td><td>Other</td></tr>
<tr><td>14</td><td>-1</td><td>-2</td><td>-6</td><td>2</td><td>3</td></tr>
</table>

44	Scheme / Technique	Straightening staggered Toucans, and make a single phase				
	Description	Traditionally toucan crossings with a crossing width over 11 metres should be considered for making a staggered facility, and those over 15 metres should be installed as a staggered facility. The staggered facility requires cyclists and pedestrians to cross the carriageway in two movements rather than just one. This introduces two delay periods due to the waiting times. This technique proposes to straighten all staggered facilities to make them a single phase crossing.				
	Pros	• Reduced deviation for pedestrians and cyclists • Improved legibility • Improved behaviour and compliance by pedestrians and cyclists • Improved capacity for cyclists • Reduced delay for cyclists and pedestrians • Increased attractiveness and comfort for cyclists • Works best where there is a high cyclist and pedestrian flow, but works with all demand levels • No additional land costs or equipment costs • Reduces street clutter • No changes needed for TSRGD • Reliable equipment				
	Cons	• Reduced capacity for motor vehicles due to the longer clearance needed when making a pedestrian to vehicle stage change • Increased delays for vehicular traffic • Could be seen as daunting for pedestrians or cyclists on very wide roads • Expensive or awkward to trial • Changes needed for local guidance documentation				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	16	8	-3	6	0	13

45	Scheme / Technique	Pre-timed maximum timer on Toucans
	Description	Maximums timers work by starting a timer that counts the number of elapsed seconds for a given phase. When pre timed max is set as “off” the timer is started when the pedestrian phase is demanded. The result of this will be that the vehicle stage will continue to run, whist there is a demand for it to do so, until the max timer has expired. Following this the stage will then change to cyclists/pedestrians. Setting the pre timed max timer to be “on” will mean that the maximum timer starts running when the road stage gains right of way, this will continue to run, whilst there is a demand for it to do so. This means that when the pedestrian/ cyclist stage is demanded the timer has already started to run or has expired. In the later state the demand for a pedestrian / cyclists stage will be answered almost immediately.

	Pros	• Reduced delays for cyclists • Reduced chance for having to stop for cyclists • Increased attractiveness and comfort for cyclists • Works best when there is a low cyclist flow and a low vehicle demand • Increases the behaviour and compliance of cyclists • Reduces delay for pedestrians • Improves attractiveness for pedestrians • No additional equipment costs • No additional land costs • No additional installation costs • No changes needed in the TSRGD • Good reliability • No additional street clutter				
	Cons	• Reduces vehicular capacity throughput of the toucan • Increases delay for vehicles • In areas of high vehicle demand queuing can occur • Could reduce compliance of motorists as priority will be with cyclists • Changes needed to the DMRB and guidance documents				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	13	3	-4	12	0	10

46	Scheme / Technique	Trixi mirrors				
	Description	This is a Swiss technique in which a heated mirror is installed on a traffic signal pole to provide motorists the ability to view cyclists approaching on their nearside.				
	Pros	• Reduction in likelihood of conflict between left-turning vehicles and straight-ahead moving cyclists • Works best with low to medium cyclist flows • No additional land costs • Reliability of equipment and compatibility with existing infrastructure good • Easy to trial with little costs and short installation time				
	Cons	• Amendments required to TSRGD and cyclist guidance documents, although a trial of Trixi mirrors on the London Cycle Superhighways occurred in 2009 • Slight increase in street clutter • Difficult to measure success of this technique, no evidence found in literature review.				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	7	0	2	11	-6	9

47	Scheme / Technique	Two green periods per cycle for cyclists (to be used with separate cycle phases)

	Description	This technique incorporates two cycle phases or stages per cycle. This is designed to reduce the delay to cyclists. Naturally this technique must be used where separate cycle phases are already installed on the junction. Likewise this technique can be used to only repeat the green for the dominant cycle phase
	Pros	• Reduced delays for cyclists • Improved capacity for cyclists • Increased attractiveness for cyclists • Works with all levels of cyclist demand • No additional land costs required • No additional equipment or installation costs • Good reliability of equipment • Compatible with current signals infrastructure • No additional street clutter
	Cons	• Increases delay for vehicles • Reduces vehicular capacity • Potentially increases delay for pedestrians • Could reduce compliance of motorists • Increased planning and design costs • Changes required to guidance

Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
10	-1	-4	9	-1	10

48	Scheme / Technique	Conversion to continental style roundabout (vehicle flows under 10 - 15,000)
	Description	This will involve removal of all traffic signals and conversion to a continental style roundabout, e.g. single lane approach and single lane circulatory carriageway with cyclists sharing the single approach lane with other traffic. Likely to be capacity and delay issues if vehicle flows exceed 15,000 vehicles per day.
	Pros	• Reduction in number of conflict points for cyclists and vehicles • Improved legibility and capacity for cyclists and vehicles • May be more attractive and comfortable for cyclist • Works best with low flows but should still be viable for all levels of cyclist flow • Reliability of equipment good • Reduction in street clutter
	Cons	• Does not support cyclist priority • Results in longer route through intersection for pedestrians and decreased legibility • May reduce safety of pedestrians as no longer under signal protection and thereby becomes less attractive • Amendments required to roundabout design documentation, Traffic Advisory Leaflets and cyclist guidance documents • Will require additional land and long design and planning process • Cost may be prohibitively expensive due to planning, land,

		equipment and installation • Suitability for trial poor due to inherent costs				
	Cyclist	Pedestrian	Other Road User	Cost Implication	Regulation and Legislation	Other
	10	-4	3	-8	0	1

7 Discussion of Results

The 48 techniques considered in this project range from simply installed markings and additional detection right the way through to more complex junction designs involving extensive kerb realignment and land take. Due to the variation of techniques it is imperative that the correct technique is utilised on the correct site to achieve net benefits for all road users, as well as cyclists.

With this in mind the following section discusses how some of the techniques provide benefits for certain aspects or users of junctions. Ultimately it is the responsibility of transportation professionals to use sound judgement of the techniques to establish the most effective scheme to use.

7.1 Best Techniques overall

The determination of the best overall techniques identified as part of the assessment process is based upon the overall aggregate score. In order for a technique to qualify the aggregate score had to be 20 or above.

This cut-off point was chosen as it was considered that the top 5 only would be far too restrictive, and that there were many techniques with similar scores. Based on the distribution of total scores, the score of 20 or more appeared to give the best balance for consideration as one of the top techniques.

Some of the techniques that attained the required score or above are already in use in the UK and therefore will not be discussed in detail.

The top scoring techniques and their scores were:

- **ID10**: Advanced cycle Stop Line (ASL) (47)
- **ID18**: Coloured cycle lane through intersection (one) (41)
- **ID44**: Straightening staggered toucans and making a single phase (40)
- **ID30**: Dwell on green for bikes (39)
- **ID1**:Intergreens designed for cyclist speed (37)

It is not surprising that these techniques achieved the highest aggregate scores as they all score well for cyclist safety and improving capacity and reducing delay while at the same time having mainly positive effects for pedestrians. Furthermore, the majority of the techniques would be relatively cost effective for the planning, design and installation and require little or no amendments to relevant legislative and guidance documentation.

Dwell on green would be a new technique for the UK. This is where priority is reversed where an off-carriageway cycle route crosses a road (cyclists are given the right of way until there is a demand for the road traffic). This technique supports priority to cyclists and reduces delay and increases capacity and safety. During the literature review it was discovered that this technique worked well in a couple of locations (Those used as the case studies in the literature). It is, however, evident that this technique requires high cyclist volumes and a low vehicular traffic volume in order to be successful. As a result, it is likely that there are very few locations where this could be implemented successfully in urban areas in the UK. Likewise it was identified that, in order to be a success, a mindset change would be required for those using the crossing (cyclists and pedestrians). It is foreseen that by returning the priority to the pedestrians and cyclists in the absence of vehicular traffic demand, then the crossing could encourage cyclists and pedestrians to rush on their approach to the crossing. The rushed approach to the crossing has the potential to cause pedestrians and cyclists to focus on crossing before their right of way has been lost, rather than on any approaching traffic. A potential solution to some of the issues presented by dwell on green can be found by configuring the signals to rest on an 'all red' stage in the absence of any demand. This technique would remove the incentive to rush on the approach to the crossing by pedestrians and cyclists, and would offer delay reduction benefits as the stage change from and 'all red' stage is quicker than a conventional pedestrian or cycle crossing. The delay reduction benefits are not only available for cyclists and pedestrians but also road traffic. It is already a standard practise in the UK for a signal controlled junction to rest on an 'all red' stage in the absence of any demand. Based on the reason stated above the 'Dwell on Green' technique will be taken forward as 'Dwell on all red' from this point onwards.

Straightening staggered toucans and making a single phase would be a relatively new process in the UK and could result in major benefits to both cyclists and pedestrians including shorter route, better capacity and reduced delay no amendments to the TSRGD. The method will in likelihood have a detrimental effect on vehicular capacity and delay though.

With regard to the other techniques that reached an aggregate score over 20 some are already in use in the UK such as staggered advanced cycle stop line (28), elephants feet road markings (31), two or more coloured cycle lanes through intersections (25), exemption of cyclists from banned movements (28) and the use of Trixi mirrors (24) and as such will not be expanded upon.

The use of inductive loops to detect cyclists (30) is already in use in the UK and scored highly due to improvements to cyclist safety, capacity, compliance and is a tried and tested method so is compatible with existing infrastructure. One of the issues with inductive loops is they can miss cycle detections if the bicycle does not cross the loop adequately. One of the new techniques identified is the introduction of a road marking to highlight the optimal cyclist path across the detector to ensure detection (22) which if allowed for the use in the UK may improve the effectiveness of inductive loops.

Another technique that scored well is the extension of intergreens by the use of detection (29). This scored well for reducing delay and the chance of stopping for cyclists while at the same time improving the attractiveness and comfort to cyclists and improving compliance and behaviour. The technique also scored relatively well for costs and other considerations and there is no requirement to amend the TSRGD, although amendments to guidance documents is required. Although this method scored the same result of -1 for capacity and delay to all other road users this is only the case when a slow moving cyclist is detected, at other times there will be no delay or reduction in capacity for motorised capacity.

Remaining with detection, the use of video technology to detect cyclists also scored well (31) by increasing the capacity for cyclists and minimising potential delay and the chance of stopping. Furthermore, there are no land costs and this form of detector is potentially cheaper to install than conventional inductive loops due to less disruption to traffic and they may not suffer from maintenance detection issues that inductive loops currently suffer. Video detectors will incur additional costs at the design and purchase stage but may well be more cost effective in the long term.

Another high scoring technique is the co-ordination of signals for cyclist progression "green wave" (22) where the progression speed of system of signalised intersections is set to that of cyclists. The method scores extremely well for cyclists due to increased safety, reduced delays, improved attractiveness, comfort, behaviour and complianceand no land costs.

A number of roadside cycle signals are used inform cyclists of the progression speed. This technique requires changes to the TSRGD. The method would have detrimental effect on motor vehicles capacity and delay.The reason why this technique scored so poorly in the assessment process is that it is a new technique and would require amendments to relevant regulatory and guidance documents. This technique also has high costs associated with design and implementation.

A reduction in cycle time (90 seconds maximum) (30) was another high scoring option, the reasoning behind implementing such a plan is similar to that when considering pedestrians and will reduce the delay time for cyclists. The technique also scored well on costs, other considerations and amendments to relevant documents as there is little planning and design required, little to no equipment required and short installation process.

Two green periods per cycle for cyclists (23) scored well for similar reasons to the reduction in cycle time as there are no land requirements, no equipment costs, small installation costs and minor amendments required to relevant documentation. Furthermore the associated benefits to cyclists include reduced delay, increased attractiveness and increased compliance.

The final technique to score higher than 20 is pre-timed maximum for toucan crossings (34) as this will provide reduced delays and chance of stopping for cyclists and pedestrians, increased attractiveness and comfort for cyclists and pedestrians, improved behaviour and compliance of cyclists while at the same time there is no requirement for additional equipment, land or installation costs. As the equipment will remain the same there is no concern over compatibility and the reliability is well known.

7.2 Worst Techniques Overall

From the extensive assessments carried out for all forty eight potential techniques, the aggregated scores have shown a selection of techniques that performed poorly. A cut-off was imposed to seek out the techniques that scored -5 or less. The schemes that have been classified as being the worst performers are shown below with their associated scores:

- **ID6**: All round cycle stages (red to traffic) “bike scramble” with cyclists off street (-8)
- **ID7**: All round cycle and pedestrian stage (red to traffic) “bike scramble” -(-10)
- **ID23**: Selective vehicle priority for cyclists (similar to bus priority) (-5)
- **ID31**: Cyclists allowed to turn left on red at any intersection(UK wide change in law)(-8)
- **ID32**: Cyclists allowed to turn left on red at specific intersection (cycle symbol green / red light during pedestrian phase) (-8)
- **ID34**: Straight ahead for cyclists on red (no green) at any 3 arm intersection (on main opposite minor road) (UK wide change in law) (-8)
- **ID35**: Straight ahead for cyclists on red (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersection (-9)
- **ID40**: Uncontrolled cycle crossing at junctions (-7)

The all round cycle stages (bike scrambles) scored particularly badly because of the additional infrastructure required to separately control bicycle traffic. This is a similar drawback to both the off-street option and the option where the bicycle scramble is combined with pedestrian movements. Likewise it was found that these techniques both require alterations to the TSRGD and associated guidance documents. It was also found that operating a bicycle scramble stage with cyclists queuing on the footway would not only cause legibility problems for pedestrians (who in this option would be separately controlled) but would also require additional street clutter to designate cycle waiting areas and crossing routes.

Selective vehicle priority for cyclists has been scored poorly because the literature review did not return any publications which referred to this technique being in use. The concept works in a similar way to bus priority, giving extended green time and reducing delays for arms of a junction that showed bicycle detection. The assessment focused on a number of drawbacks to this. Firstly as a conceptual technique little is known about the reliability of the system and the results that it could produce. It was also noted that the success of this technique relies on effective bicycle detection; however the benefits and disbenefits of the various detection strategies are well documented and discussed elsewhere in this document.

Two different variations of the left turn on red strategy have been included in the worst performers. Firstly the introduction of left turn on red for all intersections has scored badly because it was noted that this would introduce additional conflicts between cyclists turning and opposing traffic flows, which would not otherwise have been present. As this technique deviates from current UK legislation, changes to the TSRGD and local guidance documents would be required. The second left turn on red variation would allow cyclists to turn on a red signal during the green period for pedestrians. This technique introduces safety concerns and a greater potential for cyclist-pedestrian conflicts. Of particular concern is how the cyclists would interact with blind and partially sighted pedestrians. It is foreseen that vulnerable pedestrians would experience increased levels of discomfort if cyclists were turning left across their path during the pedestrian stage. Both variations of the left turn on red technique would be difficult to trial, and as a result would probably need to be simulated or tested in an off street environment.

The forty-eight proposed techniques included three different variations of technique which allowed cyclists to make an ahead movement during a red signal at ‘T’ intersections. Two of these three variations scored below -5 and have therefore been included amongst the worst performers.

The first technique involves cyclists being allowed to pass through a red signal when travelling along the main road at a three arm intersections, which could only be allowed where the cyclists do not directly cross the minor road. Even in this situation the scores given reflect that there is an increased likelihood of collisions occurring between cyclists and traffic, as such the safety has been given a -2 score. This technique allows the cyclist to progress through the red traffic signal without being provided with a dedicated cycle aspect. It is envisaged that a sign to communicate the allowance of cyclists to pass through the red would be needed. Pedestrian safety, particularly of partially sighted and blind pedestrians, could also be compromised as a result of cyclists being allowed exemption from a red signal. Low scores were also given as a result of the additional changes needed in UK legislation and guidance as well as the costs for designing and trialling this scheme.

The second variation of this technique is allowing cyclists to pass through a red traffic signal, but additionally supplying a separate green symbol aspect for cyclists at specific sites to illustrate where this manoeuvre is allowed. This technique was still considered to introduce greater safety hazards for cyclists, and an increased likelihood for conflict with vehicles, however due to the locations being selected on a case by case basis, there were less perceived safety problems with regard to conflicts between cyclists and pedestrians. Only implementing this at selected locations and incorporating a green cycle symbol aspect still has a similar impact for costs needed for trialling this scheme.

The final technique that has been included in the worst performers was the use of uncontrolled cyclist crossings for use at junctions, so that cyclists could by-pass the signals by crossing the minor roads without a signal controlled phase. This technique scored poorly as there are inherent safety concerns when considering an uncontrolled crossing in comparison to a signal controlled crossing. It was assumed that this technique would involve cyclists and pedestrians sharing the footway and the crossing space, this caused particular concern when considering blind and partially sighted pedestrians. It was also considered that this approach would only be a viable option for a low cyclist flow.

7.3 Best Techniques for Cyclists

The determination of the best overall techniques for cyclists only was based upon the total score from the cyclist theme. In order for a technique to qualify the total score had to be 20 or over. The top ten techniques were identified and are listed below along with the total score; the rationale behind by the scores will be discussed in detail for each technique.

The top ten scoring techniques were:

- **ID15:** Cycle bypass lane for straight ahead movement cycles at T intersection (within carriageway) (22)
- **ID12:** Cycle bypass lane for left turning cyclists (signal controlled) (18)
- **ID30:** Dwell on all red (*derived from Dwell on green*) (18)
- **ID10:** Advanced cycle Stop Lines (ASL) (16)
- **ID21**: Coordination of signals for cyclist progression “green wave” (16)
- **ID44:** Straightening staggered toucan crossings, make into a single phase (16)
- **ID3:** Separate cycle phases with cyclist signal aspects (15)
- **ID5:** All round cycle stage (red to traffic) “bike scramble” (on street) (14)
- **ID18:** Coloured cycle lane (one) (14)
- **ID43:** Priority for cyclists in inclement weather (14)

The cycle bypass lane for the straight ahead movement of cyclists at T-intersections (within carriageway) was the top scoring facility for cyclists and the signal controlled left turn bypass the second highest scoring method. The reason why the by-pass lanes scored so highly are the that the methods can be used for all types of cycle flow and will improve behaviour and compliance of cyclists, especially the straight ahead as there will be no requirement to stop and therefore no delay. Furthermore, the bypass will provide a reduction in the distance required to perform the manoeuvre and therefore reduce deviation.

Dwell on green scored well for cyclists because it scored the maximum +2 for the beneficial effects it will have on capacity, waiting time, chance of stopping, priority over others and attractiveness. In addition, it scored the maximum score for high and predicted levels of cycle growth as the option works well with higher levels of cyclist flow. By converting this technique to dwell on all red, the capacity and delay benefits have not been lost, instead they have been shared amongst all road users rather than focussing on the cyclists. The Dwell on all red technique will also have a positive effect on cyclist safety, comfort and behaviour.

Advanced cycle stop lines also scored positively (16), which is to be expected considering the well documented benefits to cyclists, including priority over others, safety and legibility.

Coordination of signals for cyclist progression “green wave” (16) scored highly primarily based on the fact that cyclist will encounter less delay and the reduction in the chance of stopping. As the method provides cyclists with priority it is not surprising it scores well and the only elements that do not score in the positive are deviation and capacity which received a neutral score.

Straightening staggered toucan crossings to make a single phase (16) is within the top ten for cyclists due to reduced chance of stopping (only have to stop once) and the major positive effect on legibility. It also has a positive effect on the delay waiting time and increases the capacity for cyclist movements. The only elements that do not score in the positive are safety and priority over others as there is no change in the possible conflict points and priority is not altered, both received a neutral score.

Separate cycle phases with cyclist signal aspects (15) scored well with a maximum score +2 attributed to increased legibility, safety, attractiveness, comfort, behaviour and compliance. This is due to the fact that the method will negate all conflicts with motor vehicles with cyclists having their own protected phase. The method did score negatively for one element, this being low cyclist flows as the option is not cost effective for a low number of users which could lead to abuse by other road users.

The on-street bike scramble (14) scored highly because it provides shorter routes through the intersection, increased attractiveness and comfort for cyclists. It scored a minor positive on the majority of other elements except for priority over others and chance of stopping which received a neutral score. There was minor negative score assigned for waiting time as an additional phase will need to be added to the cycle.

Coloured cycle lane (one) (14) scored well based on the fact that it was assigned maximum positive scores for its proven safety record and increased legibility. As this technique can be utilised in any situation for any level of cyclist flow it scored maximum positive for all flow levels. The method did score a minor negative result for priority over others owing to the fact that the cyclists route is predetermined through the intersection.

The final top ten scoring cyclist technique is priority for cyclists in inclement weather (14) which scored well as this method will work well for all levels of cyclist flows. Furthermore, it assigns priority to cyclists and will reduce delay and chance of stopping during poor weather conditions.

7.4 Worst Technique for Cyclists

When determining the worst techniques for cyclists only those scores that were zero and under were considered. A negative score means that the introduction of the method will result in a worse situation than the assumed base scenario of standard width cycle lane on the approach to an intersection under signal control with standard red / amber / green traffic signals. Any positive score, no matter how minor, would result in a better situation than the base scenario and therefore cannot be considered as worse for cycles.

Only three techniques attained a negative score for cyclists, which were:

- **ID40:** uncontrolled cycle crossing (-5)
- **ID24:** Two stage right turn (-2)
- **ID25:** Two stage right turn (banned from right traffic lane) (-1)

Uncontrolled cycle crossings scored badly because of the increase in potential conflicts due to the unprotected nature of the crossing, reduced priority over other users, reduced comfort and the fact that the method would not be suitable for high levels of cyclists.

The two stage right turn techniques scored badly as these methods would increase the distance cyclists will need to travel to complete the manoeuvre, reduced levels of legibility with cyclists potentially unsure of required movements, increased waiting time and that these systems cyclists will have to stop twice. This in turn may lead to poor compliance and behaviour which may negate some of the safety benefits accrued by implementing the measure.

7.5 Key Themes: Capacity

Capacity has been considered a key theme throughout this project, as an effective balance must be sought by practitioners to ensure that prioritising one mode of transport does not have an excessively negative impact on another. In this case particular attention was paid to how these proposed techniques influenced the capacity of pedestrians and other road users (including public transport). The primary impact on capacity from these schemes is to that of vehicle throughput; as a result these figures have been used to determine the best and worst schemes from a capacity point of view.

From the assessment stage it was discovered that there are techniques that returned a low score indicating that overall capacity would suffer a notable decrease and techniques that showed an increased capacity was likely by returning a high score. The vehicle capacity scores revealed the following five schemes that are likely to return a notable capacity gain.

- **ID14:**Cycle bypass lane for straight ahead movement cyclists at T-intersection (onto footway) (+1)
- **ID15:**Cycle bypass lane for straight ahead movement cyclists at T-intersection (within carriageway) (+1)
- **ID16:**Cycle tunnels (+1)
- **ID40:**Uncontrolled cycle crossing at junctions (+1)
- **ID48:**Conversion to continental style roundabout (vehicle flows under 10 - 15,000) - (+1)

In all these techniques listed above the capacity of vehicles was positively influenced as the technique does not require an alteration to the signal sequence, green splits or the cycle time in general. More importantly none of these schemes require giving cyclists their own phase and therefore do not increase the lost time to vehicles.

The assessment stage highlighted the following schemes as having a negative impact on vehicle capacities through junctions. These were all scored as either -1 or -2 for the capacity criteria to reflect the perceived level of the capacity impact.

- **ID3:** Separate cycle phases with cyclist signal aspects- (-2)
- **ID8:** Pre signal for cyclists for early start (cycle aspect only) (-1)
- **ID9**: Pre signal for cyclist for early start (separate red/amber/green signal head) (-1)
- **ID21:** Coordination of signals for cyclists progression "green wave" (-2)
- **ID30:** Dwell on all red (derived from Dwell on green) (-1)
- **ID44:** Straightening staggered Toucans, and make a single phase (-1)
- **ID45:** Pre-timed maximum timer on Toucans (-1)
- **ID47:** Two green periods per cycle for cyclists (to be used with separate cycle phases) (-1)

As expected most of these schemes involve taking a proportion of the cycle time away for vehicular traffic and giving it to cyclists, the result of which is decreased capacity for vehicles. The exception to this is the technique that proposes that pre-timed maximum timers should be used on all toucan crossings. This does not take time away from vehicular traffic, but results in priority changing to cyclists with a reduced delay. This will result in more cyclist stages per unit of time, and thus reduce the vehicular throughput at the crossing. However, scoring poorly on the capacity criteria should not be taken as meaning that the technique offers no potential gains. Instead what is being shown is that these techniques need to be implemented strategically where vehicle capacity can cope with a marginal reduction. An example could be the dwell on green for bicycles technique, where cyclist demand outweighs vehicular demand this is an appropriate strategy to employ, resulting in a better performance overall, despite being at the cost of vehicle capacity. The dwell on red version of this technique that is recommended in this report reduces the penalty to vehicle capacity

7.6 Key Theme: Safety

Safety has been considered a key theme throughout this project not only for cyclists but also any effects the techniques may have on pedestrians and other road users. The techniques considered for discussion were mainly based on the safety score for the themes of cyclists, pedestrians and other road users. In order for a technique to qualify a score of +2 or -2 had to be achieved in at least one of the above mentioned themes. It should be noted that none of the techniques scored +2 for pedestrian or vehicle safety, which is not completely unexpected as cyclists are the priority for all these techniques. Firstly, the most positive scoring techniques for safety of cyclists will be discussed.

A cycle phase which involves the specification of cyclist only phases separately controlled to vehicular traffic received a +2 score. The reason being that by having a separately controlled phase removes all possible conflict between cyclists and motor vehicles, thereby significantly reducing the likelihood of collisions and the severity of injuries sustained as in theory only cyclist to cyclist collisions will occur. The introduction of a separate cycle phase is likely to reduce the likelihood of conflict for pedestrians and other vehicles (both scoring +1).

Advanced cycle stoplines have a proven safety record in both the UK and around the world with regard to cyclist collisions with a reduction of between 25 – 35percent. The introduction of an ASLis also likely to reduce the likelihood of conflict for pedestrians and other vehicles (both scoring +1) due to the greater separation of the two modes at the conflict point.

A signal controlled left turn bypass received a excellent safety score for cyclist safety as it is negating the conflict with motor vehicles for this movement of cyclists. The introduction of signal controlled left turn bypass will also likely to reduce the likelihood of conflict with other vehicles (scoring +1). Pedestrian safety remains unchanged by this technique as the cyclist movement is signal controlled. It is recognised however, that the inclusion of the by-pass lane may have an impact on where pedestrian facilities can be located at the intersection.

A single coloured cycle lane through an intersection scored highly with a proven safety record from Denmark with a ten percent reduction in collisions and nineteen percentreduction in injuries for cyclists. Furthermore, there is slight increase in safety for other motor vehicles (+1) when a single lane is implemented. This increase in safety can be attributed to motorists becoming more aware of possible cycle movements and yielding to cyclists and slowing before entering the blue marking area. Conversely, this is the opposite for when there are two or more blue lanes at intersection, the same

Danish study showed there to be an increase of twenty three percent in collisions and forty eight percent in injuries and for two lanes, and for four lanes increases of sixty percent of collisions and one hundred and eighty nine percent in injuries were recorded. The increases were predominantly in rear-end-shunt collisions among motor vehicles and red-light running motorists, as such two or more blue cycle lanes were attributed a safety score of -2 for other road users while receiving a +1 for cyclist safety.

The final technique to score a +2 for cyclist safety was the two-stage right turn with cyclists banned from the vehicular right turn lane. The scheme attained such a high score for similar reasons as the left-turn bypass in that the technique would negate the conflict between right turning cyclists and motor vehicles and between right turning cyclists and vehicles travelling in the opposing direction that are controlled under the same phase.

The next few paragraphs describe those techniques that scored a -2 for cyclist, pedestrian or other road user safety.

Four of the six identified ‘proceed on red’ techniques received the maximum negative score for cyclist safety. The four techniques include two for left turns and two for straight ahead where there is no defined cycle lane through the intersection. The reasoning behind the maximum negative score is that by allowing the movements through red there would be an increase in the number of potential conflict points for the cycle movements, although cyclists would be required to treat the junction as ‘give way’ rather than being given priority. The four techniques also scored poorly for both pedestrian and other road user safety. For interest, the two techniques where a designated lane is provided for the ‘passing through red’ movement were not attributed the maximum negative value as it was concluded that the defined route would provide increased awareness and visibility of cyclists.

The final poorly scoring technique for safety is the uncontrolled cycle crossing at intersections. This was attributed a -2 for cyclists and -1 for pedestrians as the cyclist movement is no longer protected under a separate crossing phase and thereby cyclists will be more at risk and increasing the likelihood of collisions with motor vehicles.

7.7 Key Theme: Delay to Vehicles

Delay for all road users has been considered as a key theme when carrying out the assessment of the various techniques. This section focuses on the delay that is imposed on public transport (buses) and private motor vehicles. For simplicity, commercial vehicles were considered within the private motor vehicles category as they do not have dedicated lanes or facilities in the same way as public transport vehicles do. Naturally, as with capacity, the schemes that take time away from the vehicle stage or prioritise the stage sequence for the gain of separately controlled cyclists will have a negative impact on the vehicle delay. The following techniques have been highlighted as schemes that would cause additional delay to vehicles:

- **ID1:** Intergreens designed for cyclist speed
- **ID2:** Intergreens extended using detection
- **ID3:** Separate cycle phases with cyclist signal aspects
- **ID5:** All round cycle stages (red to traffic) “bike scramble” with cyclists on street
- **ID6:** All round cycle stages (red to traffic) “bike scramble” with cyclists off street
- **ID7:** All round cycle and pedestrian stage (red to traffic) “bike scramble”

- **ID8:** Pre signal for cyclists for early start (cycle aspect only)
- **ID9:** Pre signal for cyclist for early start (separate red amber green signal head)
- **ID21:** Coordination of signals for cyclists progression "green wave"
- **ID23:** Selected vehicle priority for cyclists (similar to bus priority)
- **ID30:** Dwell on all red (derived from Dwell on green)
- **ID37:** Junction cycle time reduction (90 second maximum)
- **ID38:** Channelization of left, right and ahead cyclists
- **ID39:** Cycle tracks converted to lanes on final approach to intersections
- **ID44:** Straightening staggered Toucans, and make a single phase
- **ID45:** Pre-timed maximum timer on Toucans
- **ID47:** Two green periods per cycle for cyclists (to be used with separate cycle phases)

It is expected that a scheme designed for cyclists would cause a disbenefit to other road users, however there are also five techniques which have been given positive scores indicating that an expected improvement in delay for vehicles could be expected by implementing this technique. These schemes are:

- **ID14:** Cycle bypass lane for straight ahead movement cyclists at T-junction (onto footway)
- **ID15:** Cycle bypass lane for straight ahead movement cyclists at T-junction (within carriageway)
- **ID16:** Cycle tunnels
- **ID40:** Uncontrolled cycle crossing at junctions
- **ID48:** Conversion to continental style roundabout (vehicle flows under 10 - 15,000pcu/day) per day

7.8 Key Theme: Delay to Cyclists and Pedestrians

In order to consider the delay effects on cyclists and pedestrians, the scores for pedestrian delay, cyclist delay: waiting time and cyclist delay: chance of stopping were summed to give an indication as to the overall delay impact on these road users. This exercise gave three distinct schemes that gave a notable positive impact on pedestrian and cyclist delay and schemes that resulted in a notable delay disbenefit.

The techniques that are likely to give a positive improvement for pedestrian and cycle delay are:

- **ID16:** Cycle tunnels
- **ID30:**Dwell on all red (derived from Dwell on green)
- **ID45:** Pre-timed maximum timer on Toucans

The techniques that are likely to give a notable disbenefit for pedestrian and cyclist delay are:

- **ID3:** Separate cycle phases with cyclist signal aspects
- **ID5:** All round cycle stages (red to traffic) “bike scramble” with cyclists on street
- **ID6:** All round cycle stages (red to traffic) “bike scramble” with cyclists off street

- **ID24:** Two stage right-turn (major / complicated intersections)
- **ID25:** Two stage right-turn - cyclists banned from right traffic lane

The separate cycle phases with cyclist aspects technique showed an increased delay to illustrate the likely increase to the cycle time. The cycle time is likely to increase because the additional cycle phases may need to be run in separate stages from other existing phases. The increase in the cycle time length would be expected to result in cyclists having to wait longer before they received green. Likewise, pedestrian phases would also suffer increased delay as the cycle would take longer to return to their stage(s). However it should be noted that this technique is primarily aimed at supplying greater degrees of comfort to the cyclists and increased safety and compliance. All round cycle (scramble) stages incorporate additional lost time into the cycle time, and therefore result in increasing delay.

The final techniques in this category relate to the methods that require cyclists to make a two stage turn rather than simply turning right at a junction. This technique would be implemented where making a right turn is particularly hazardous and would be incorporated for safety reasons. The delay to cyclists is unavoidable; however it is counterbalanced by increased safety.

7.9 Key Theme: Value for Money

Value for money has been judged by considering the benefits the technique offers to cyclists as well as considering the costs that would be required to design, equip and install. Schemes with a good score for this theme show that they offer the best improvements for the least cost outlay. The top five techniques offering good value for money are:

- **ID30:**Dwell on all red (derived from dwell on green)(29)
- **ID10:** Advanced cycle stop lines (27)
- **ID45:** Pre-timed maximum timer on Toucans (25)
- **ID18:** Coloured cycle lanes through intersections (one) (25)
- **ID17:** Elephants feet markings through intersection (24)

The Dwell on green technique was highlighted as a technique that did not require a large outlay of costs to install; this has not been changed by converting this technique to dwell on all red. It is likely that this technique will require reconfiguration of the crossing controller, and potentially the addition of some detection equipment.

Advance stop lines are already widely used, and their benefits are well documented in both UK and overseas publications, they have scored well as they require a relatively modest investment to install. Coloured cycle lanes and elephants feet markings require a similar investment to install however they are not as widely used, and their benefits are not as well documented. Pre-timed maximum at toucan crossings offers significant delay savings to cyclists and only requires an engineer’s time to implement on site. This technique would however require policy and guidance changes as pre timed max is currently only used in isolated instances.

In addition to the techniques that offer the best value for money the assessment identified five schemes that returned results suggesting that they offered poor value for money. These schemes offered only limited benefits for cyclists for a medium or high cost investment. These techniques are:

- **ID40:** Uncontrolled cycle crossing at junctions (-6)
- **ID16:** Cycle tunnels (-1)

- **ID32:** Cyclists allowed to turn left on red at specific intersection (cycle symbol green / red light during pedestrian phase) (1)
- **ID35:** Straight ahead for cyclists on red (cycle symbol green / red light during pedestrian phase) at specific 3 arm intersection (1)
- **ID41:** Speed bumps and plateaus (1)

Uncontrolled crossings at junctions do not offer significant benefits to cyclists, as discussed in earlier sections there are safety implications for imposing an uncontrolled crossing movement on the cyclists. This impact is coupled with the fact that the installation of these crossings requires civil engineering work that can be costly in materials as well as time and costs for traffic management.

Cycle tunnels are one of the most expensive schemes proposed in this project. This expense is not counterbalanced by the benefits, despite being a good scheme for delay and capacity for cyclists. Cycle tunnels suffer from the same problems as pedestrian subways in terms of poor perceived personal security and environment, as well as increased detour and lack of legibility. The left turn on red and straight ahead on red schemes both introduce safety concerns whilst also requiring an investment for additional signalling equipment for cyclist control or communication of the exemption.

7.10 Key Theme: Legislation, Regulation and Guidance

The impact that changes to legislation and regulations are largely dependent on whether the scheme is already in use in the UK or would be a new technique. It is obvious from the Regulation and Legislation theme table what methods would be innovative from a UK perspective as these have generally scored a total of -8 for this theme. However, just because a technique has scored poorly it should not be discounted for consideration for trial and possible future implementation.

Likewise, those methods already in use in the UK will have scored a relatively positive score which will have added to the overall aggregate score. It was evident during the assessment process that some existing methods or amendments to the working of existing methods will require alterations to the TSRGD, DRMB and other highway guidance documentation. As detailed in the previous paragraph the requirement to alter existing documentation or provide new guidance should not discount a potentially beneficial technique.

7.11 Suitability for Trials

Some of the techniques listed in the assessment section are already implemented on the UK road network, and therefore do not require further trialling. Naturally any variations of these schemes would benefit from research before extensively implementing.

As highlighted in the discussion of safety as a key theme a selection of these schemes have potential safety implications, and as such may not be suitable for trial on the public road. Specifically these are the techniques which require road user education and promotion of regulation changes or where a mindset change would be required for safe operation. An example of a scheme that falls into this category would be the left turn on red for cyclists.

The following schemes have been highlighted as cost effective to trial:

- **ID18:** Coloured cycle lanes through intersections (one)
- **ID19:** Coloured cycle lanes through intersections (two or more)
- **ID26:** Road markings to highlight loop detectors

- **ID37:** Junction cycle time reduction (90 second maximum)
- **ID45:** Pre-timed maximum timer on Toucans
- **ID47:** Two green periods per cycle for cyclists (to be used with separate cycle phases)

These schemes tend to just require alterations to existing equipment or the addition of road markings. Cost effectiveness for trial also considered the disruption for installation and decommissioning of the proposed trial scheme. These costs were estimated by practitioners as seeking accurate costs for each trial was beyond the scope of this project.

The dwell on green technique was not included in the list of techniques suitable for trial as it scored poorly when considering the related criteria during the assessment stage. It was foreseen that reversing the priority on a toucan crossing away from what is commonly seen in the UK, has the potential for increasing the likelihood of pedestrian accidents. As already discussed in this report, it is thought that there would be an increased chance of pedestrians rushing towards the crossing in order to complete their crossing prior to the loss of right of way. Similarly the dwell on green technique is only suitable for trial at a limited number of crossing sites, as a high cyclist to vehicle ratio is required. By modifying this technique to operate as dwell on red the suitability for trial is greatly improved. Dwell on red is already used for signal controlled junctions during quiet periods, and it is not expected to increase the likelihood of pedestrian accidents.

8

9 Summary

The discussions put forward in Section 8 highlight the top scoring techniques from the assessment stage. Those techniques that scored well are generally those that provided priority to cyclists whilst improving safety and legibility, it is therefore unsurprising that these should return such positive assessment scores.

The various sections in the discussion show that some techniques have proven to be positive when considering one criterion, yet then show notable negative aspects when considering a different criterion. This has emphasised that the selection techniques to assist cyclists at traffic signals is a balance between the various road users and the associated implementation costs.

The best overall category indicates which techniques are the best when considering the assessment as a whole; however a simple comparison of total scores has a limitation in that a five point scale does not allow the assessment to take into account the relative importance of the different criteria. For example, cyclists safety can't really be compared with cost to update legislation, however, if safety is given a +2 score to indicate that the scheme offers good overall safety, this can then be neutralised in the total score by adding a -2 for one or more of the categories within the legislation theme. As a result of this the best overall category gives a good idea of the best schemes, however this should be considered alongside the other categorical breakdowns.

Many schemes scored average scores in the various categories, and as a result some didn't feature in the discussion at all as they never appeared as either the best or worst technique when considering one attribute. These schemes should not be ignored, however, as their implementation on suitable stretches of carriageway could still produce positive results.

A common low scoring criteria throughout the assessment has been the changes required to the TSRGD, other highway engineering guidance and the Highway Code. The costs associated with updating these documents is likely to be a one off cost that could make a number of schemes possible, and would have an impact on the relative scores between the techniques. It could be expected that some of the techniques that are proven overseas but are not currently covered by UK legislation would score better. Examples of these schemes would be the Pre green signal for bicycles and separate signals for bicycles. However, change to the TSRGD, or even the Highway Code, is a very time consuming and costly process and it is not done often.

Arguably a more indicative category to consider when seeking the best scheme for cyclists would be by simply comparing the overall scores for each technique for just the cycle theme. This gives a thorough appraisal of the technique without negatively biasing it with policy change costs or equipment costs. This measure gives a truer picture of what constitutes the better schemes for cyclist safety and comfort, the logistical hurdles can then be considered separately. To help give an idea of how the best schemes for cyclists perform when factoring in installation costs, equipment costs and land costs, the value for money key theme has been considered. This theme looks at the balance between assumed financial outlay against benefits to cyclists.

The 'Dwell on red (derived from dwell on green)' technique was not scored as part of the assessment process however it would be considered to have scored similarly. The Dwell on Green technique featured in the Top 5 best overall category, the top performers from best for cyclist category and the top 5 schemes when considering value for money. This gives a strong indication that this technique is one of the best all round solutions to come out of the assessment.

ASLs and the technique looking to introduce a single coloured cycle lane through a junction feature on the top 5 overall and the best 5 when considering value for money.

The technique looking to straighten staggered toucans features in both the best schemes for cyclists as well as the best overall. The reason that it does not feature on the best when considering value for money is that to straighten a staggered crossing requires expensive civil engineering works as well as significant traffic management costs. In comparison many of the schemes listed in the assessment section do not require a large outlay of cost as they require reconfiguration of existing equipment or additional road markings. This scheme is still considered a well rounded solution.

To emphasis the point of selective implementation both the dwell on green and straightening of staggered crossings also feature on the worst performer's lists when considering capacity and delay of vehicles.

When considering the reoccurring worst performers it is clear to see that three main techniques stand out. Firstly, the use of uncontrolled crossings to allow cyclists to bypass signals when at a cross roads has appeared on the worst performers list for safety, worst overall, worst for cyclists and worst value for money. Cyclists being allowed to turn left on red appeared on the worst list when considering safety and worst overall, however it should be noted that this idea has a number of iterations involving marginal design changes and these have helped it score better in various categories. All round cycle stages "scramble stages" have also appeared on the worst overall list, as well as the worst when considering delay.

The assessment has shown that no one scheme has returned a perfect score, as expected there are positive and negative impacts for the introduction of any of these schemes. There are clear front runners that offer many benefits without incurring extensive costs. Likewise there are schemes which have not performed so well, some of the reasons for these are that they offer relatively modest benefits, introduce additional safety concerns, or require extensive investment to implement.

10 Recommendations

The techniques detailed in the assessment results chapter which attained positive scores and were highest scoring in the various discussions will form the majority of the methods recommended in this chapter. Each technique will be examined alongside the reasons for recommendation. Some of these techniques require further investigation before full cost benefit analysis could be quantified. However by trialling these techniques strategically on street will help understand the benefits further. It is understood that to implement some of these techniques, local highway authorities will require authorisation from the Department for Transport, others however may need changes to the TSRGD. However future aspirations are to incorporate techniques with a proven success rate into legislation and guidance documents. It is therefore recommended that a collaborative effort is made between the Department for Transport and local authorities to trial the following techniques at suitable sites. These techniques should be considered carefully for their suitability for each on street application.It is envisaged that techniques with successful outcome would form a toolkit for transport practitioners to use when considering options for cyclists at traffic signals.

10.1 Advanced cycle stop line (ASL) (technique ID 10 and 11)

ASLs featured in four of the assessment discussion sections, thereby proving this technique's worth as a valid technique for aiding cyclist movements through a signalised intersection. ASLs were the best overall technique in that they provide good benefits for cyclists whilst having little to no effect on motorised traffic. ASLs have a proven safety benefit for cyclists and subsequently offer value for money.

Therefore, it is recommended that ASLs continue to be supported and promoted as a notable technique for aiding cyclists through signalised intersections.

In addition, it is recommended that the TSRGD is altered to allow the use of staggered ASL at T intersection where there is no cyclist right turn movement. The overall score for staggered cycle stop lines was 28 and is implementation could prove beneficial in certain situations. A trial could be undertaken to ascertain the effectiveness of this technique for different cyclist flows.

10.2 Coloured cycle lanes (one) (technique ID18)

A single coloured cycle lane through an intersection also featured in four of the assessment discussion sections. This method was in the top five overall techniques and the top ten for cyclists. In addition, they have a proven safety record and used frequently throughout parts of Europe. Lastly, a single coloured lane has been highlighted as a cost effective method.

Therefore, it is recommended that this technique is taken forward to trial to ascertain its potential benefits in the UK. Changes would be needed to local guidance to trial this technique.

The research has shown that where there is more than one coloured cycle lane there is an increase in collisions between motor vehicles. The reason being that motorists become more confused where there is more than one lane, and subsequently resulting in an increase in rear end shunt incidents. Undertaking a trial on-street of this option may not be realistic. Therefore an off-street trial for more than one could be considered prior to a street trial. Also, a more comprehensive study could be undertaken with further contact with relevant bodies in Europe.

10.3 Dwell on all red (derived from dwell on green) (technique ID30)

This technique appeared as a positive method in three of the assessment discussion areas as a way of aiding cyclist movements off carriageway. This method was also highlighted by the assessment team as one of the promising and innovative solutions that can be adopted in the UK. The method is cost-effective and has the potential to provide numerous benefits to cyclists and also pedestrians.

It is recommended that this method is taken forward to trial. If it is implemented as Dwell on green,it is imperative that the technique is trialled at a suitable location where there is a high cyclist to vehicle ratio to minimise the delay and capacity problems that are known to be linked with this technique.

As already outlined in the discussion section of this report a potential alternative to the dwell on green technique is to configure the crossing to rest on all red in the absence of any demand. This will reduce the time required to move to either the pedestrian / cyclist stage or to the traffic stage. Dwell on all red might also offer safety benefits. It is foreseen that there might be potential conflicts with dwell on green if cyclists approaching the green signal continue crossing the road as the signals change to serve a vehicle demand. There is no facility to hold the cyclist green in this instance until the cyclists has completed their crossing. There was no mention of this type of conflict in the literature researched for this project.

Dwell on all red is already used in the UK at signalised junctions during periods of low demand. The dwell on all red variant of this technique offers many of the benefits of Dwell on green whilst also combating the potential safety concerns of pedestrians and cyclists rushing on the approach to the crossing.

10.4 Pre- timed maximum for toucans (technique ID45)

This technique scored well for the overall aggregate total and was marginally outside the top ten for cyclist only benefits. The cost implications are relatively minor and as such could easily be taken forward to trials. This was another of the new techniques discovered in the literature review that the assessment team highlighted early on as a promising and innovative solution.The use of pre-timed maximums needs to be carefully considered as it can cause significant delay to roads with a high traffic demand, therefore if it should not be installed where both the cycle demand and traffic demand is high.

It is recommended that this method is taken forward to widen the scope of where they are currently used.

10.5 Bypass for straight ahead movements within the carriageway (technique ID15)

This bypass option is only one that achieved two scores in the top ranks of the assessment results. This was found to be the most beneficial method for cyclists and also achieved a capacity and delay improvement for motor vehicles.

This method is already in use in the UK but was found to have limited details provided in the UK guidance. As such it is recommended that the relevant documents are updated to highlight the benefits that this technique can provide for cyclists.

10.6 Bypass for left turning cyclists (signal controlled) (technique ID12)

This bypass option was found to be one of the most beneficial methods for cyclists, while at the same time having no effect on the capacity and delay for motor vehicles.

This method is already in use in the UK but was found to have limited details provided in the UK guidance. As such it is recommended that the relevant documents are updated to highlight the benefits that this technique can have for cyclists.

10.7 Bypass for ahead movements within the footway (technique ID14)

This bypass option was found to be one of the most beneficial for improving capacity and delay for motor vehicles. In addition, it was marginally outside the top ten for cyclist only benefits.

This method is already in use in the UK but was found to have limited details provided in the UK guidance. As such it is recommended that the relevant documents are updated to highlight the benefits that this technique can have for cyclists.

10.8 Intergreens designed for cyclist speed (technique ID1)

This scored highly in the overall aggregate score and should already be in use within the UK. However, it is considered that this not universally adopted.

Therefore, is recommended that technique for extension of intergreens is reviewed both at sites and within the existing documentation to ensure that it is appropriately specified.

10.9 Intergreens extended by detection (technique ID2)

This scored highly in the overall aggregate score and is marginally outside the top ten for cyclists. This method may already be in use within the UK. However, it is considered that this not universally adopted.

Therefore, it is recommended that this technique for extension of intergreens is reviewed both at sites and within the existing documentation to ensure that it is appropriately specified for sites where excessive delay could be experienced by vehicles when compared against standard intergreen extension, this could be particularly beneficial at large intersections.

10.10 Straightening staggered toucans and making into a single phase (technique ID44)

This technique scored highly for cyclists and as a by-product would also beneficial to pedestrians. As all the equipment is already in use in the UK there would be no difficulty in adopting this practice as a widespread policy. This was another of the new techniques discovered in the literature review that the assessment team highlighted early on as a promising and innovative solution.

It is recommended that this technique is trialled to ascertain its potential benefit to cyclists and pedestrians and disbenefits to motor vehicles. Due to the expensive nature of trialling this system in the first instance the trial should be in the form of a simulation.

10.11 Conversion to continental roundabout (technique ID48)

This technique was identified as one of few that may improve capacity for motor vehicles whilst at the same time providing a better facility for cyclists, as long as vehicle flows are not excessive.

It is recommended that the Traffic Advisory Leaflets and associated guidance documents are updated to ensure that this technique is adequately described so relevant decision makers are aware of the option and its associated benefits. In addition, in order to determine threshold of the number of vehicles where capacity and delay worsens, simulation trials could be undertaken when compared to signalised intersection.

10.12 Road marking to highlight loop detectors (technique ID26)

This technique had a high overall aggregate score due to its potential benefits, lack of impact on pedestrians and motor vehicles and value for money due to limited expenditure of installation.

It is recommended that a new road marking is developed and trialled at existing sites which experience problems with cyclist detection for inductive loops to ascertain the road markings effectiveness. If successful then consider including the road marking within the TSRGD as an authorised diagram.It is, however, appreciated that as above ground detector technology progresses the numbers of sites still using inductive loop technology is likely to reduce. It is therefore also recommended that continued research is focussed on detector technologies with associated issue of guidance, educating practitioners as to the relative advantages and disadvantages of loop based technology in comparison to above ground detection.

10.13 Trixi mirrors (technique ID46)

This technique to make cyclists more visible to drivers at traffic signal controlled intersections is already in use in the UK. Transport for London have trialled this technique on parts of the London Cycle Superhighway, likewise the use of Trixi mirrors overseas and their benefits are well documented.

It is recommended that Trixi mirrors are more widely trialled on UK roads and further studies are conducted to establish how far reaching the benefits of installation are when considering accident data. It is highlighted in section 6.9 that Trixi mirrors currently require specific approval or an alteration in the TSRGD. For this alteration to be made to current regulations, more needs to be known about the use of these mirrors. To this end a greater number of trial locations on UK roads are required.

10.14 Coordination of signals for cyclists progression "green wave" (technique ID21)

The "green wave" for cyclists method was considered to be one of the most favourable for cyclists after the assessment process. The system has already been implemented in both Denmark and the Netherlands and as such has a proven success record. Because of the requirement of high cyclist / vehicle flows it may have limited usefulness within the UK. This was another of the new techniques discovered in the literature review that the assessment team highlighted early on as a promising and innovative solution.

It is recommended that the "green wave" for cyclists is taken forward for potential use in the UK. Consultation should be undertaken with the relevant authoritative bodies where this has been used in Europe, to ascertain levels of service for both cyclists and other vehicles. Following this the impacts to vehicle and cyclist capacity and delay can be assessed for potential sites by conducting traffic signals modelling using a software product such as TRANSYT. On completion of this investigation the methodology could be trialled at a suitable site, the trial costs should be relatively inexpensive (equipment wise)

10.15 Separate phase for cyclists (technique ID3)

This method was one of the highest scoring for the potential benefits to cyclists both in terms of safety and legibility and attractiveness and comfort. However, it did score poorly for the potential detrimental effects both on public and private vehicles in terms of capacity and delay. This was another of the techniques discovered in the literature review that the assessment team highlighted early on as a promising and innovative solution.

Because of the significant potential benefits for cyclists this technique should be investigated further. However, owing to the complexities and expense of creating a trial site in the UK it is recommended that consultation is undertaken with the relevant authoritative bodies where this has been used in Europe, to ascertain impacts on both cyclists and other vehicles. From this consultation it will be possible to determine levels of cyclist and traffic flow where this approach could be implemented and a pilot site identified where there is a high modal share for cyclists.

10.16 Two green periods per signal cycle for cyclists (technique ID47)

The two green periods for cyclists achieved a good overall aggregate score based on the potential benefits to cyclists and good results with regard to cost and other implications. The potential application of this method could be restrictive as evidence suggests that in some places where this has been implemented in Europe it was subsequently removed because of the detrimental effects on the vehicular delay.

It is recommended that this option is taken forward for further investigation. Initially this could take the form of simulation trials, possibly utilising micro-simulation, to gain a better understanding of the levels of flow required for the necessity of this method and the potential effects.

10.17 Pre signal for cyclists (aspect or separate red, amber and green signal head) (technique ID 8 and 9)

This was a technique discovered in the literature review that the assessment team highlighted early on as a promising and innovative solution. However, it did not score particularly well, partly as a result of being a new method for the UK and therefore would require changes to the TSRGDand associated guidance documents, and partly because of potential disbenefits for motorised vehicles.

In light of the above the assessment team are of the opinion in that this technique could offer a significant improvement to cyclists and as such further investigation should be performed. This could be in the form of consultation with European countries that already utilise this technique to improve our understanding and ascertain the conditions that it is employed. Furthermore, the technique could be modelled in simulated trials to ascertain its effectiveness using software such as TRANSYT.

10.18 Priority for cyclists during inclement weather (technique ID43)

This was a technique discovered in the literature review that the assessment team highlighted early on as a promising and innovative solution. However, it did not score particularly well because it is a new method for the UK and therefore would require changes to local guidance and practices and associated guidance documents. Added to this are relatively expensive installation costs and the potential disbenefits for motorised vehicles.The majority of the additional costs involved relate to the weather station monitoring equipment that is required for determining when the priority should be operational. It is possible that this equipment could use existing weather recording devises already positioned out on street with some collaboration from all stakeholders. Alternatively the additional cost could be minimised by sharing the weather monitoring equipment between many sites or investigating the possibility of operating one central weather monitoring station for a city. However it should be noted that for large cities such as London one central monitoring station may not provide data that is indicative for weather conditions at all sites.

In light of the above the authors are of the opinion that this technique could offer significant improvements to cyclists and as such further investigation should be carried out. This could be in the form of consultation with European countries that already utilise this technique to improve our understanding and ascertain the conditions that it is employed. Furthermore, the technique could be modelled in simulated trials to ascertain its effectiveness.

11 Capacity analysis of selected recommended techniques

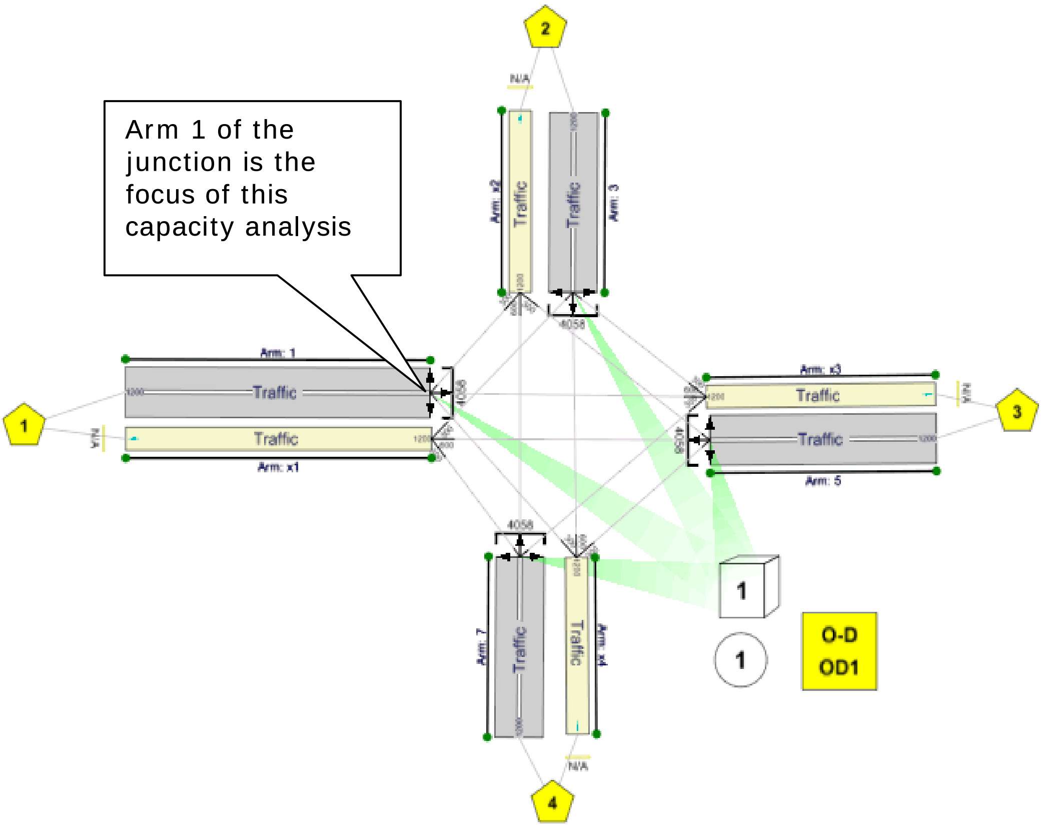
It is understood that capacity of junctions is of critical importance, and that the inclusion of a technique or facility to assist cyclists must not have a detrimental effect on the performance of the junction. Many of the techniques discussed require road space to be reallocated for cycle lanes, and green time redistributed so that cyclists gain priority, it is important therefore that the influence this has on other road users is maintained within acceptable limits. Many junctions in the UK only have limited spare capacity, as some capacity analysis was undertaken to establish how the recommended techniques might influence the capacity of a typical junction. Of the 17 recommended techniques it is only possible to model the capacity influences for five of them. The other techniques are either already implemented on the UK road network or don't have an impact on capacity that is measureable.

Capacity analysis of recommendations

This capacity analysis is based upon typical junction layout, and is not based on any 'real world' sample site. As a result the capacity results can only be seen as indicative rather than being a site specific prediction.

To undertake this analysis a base scenario was configured to offer a comparison to the recommended techniques. The capacity analysis has been carried out for only one arm of the junction unless otherwise stated. The base scenario assumed the following junction details:

- Four arm intersection ;
- Zero degrees gradient;
- Two lanes per approach (each 3.5 metres);
- Cycle lane on each approach leading to a standard ASL (cycle lane 1.5 metres wide); and
- The base scenario assumes a traffic flow of 1200 PCU/ hr on the studied arm of the junction 50 percent of this traffic travels straight ahead, 25 percent turns left and 25 percent turns right.



Using TRANSYT 14 it is possible to establish many result parameters from this junction; however this analysis is going to focus on the capacity of the traffic on Arm 1. The capacity of an approach can also be calculated using the equation below:

Capacity of an approach = (g x s)/C

Where,
g = effective green time (green time + 1 second)
s = Saturation flow of the approach
C = Cycle time of the junction

Webster and Cobbe (1966)

The saturation flow in this capacity analysis is produced using the method outlined in TRL report RR67 (1986) For the base scenario this has resulted in a calculated saturation flow of 2029 PCU/hr for each of the two lanes, therefore an approach saturation flow of 4058 PCU/hr. Saturation flow varies on a site by site basis, as such the RR67 calculation only gives an approximation, for a precise capacity calculation on street measurements of saturation flow would be recommended.

Assuming a 90 second cycle time for the base scenario, and an even distribution of green time the capacity of Arm 1 of this example junction is 902 PCU/hr.

A more detailed report of the base scenario can be found in Appendix B.

Intergreens designed for cyclist speed (ID1)

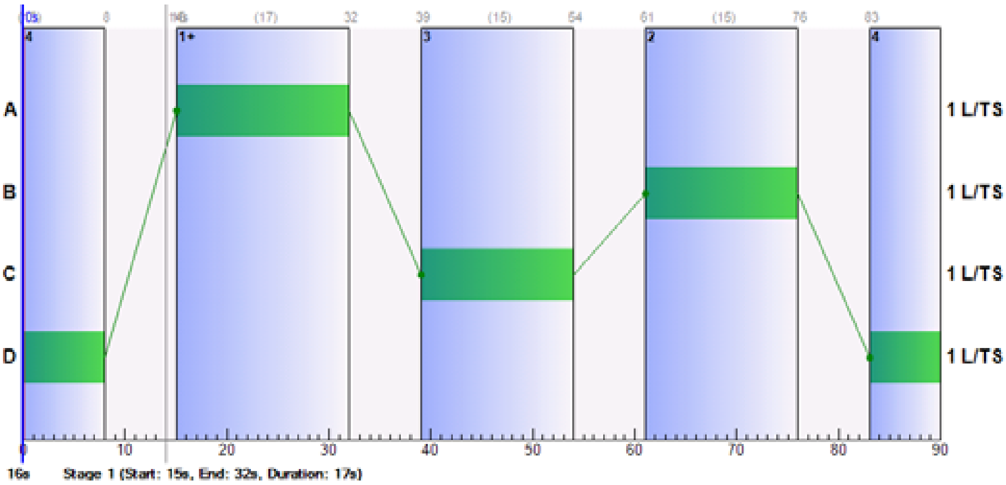
Capacity analysis has been undertaken for this technique. To do this a 7 second intergreen was applied to each stage change in the base scenario for slower cyclists to clear the intersection before the release of conflicting traffic. In this technique cyclists are still sharing road space with other vehicles. The cycle time was kept at 90 seconds, so that the additional intergreen time results in lost time to traffic.

\	A	B	C	D
A	-	5	5	5
B	5	-	5	5
C	5	5	-	5
D	5	5	5	-

Base scenario

\	A	B	C	D
A	-	7	7	7
B	7	-	7	7
C	7	7	-	7
D	7	7	7	-

Increased intergreens



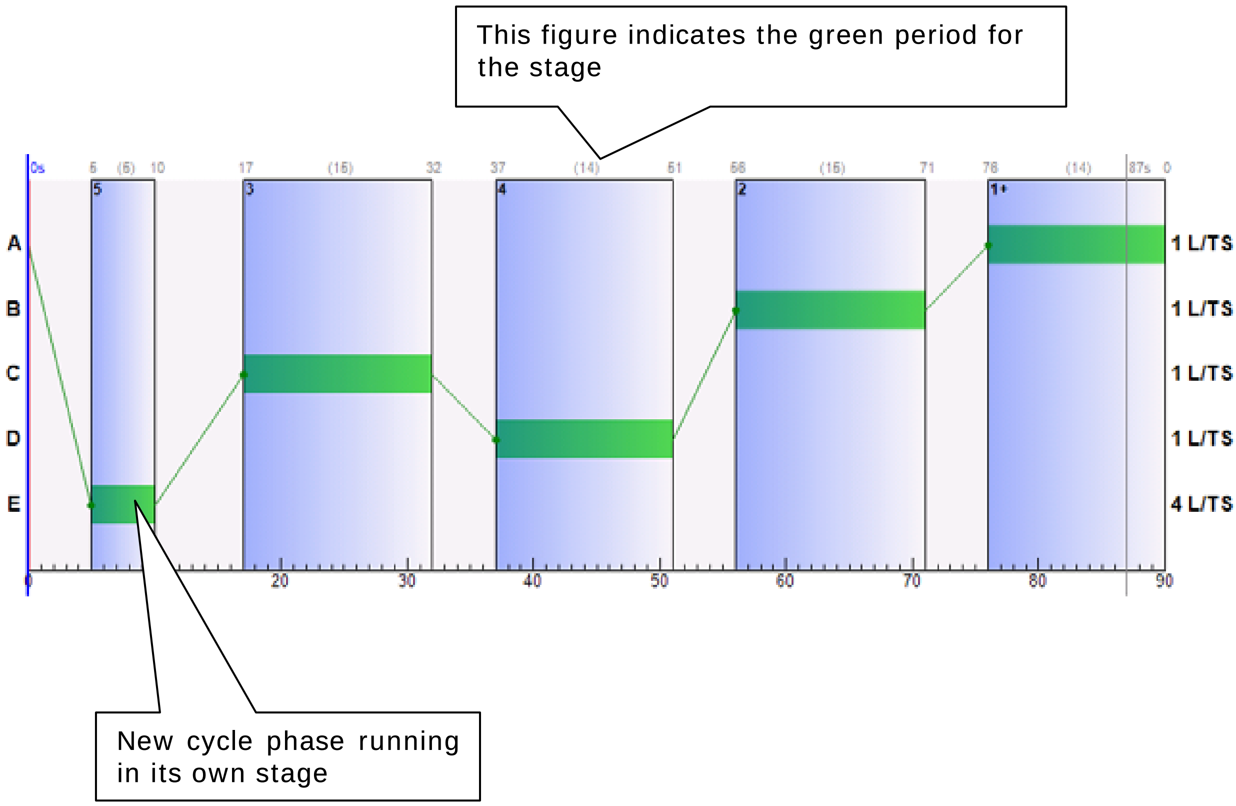
Timing diagram showing the stage structure of the intergreen scenario

The result of this change on the capacity of Arm 1 of the junction is a reduction to 812 PCU/hr.This **10 percent reduction in capacity** for this approach reflects that the motorised vehicles are receiving less green time per cycle. Naturally where junctions are at or near saturated levels then additional queuing will also be noted.

Separate phase and stage for cyclists (ID3)

The separate phase for cyclists was run in its own stage for this capacity analysis and was only implemented on Arm 1. If an additional phase for cyclists was required elsewhere in the junction then the decision would need to be made as to whether it ran with the first cycle phase, or in a separate stage. Likewise at some junctions it may be possible to run a cycle phase alongside other traffic phases, for this analysis it has been assumed that the phase must be run separately, thus resulting in reduced green time for other vehicular movements.

The intergreens used in this analysis are 5 seconds when leaving traffic stages and 7 seconds when leaving stage 5, the cycle stage.



The cycle stage in this example is set at 5 seconds long, this decision was based on the fact that cyclists only require a short period of time to get going, and adequate clearance time is provided for them during the intergreen period. The green period would need extending to ensure that cyclist demand is satisfied by the green split offered. However the increase of this green time can have an effect on the capacity of the other traffic stages and the delay experienced by other road users.

As this technique requires the cyclists to be given right of way separately to the other vehicles the ASL would need to be removed and a separate cycle waiting area be provided adjacent to the main stop line. It has been assumed that for this technique the cycle lane would need to be widened to give effective capacity for cyclists from 1.5 metres wide to 2.0 metres. Assuming no land take has been involved this would result in the saturation flow reduction to 4010 PCU/hr combined for the traffic lanes.

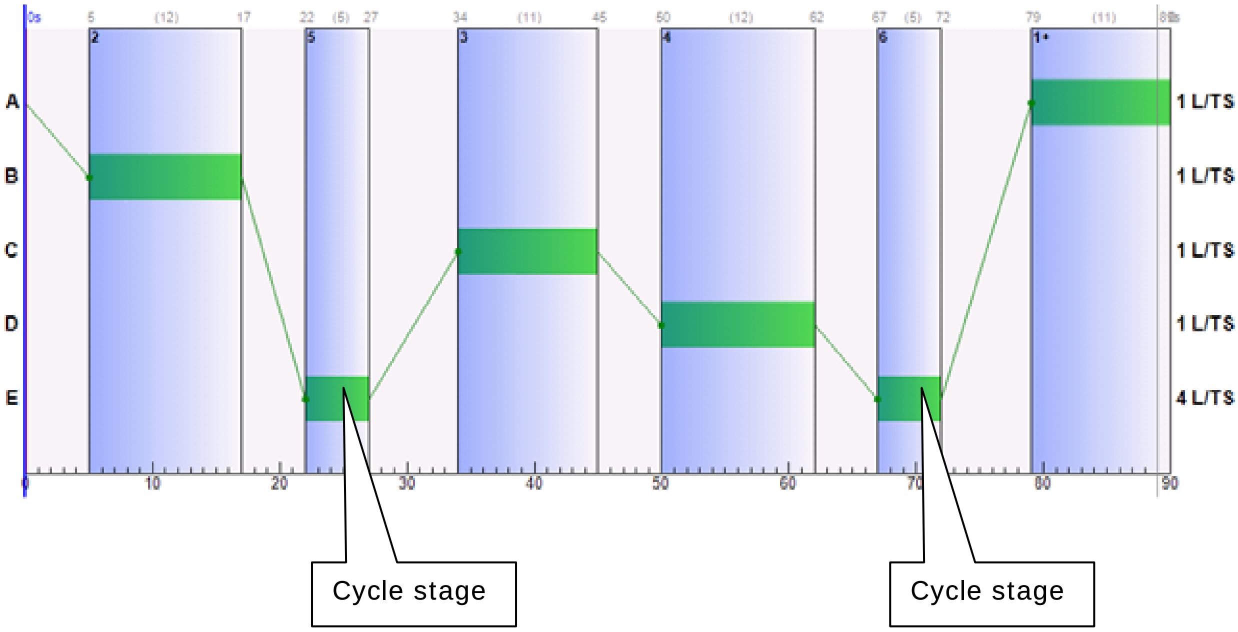
This modification to incorporate the separate cycle phase technique has resulted in capacity for Arm 1 of 668 PCU/hr.This technique has shown a **25 percent reduction in vehicular capacity** on Arm 1. This analysis is very much a worst case scenario as there are numerous ways to lessen this impact, for example the increase of the cycle time or acquiring the additional land required by narrowing the footway rather than the traffic lanes.

Two green periods for cyclists (ID47)

For the capacity analysis investigating the impact of repeating the cyclist green twice within a cycle the following assumptions needed to be made. Just a single phase has been included in the timing diagram for clarity, however numerous cycle movements could be controlled by this phase or by separate phases running in parallel.

It was also assumed that in a similar way to the separate phase for cyclist's technique this technique would require a wider cycle lane to allow cyclists to discharge efficiently during their green period. As a result of this the saturation flow for traffic has been based on 3.25 metre wide lanes whereas the base scenario used 3.5 metre wide lanes.

All intergreens from traffic phases have been set to 5 seconds whereas the intergreens from cyclist phases have been set to 7 seconds.



The impact this has had on the capacity of Arm 1 is areduction to 535 PCU/hr.This shows that this technique has given rise to a **29 percent reduction** in the capacity of Arm 1.

When considering this figure it should be noted that the increase in cycle time will inevitably have an impact on traffic delay, queuing and therefore the junction performance as a whole. To establish the further reaching impacts of this technique detailed modelling would need to be undertaken for the site in question as many of the parameters are site specific.

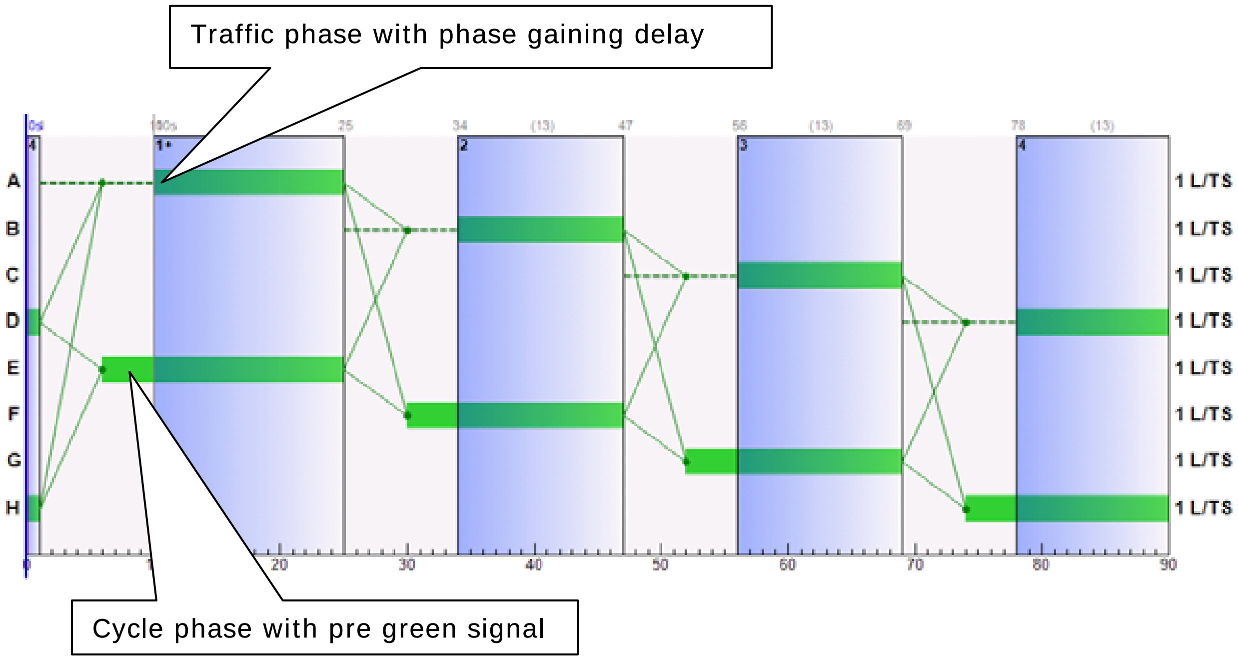
Pre green for cyclists (ID9)

The pre green for cyclist technique is assumed to use the existing layout of approach lanes, in that cyclists are provided with an ASL to wait in during the red period, and allowing them to get ahead of the traffic for their advanced signal.

It has also been assumed that this technique will not require the cycle time to be increased; instead the additional time required for the cyclist is taken away from the other vehicles.
Naturally the impact on capacity of Arm 1 will depend largely on how long the cyclist pre signals is as this is the additional lost time to traffic. As a result two alternatives have been modelled for this technique; the first involves a four second pre green, whereas the second gives a two second pre green.

The pre green has been applied on all arms of the junction, however the safety impacts of doing this should be considered before implementation

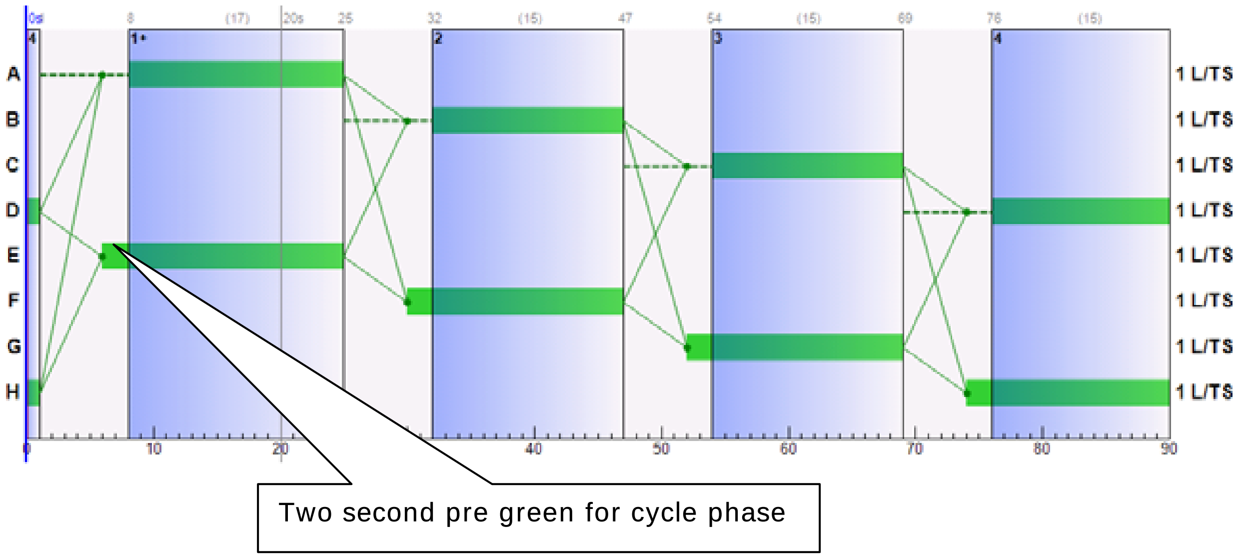
As the timing diagram below shows the cycle phases are run alongside the traffic phases, however there is a phase gaining delay imposed on the traffic phase to allow the cyclists to have a four second pre green
Intergreen times have been set to 5 seconds so that this model can be more accurately compared to the base scenario.



The four second pre green gives a capacity for Arm 1 of areduction to 721 PCU/hr.This equates to **a capacity reduction of 20 percent** over the base scenario.

The second capacity calculation for this technique uses an assumed pre green for cyclists of only two seconds. Two seconds has been used as a pre green for cyclists with some success in Denmark and the Netherlands, however the number of seconds can be increased to meet the demand for cyclist volumes.

The timing diagram below shows the same stage structure as before however due to the reduced pre green time there has been less time taken away from the traffic phases.



The capacity result for Arm 1 with a two second pre green for the cycle phase is 812 PCU/hr.This technique has resulted in **10 percent capacity reduction**.

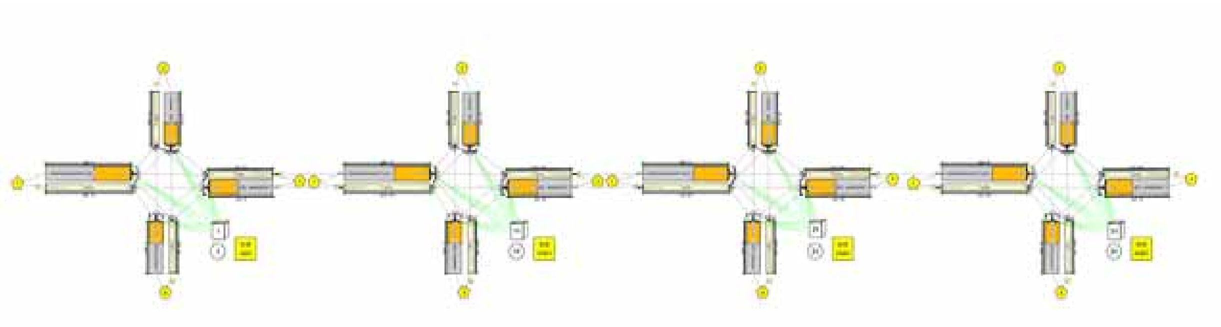
Coordination of signals for cyclist progression "green wave" (ID21)

This technique can only be considered network wide rather than on a junction by junction basis. As such the base model used in the previous capacity analysis is not suitable for comparison. To carry out the analysis a base network model was built using a cruise speed suited to motorised vehicles; this was then compared to a replicated version of this model where the cruise speed had been set at a reduced speed of 18 kph, which is far similar to cyclist behaviour.

The reason 18kph was chosen for cyclist cruise speed was due to research identified in the literature review. The CTC document Traffic signals and Cyclists states that mean cycle speeds are between 10 and 15 mph. 18 kph equates to 11.2mph. This same document indicates that successful schemes in Denmark and the Netherland have used cruise speeds of 20 kph and 18 kph. By using 18 kph this analysis presents the worst case scenario for vehicles

It is not possible to gauge the impact on capacity for this scheme as the reduction of the modelled cruise time for a group of closely spaced junctions only alters the green splits between the various phases and the offsets between consecutive greens. Unlike the previous modelling this technique has been modelled to use optimum signal timings and offsets. As a result there is no notable difference in capacity figures or queue lengths between the base network model using 55 kph cruise time and the reduced cruise time used in the proposed model of 18 kph.

The network studied is shown in the following diagram, this network is not modelled on a particular study site, instead it has been constructed using typical input data.



To quantify the impacts on the network that the lower progression speed has had the journey times for traffic travelling from left to right were compared for each model.

The resultant journey times are as follows:

- **55 kph – journey time from entry on left of network to exit on the right of network**

  208.17 seconds

- **18 kph – journey time from entry on left of network to exit on the right of network**

300.16 seconds

These results show that there is a **44 percent increase in journey time** when travelling through this network when the signals are optimised for 18kph cruise speed.

The TRANSYT program is not able to separate cyclist traffic flow from other vehicles, as a result it is not possible to show the improvement to cyclist journey times by reducing the cruise speed to 18 kph. However even without being able to quantify this journey time, it is clear that with a cruise speed set for cyclist progression, there will be vastly reduced chance of cyclists having to stop therefore providing an efficient progression along the length of the network.

Base model data used for these analysis examples can be found in Appendix B.

12 Conclusions

From a literature review and consultation with experts, forty-eight possible techniques to aid cyclists in negotiating traffic signalised intersections were identified and taken forward for inclusion in the assessment process. The assessment methodology was developed as part of the project to ensure that each technique was thoroughly appraised for potential use in the UK.

The assessment process identified those techniques that were concluded to be most beneficial to cyclists, whilst at the same time taking into consideration the impact on other road users, cost implications, legislative requirements and other considerations.

Following the literature review and assessment process, taking into account potential positive and negative impacts the following techniques were short listed and are seen to be the most appropriate for greater widespread use, trials or deployment in the UK.

- **ID10:** Advanced cycle Stop Line (ASL)
- **ID18:** Coloured cycle lanes (one)
- **ID30:** Dwell on all red (derived from dwell on green)
- **ID45:** Pre timed maximum for toucans
- **ID15:** Bypass for straight ahead movements within the carriageway
- **ID12:** Bypass for left turning cyclists (signal controlled)
- **ID14:** Bypass for ahead movements within the footway
- **ID1:** Intergreens designed for cyclist speed
- **ID2:** Intergreens extended by detection
- **ID44:** Straightening staggered toucans and making into a single phase
- **ID48:** Conversion to continental roundabout
- **ID26:** Road marking to highlight loop detectors
- **ID46:**Trixi mirrors
- **ID21:** Coordination of signals for cyclists progression “green wave”
- **ID3:** Separate phase for cyclists
- **ID47:** Two green periods per cycle for cyclists
- **ID9:** Pre signal for cyclists (aspect or separate red, amber and green signal head)
- **ID43:** Priority for cyclists during inclement weather

As the capacity analysis shows for the techniques modelled there is a large variation in the impact that these schemes have on other road users. This analysis was carried out on models of typical junctions; therefore the exact impact if implemented on a real site could be significantly different. Whilst this capacity analysis is indicative only, it emphasises an important point, that the implementation of these techniques needs thorough consideration prior to installation. It is therefore recommended that transport practitioners carry out detailed traffic modelling of proposed sites to ensure that the correct technique has been selected, and that impact on other road users is within tolerable limits.

It is envisaged that the next stage in the process of introducing additional measures to assist cyclists at traffic signals will be progressing the recommendations for the techniques listed above.

These additional measures will help to encourage increased travel by bicycle with an improvement of the service offered to cyclists and increasing safety and comfort levels at traffic signals. The conclusion of which is a more attractive and sustainable travel option across the UK and will aid in meeting relevant policy target for cycle numbers.

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Appendix A: Score Descriptions by Theme

A.1 Cyclists

		Deviation	Legibility	Safety	Capacity	Delay: waiting time	Delay: chance of stopping	Attractive-ness	Comfort
		Deviation looked at whether cyclists were forced to deviate from their desired route	Legibility suggested how legibile the technique would be to cyclists	Safety looked at to what extent safety was improved for cyclists	Capacity investigated how the technique altered the cyclist capacity through the junction	Focuses on how long cyclists have to wait before they receive a green signal	focuses on how likely it is that cyclists will have to stop as a result of the proposed technique	Would the technique encourage people to cycle	how comfortable would cyclists feel with the inclusion of a technique.
-2	Major negative effect	There is significant deviation to users, increasing the distance travelled through the junction	Levels of legibility are likely to be decreased and compromise the safety of cyclists	May not improve visibility and awareness of cyclists to other road users unlikely to reduce likelihood of relevant conflict points or increase potential for conflict to occur	Facility may reduce available capacity for cyclists to proceed through intersection	Average and maximum waiting times likely to significantly increase	Chance of stopping likely to significantly increase	Facility will decrease the attractiveness to cycle through the intersection	Will result in cyclists being close to or merged with traffic lanes leading to discomfort.
-1	Minor negative effect	There is localised or minor deviation for users	There may be a minor negative change in legibility for cyclists, but the overall impact is small	May not improve visibility and awareness of cyclists to other road users unlikely to reduce likelihood of relevant conflict points	There may be a minor negative change in capacity for cyclists, but the overall impact is small	There may be a minor negative impact on waiting times , but the overall impact is small	Chance of stopping likely to be slightly increased by introduction of facility	There may be a minor negative impact attractiveness to cycle	May not be suitable for all types of cyclists and lead to some discomfort
0	Neutral	There is no change to the route through the intersection for cyclist	There is no change to legibility through the intersection for cyclist	There is no change to cyclist safety through the intersection for cyclist	Facility will have no noticeable effect on capacity to proceed through intersection	Facility will have no noticeable effect on waiting times	Chance of stopping likely to remain at current levels.	Facility likely to have no impact on improving attractiveness to cycle	will have no impact on current comfort levels
1	Minor positive effect	There is a small decrease in the deviation reducing the distance travelled through the junction	There may be a minor positive change in legibility, but the overall impact is small	Likely to improve visibility and awareness of cyclists to other road users and reduce likelihood of relevant conflict points	There may be a minor positive change in capacity, but the overall impact is small	There may be a minor positive impact on waiting times, but the overall impact is small	Chance of stopping likely to be reduced by introduction of facility	There may be a minor positive impact attractiveness to cycle	Facility may result in small increase of comfort levels for cyclists
2	Major positive effect	There is a large decrease in the deviation reducing the distance travelled through the junction	Legibility for cyclists is improved through the use of the technique	Likely to improve visibility and awareness of cyclists to other road users and negate relevant conflict points	Facility likely to increase the capacity for cyclists to proceed through intersection	Facility will result in significant reduction in the average and maximum waiting times	No requirement for cyclists to stop at intersection	Facility will improve attractiveness to cycle through the intersection	If well maintained and designed will provide facility for cyclists away from traffic lanes and greater feeling of comfort

		LOS: Existing Flows Low	LOS: Existing Flows Medium	LOS: Existing Flows High	LOS: Predicted Growth	Behaviour and Compliance	Priority over others
		How does this technique perform when cyclist flow is low	How does this technique perform when cyclist flow is medium	How does this technique perform when cyclist flow is high	How does this technique perform when considering future growth of cyclist demand	What influence do techniques have on the behavoiur of cyclists and their compliance to the traffic signals	Does the technique award priority to cyclists over other road users
-2	Major negative effect	Technique performs poorly with a low quantity of cyclists may lead to encroachment or abuse by other road users	Technique performs poorly with a medium quantity of cyclists may lead to encroachment or abuse by other road users	Technique performs poorly with a high quantity of cyclists	Technique will perform poorly with a an increase in the number of quantity of cyclists	May lead to poor behaviour or compliance at this or other sites	Cyclists have no priority of other road users and must wait for extended period before proceeding
-1	Minor negative effect	There may be a minor negative impact on the level of service for a low quantity of cyclists	There may be a minor negative impact on the level of service for a medium quantity of cyclists	There may be a minor negative impact on the level of service for a high quantity of cyclists	There may be a minor negative impact on the level of service for a continued increase in the cyclists	Likely to lead to a small decrease in compliance and slight increase of current poor behaviour	Cyclists share priority with other roads users and may suffer some delay
0	Neutral	Technique offers an acceptable level of service for a low quantity of cyclists	Technique offers an acceptable level of service for a medium quantity of cyclists	Technique offers an acceptable level of service for a high quantity of cyclists	Technique will continue to offer an acceptable level of service for an increase in cyclists	No noticeable affect on current behaviour or compliance at this or other sites	Priority of cyclists remains at current level
1	Minor positive effect	There may be a minor positive impact on the level of service for a low quantity of cyclists	There may be a minor positive impact on the level of service for a medium quantity of cyclists	There may be a minor positive impact on the level of service for a high quantity of cyclists	There may be a minor positive impact on the level of service for a continued increase in the cyclists	Likely to lead to a small increase in compliance and slight reduction of current poor behaviour	Cyclists have priority over some other road users and suffer reduced delay
2	Major positive effect	Technique offers a good level of service for a low quantity of cyclists	Technique offers a good level of service for a medium quantity of cyclists	Technique offers a good level of service for a high quantity of cyclists	Technique offers a good level of service for a continued increase in the cyclists	Likely to lead to high level of compliance and reduce current poor behaviour	Cyclists have priority over all other road users and suffer little to no delay

LoS = Level of Service. This is a six point scale that rates the performance of traffic throughput at a junction

A.2 Pedestrians

		Deviation	Legibility	Legibility: Sensory Impaired Pedestrians	Safety	Capacity	Delay	Distance to Cross	Attractive-ness
		Deviation looked at whether pedestrians were forced to deviate from their desired route	Legibility suggested how legibile the technique would be to pedestrians	Legibility suggested how legibile the technique would be to sensory impaired pedestrians	Safety looked at to what extent safety was improved for pedestrians	Capacity investigated how the technique altered the pedestrian capacity through the junction	What influence the techniques have on pedestrian delay	Does the technique require pedestrians to make a longer crossing	Does the technique have any influence on how attractive the environment is for pedestrians
-2	Major negative effect	Significant deviation to pedestrians likely, increasing the distance travelled through the intersection	Levels of legibility are likely to be decreased and may result in a misunderstood layout with potential safety implications	Levels of legibility are likely to be decreased and may result in a misunderstood layout with potential safety implications	May reduce visibility and awareness of pedestrians to other road users and may increase likelihood of conflict to occur	Facility may reduce available capacity for pedestrians to proceed through intersection	Delay incurred for pedestrians likely to increase significantly due to facility	Distance for pedestrians to cross will increase significantly	Facility will decrease the attractiveness to walk through the intersection
-1	Minor negative effect	There is localised or minor deviation for pedestrians resulting in slightly longer route	There may be a minor negative change in legibility for pedestrians, but the overall impact is small	There may be a minor negative change in legibility for pedestrians, but the overall impact is small	May not improve visibility and awareness of pedestrians to other road users unlikely to reduce likelihood of relevant conflict points	There may be a minor negative change in capacity for pedestrians, but the overall impact is small	There may be a minor negative impact on delay, but the overall impact is small	There may be a minor negative impact on crossing distance, but the overall impact is small	There may be a minor negative impact attractiveness to pedestrians
0	Neutral	No effect on the pedestrian route through the intersection	There is no change to legibility through the intersection for pedestrians	There is no change to legibility through the intersection for pedestrians	No noticeable safety benefits or disbenefits for pedestrians	Facility will have no noticeable effect on capacity for pedestrians to proceed through intersection	Delay incurred for pedestrians likely to remain at current levels due to facility	Distance for pedestrians to cross likely to remain at current levels	Facility likely to have no impact on improving attractiveness to walk
1	Minor positive effect	There is localised or minor deviation for pedestrians resulting in slightly shorter route	There may be a minor positive change in legibility, but the overall impact is small	There may be a minor positive change in legibility, but the overall impact is small	Likely to improve visibility and awareness of pedestrians to other road users and reduce likelihood of relevant conflict points	There may be a minor positive change in capacity for pedestrians, but the overall impact is small	There may be a minor positive impact on delay, but the overall impact is small	There may be a minor positive impact on crossing distance, but the overall impact is small	There may be a minor positive impact attractiveness to pedestrians
2	Major positive effect	Significant reduction in the deviation to pedestrians likely, decreasing the distance travelled through the intersection	Legibility for pedestrians may be improved through the use of the technique	Legibility for sensory impaired pedestrians may be improved through the use of the technique	Likely to improve visibility and awareness of pedestrians to other road users and negate potential conflict points	Facility likely to increase the capacity for pedestrians to proceed through intersection	Delay incurred for pedestrians likely to be reduced significantly due to facility	Distance for pedestrians to cross likely to decrease significantly	Facility will improve attractiveness to walk through the intersection

A.3 Other Road Users (Traffic Management)

		Legibility	Safety	Capacity	Delay: Public Transport	Delay: Private Vehicles	Saturation Flow Effect	Uptream and downstream factors	Behaviour and Compliance
		Legibility suggested how legibile the technique would be to other road users	Safety looked at to what extent the level of safety was changed for other road users	Capacity investigated how the technique altered the other road user capacity through the junction	What influence the techniques have on public transport delay	What influence the techniques have on the delay of private vehicles	How the saturation flow of traffic is influenced by the various techniques	How the upstream and downstream flow of traffic is altered by the technique	What influence do the techniques have on the behavoiur of other road users and their compliance to the traffic signals
-2	Major negative effect	Levels of legibility are likely to be decreased and may compromise the safety	Technique will not reduce existing conflict points or results in increased potential for conflict to occur	Facility may significantly reduce available capacity for vehicles to proceed through intersection	Delay incurred for public transport likely to significantly increase due to facility	Delay incurred for private vehicles likely to significantly increase due to facility	Technique will cause significant reduction in traffic saturation flow at the stop line	Technique has possibility for significant detrimental impact on upstream and downstream flow of traffic	May lead to high level of poor behaviour or compliance at this or other sites
-1	Minor negative effect	There may be a minor negative change in legibility for other road users, but the overall impact is small	Unlikely to reduce existing conflict points	There may be a minor negative change in capacity for vehicles, but the overall impact is small	There may be a minor negative change in delay to public transport, but the overall impact is small	There may be a minor negative change in delay to private vehicles, but the overall impact is small	Technique likely to cause minimal reduction in traffic saturation flow at the stop line	Technique has minimal negative impact on upstream and downstream flow of traffic	May lead to low level of poor behaviour or compliance at this or other sites
0	Neutral	There is no change to legibility through the intersection for other road users	No noticeable safety benefits or disbenefits for other road users	Facility will have no noticeable effect on capacity for vehicles to proceed through intersection	Delay incurred for public transport likely to remain at current levels due to facility	Delay incurred for private vehicles likely to remain at current levels due to facility	Technique has no effect on traffic saturation flow at the stop line	Technique has no impact on upstream and downstream flow of traffic	No noticeable affect on current behaviour or compliance at this or other sites
1	Minor positive effect	There may be a minor positive change in legibility for other road users, but the overall impact is small	Likely to reduce conflict points in number or minimise severity	There may be a minor positive change in capacity for vehicles, but the overall impact is small	There may be a minor positive change in delay to public transport, but the overall impact is small	There may be a minor positive change in delay to private vehicles, but the overall impact is small	Technique likely to cause minimal increase in traffic saturation flow at the stop line	Technique has minimal positive impact on upstream and downstream flow of traffic	Likely to lead to low level increase of compliance and reduce current poor behaviour
2	Major positive effect	Legibility likely to be improved through the use of the technique	Likely to negate all relevant conflict points	Facility likely to significantly increase the capacity for vehicles to proceed through intersection	Delay incurred for public transport likely to be significantly reduced due to facility	Delay incurred for private vehicles likely to be significantly reduced due to facility	Technique will cause significant increase in traffic saturation flow at the stop line	Technique has possibility for significant positively impact on upstream and downstream flow of traffic	Likely to lead to high level of compliance and reduce current poor behaviour

A.4 Cost Implications

		Planning and Design Costs	Land Costs	Equipment Costs	Installation Costs	Costs for Trials	Ongoing Costs e.g. Maintenance
-2	Major negative effect	Large costs required for planning and design over extended period	The amount of land required would result in significant investment	Numerous new pieces of equipment required for technique	Installation would be over an extended period and would require extensive traffic management or closures	Trials may be prohibitively expensive including outlay of specific equipment	The maintenance programme would require a significant amount of financial and time investment
-1	Minor negative effect	Large costs implications for planning and design over intermediate period	Will require land in all environments and require some investment	Limited amount of new expensive equipment required	Installation would be over a intermediate period and would require extensive traffic management or closures	Trials may be expensive and large amount specialised equipment required.	The maintenance programme would require a financial time investment
0	Neutral	Outlay of reasonable amount of funds for either planning or design over intermediate period	Some land take maybe required in certain environments and existing highway boundaries	Will require large amount of non-expensive equipment	Installation would be over a intermediate period and would require some traffic management	Trials may be expensive and some specialised equipment required.	Amendment required to existing maintenance program
1	Minor positive effect	Some costs implications for design and planning over short timescale	Will require small amount of land in certain environments and existing highway boundaries	Will require small amount of equipment, e.g. New road markings	Installation can be achieved within a short timescale with little or no traffic management requirements	No specialised or expensive equipment required for trial, l set-up costs may be expensive	Small amendment required to existing maintenance program (e.g. Specific sweeping of areas that cannot be reached by regular equipment)
2	Major positive effect	Minimal time required for planning and design	No additional land is required, so land costs are not a consideration	No additional equipments is required, equipment costs are not a consideration	Installation can be achieved within a single day with no traffic management requirements	No specialised or expensive equipment required for trial, relatively minimal set-up costs	No specific maintenance required, can be achieved as part of regular maintenance program

A.5 Regulation and Legislation

		TSRGD & associated legislation & guidance documents	DMRB & associated legislation	Guidance	Highway Code
-2	Major negative effect	Technique cannot be used without significant amendments to the TSRGD with new diagram	No evidence of prior use in UK and technique cannot be used without major amendments to the DMRB or new section	New technique for the UK and will require new guidance documents	No evidence of prior use in UK and technique new areas of Highway Code required.
-1	Minor negative effect	Technique cannot be used without amendments to the TSRGD such as new permitted variants and directions, and regulations	No evidence of prior use in UK and technique cannot be used without major amendments to the DMRB	New technique for the UK and will require updating with new sections within existing guidance documents	New technique for the UK and will require updating with new sections.
0	Neutral	The TSRGD allows installation of similar techniques, may require minor changes such as new permitted variants and directions	The DMRB allows installation of similar techniques, may require some changes.	Some amendments required to guidance documents	Some amendments required to the Highway Code
1	Minor positive effect	The TSRGD allows installation of similar techniques, may require minor changes such as new permitted variants	The DMRB allows installation of similar techniques, may require minor changes	Partially covered within existing guidance documents, slight amendments required	Partially covered within existing Highway Code, slight amendments required
2	Major positive effect	The TSRGD allows installation of this technique	The DMRB allows installation of this technique	Fully covered within existing guidance documents	No effect on the Highway Code and no amendments required

A.6 Other

		Land / Size	Timescale for Installation	Reliability of Equipment	Compatibility with existing setup	Feasibility for trial	In Use	Source of Technique	Streetscape (clutter)
		Considers the amount of space and any additional land required for the techniques	Estimated time for implementation	Is the equipment proven or is it new	Will the new technique work with existing equipment?	Is the technique suitable for trial, taking into account cost and disruption on the highway	How well adopted is the technique	What is the origin of the technqiue with regard to the literature review	Do the techniques add additional streetclutter?
-2	Major negative effect	Would require significant space for installation and may be unfeasible for urban environment	Long-term installation (1 year +)	The equipment is in design or prototype stage, and reliability is unknown	Compatibility is unfeasible without significant investment in time, money or both	Not feasible for trial, owing to equipment requirements, design constraints or potential safety implications	There are no examples of this technique being used, theory only	This technique has been highlighted through anecdotal evidence (e.g. via LinkedIn consultation) only	Facility requires excessive road marking, signing and other infrastructure creating a cluttered environment
-1	Minor negative effect	Would require some space for installation and may be unfeasible in certain circumstances in the urban environment	Long-term installation (9- 12 months)	Equipment/technique used overseas in limited numbers but no knowledge of reliability	Compatibility with existing set-ups can be achieved over extended period and some cost implications	Trials could be undertaken but may be prohibitively costly or there may be a significant delay in a trial becoming possible	This option is not in use in the UK, but has been applied on small scale internationally	N/A	Facility requires additional infrastructure creating a more cluttered environment
0	Neutral	N/A	Medium-term installation (6 - 9 months)	Equipment / technique used overseas with proven reliability	Compatibility with existing set-ups can be achieved quickly and with little cost	Possible to trial but subject to significant cost and requires a long study period	This option is not in use in the UK, but has been applied widespread internationally	This technique has been cited in international guidance or by international practitioners	Facility requires no change to the existing infrastructure
1	Minor positive effect	May require a small amount of land but can be accommodated within urban fabric with minimal effect	Short-term installation (3-6 months)	The necessary equipment has been used in the UK on limited basis but is considered reliable with a proven history in UK	Is compatible with the majority of existing signal set-ups	Possible to trial but subject to significant cost or requires a long study period	This option is either in mainstream use in the UK but either needs authorisation or issued on a limited basis	N/A	Facility requires slight reduction in infrastructure enabling a less cluttered environment
2	Major positive effect	Does not require any additional space	Short-term installation (0-3 months)	The necessary equipment is in mass production and is considered reliable with a proven history in UK	Is compatible with all existing signal set-ups, or does not interface with existing equipment	Would be well suited to further investigation and on/ off-street trials. Minimal cost or delay	This option is in mainstream use in the UK	This technique is recommended in UK guidance documents	Facility may improve attractiveness of area by implementation of specific infrastructure or removal of existing infrastructure

Appendix B : Input data used in Capacity Analysis

TRANSYT 14

Version: 14.0.4.241 [21/03/11]

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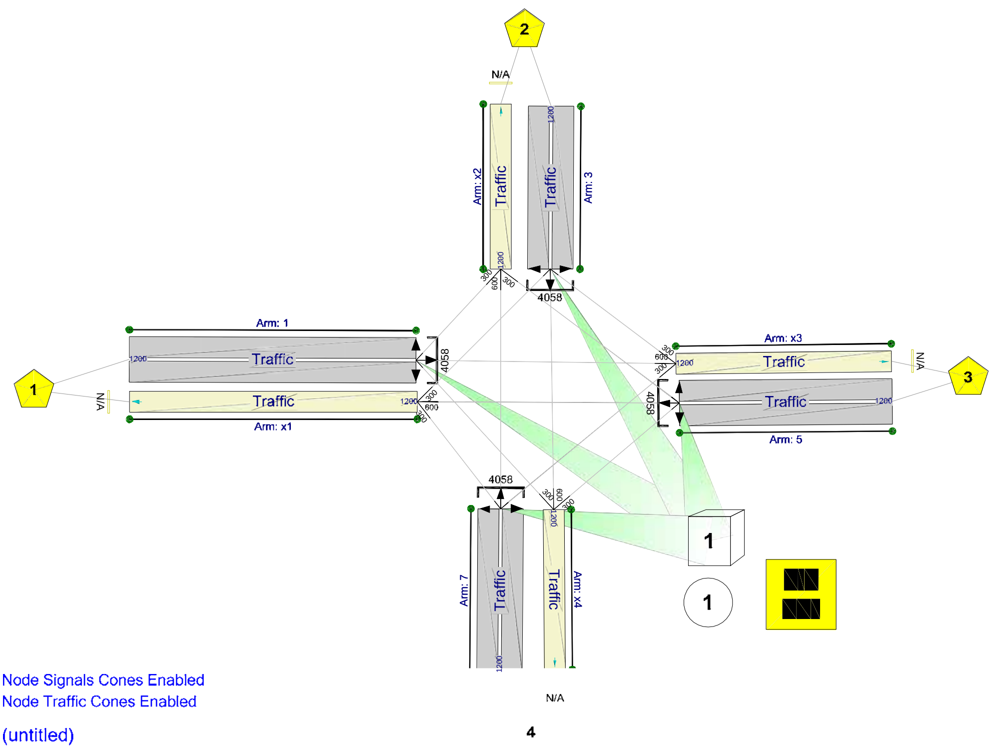
Network Diagram



Node Signals Cones Enabled
Node Traffic Cones Enabled

(untitled)
Cycletime 0s / 90s , Timesteps 0 / 90
Diagram produced using TRANSYT 14.0.4.241 Network Construction Editor

Network Options

Network Timings

Network Cycle Time (s)	Resolution	Number Of Steps	Time Segment Length (min)	Number Of Time Segments	Modelled Time Period (min)
90	1	90	60	1	60

Signals Options

Equal Length Multiple Cycling	Start Displacement (s)	End Displacement (s)	Phase Minimum Broken Penalty (£)	Phase Maximum Broken Penalty (£)	Intergreen Broken Penalty (£)
True	2	3	10000.00	10000.00	10000.00

Traffic Options

Traffic Model	DOS Threshold (%)	Flow Scaling Factor (%)	Cruise Scaling Factor (%)	Cruise Times Or Speeds	Use Link Stop Weightings	Use Link Delay Weightings	Exclude Pedestrian Links	Random Delay Mode	Type of Vehicle-in-Service	Type Of Random Parameter	PCU Length (m)
Quick PDM	90	100	100	Cruise Speeds	True	True	False	Complex	Uniform (TRANSYT)	Uniform (TRANSYT)	5.75

Optimisation Options

Auto Redistribute	Optimisation Type	Optimisation Level	Hill Climb Increments	Shotgun Number Of Runs	SAStart Temperature	SACooling Factor	Random Seed	Use Enhanced Optimisation	Optimisation Order	Locked Green Splits
True	HillClimb	Offsets And Green Splits	15,40,-1,15,40,1,-1,1	N/A	N/A	N/A	N/A	False		

Traffic Streams

Arm	Traffic Stream	ID	Name	Description	Length (m)	Traffic Model	Has Restricted Flow	Saturation Flow Source	Saturation Flow (PCU/hr)	Cell Saturation Flow (PCU/hr)	Is Signal Controlled	Controller Stream	Phase	Phase2 Enabled	Phase2	Is Give Way	Traffic Type
1	**1**	1	Traffic		100.00	([Quick PDM])	True	DirectlyEntered	4058	(N/A)	True	1	A	False	(N/A)	False	Normal
3	**1**	1	Traffic		100.00	([Quick PDM])	True	DirectlyEntered	4058	(N/A)	True	1	B	False	(N/A)	False	Normal
5	**1**	1	Traffic		100.00	([Quick PDM])	True	DirectlyEntered	4058	(N/A)	True	1	C	False	(N/A)	False	Normal
7	**1**	1	Traffic		100.00	([Quick PDM])	True	DirectlyEntered	4058	(N/A)	True	1	D	False	(N/A)	False	Normal
x1	**1**	1	Traffic		100.00	([Quick PDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
x2	**1**	1	Traffic		100.00	([Quick PDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
x3	**1**	1	Traffic		100.00	([Quick PDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
x4	**1**	1	Traffic		100.00	([Quick PDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal

Lanes

Arm	Traffic Stream	Lane	ID	Name	Description	Use RR67	Surface Condition	Site Quality Factor	Gradient (%)	Width (m)	Proportion That Turn (%)	Turning Radius (m)	Nearside Lane	Saturation Flow (PCU/hr)
1	**1**	**1**	1	(untitled)		False	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[Direct on Traffic Stream]
1	**1**	**2**	2	(untitled)		False	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[Direct on Traffic Stream]
3	**1**	**1**	1	(untitled)		False	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[Direct on Traffic Stream]
3	**1**	**2**	2	(untitled)		False	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[Direct on Traffic Stream]
5	**1**	**1**	1	(untitled)		False	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[Direct on Traffic Stream]
5	**1**	**2**	2	(untitled)		False	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[Direct on Traffic Stream]
7	**1**	**1**	1	(untitled)		False	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[Direct on Traffic Stream]
7	**1**	**2**	2	(untitled)		False	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[Direct on Traffic Stream]
x1	**1**	**1**	1	(untitled)		False	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1800
x2	**1**	**1**	1	(untitled)		False	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1800
x3	**1**	**1**	1	(untitled)		False	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1800
x4	**1**	**1**	1	(untitled)		False	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1800

Modelling

Arm	Traffic Stream	Stop Weighting Multiplier (%)	Delay Weighting Multiplier (%)	Exclude From Results Calculation	Max Queue Storage (PCU)	Has Queue Limit	Queue Limit (PCU)	Excess Queue Penalty (£)	Has Degree Of Saturation Limit	Degree Of Saturation Limit (%)	Excess Degree Of Saturation Penalty (£)	Low Degree Of Saturation Penalty (£)
1	**1**	100	100	False	0.00	False	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)
3	**1**	100	100	False	0.00	False	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)
5	**1**	100	100	False	0.00	False	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)
7	**1**	100	100	False	0.00	False	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)
x1	**1**	100	100	False	0.00	False	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)
x2	**1**	100	100	False	0.00	False	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)
x3	**1**	100	100	False	0.00	False	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)
x4	**1**	100	100	False	0.00	False	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)

Modelling - Advanced

Arm	Traffic Stream	Normal Dispersal Type	Normal Dispersal Coefficient	Normal Travel Time Coefficient	Initial Queue (PCU)	Point1 Time Step (s)	Point2 Time Step (s)	Type of Vehicle-in-Service	Vehicle-in-Service	Type Of Random Parameter	Random Parameter
1	**1**	Default	35	80	0.00	0	0	NetworkDefault	Not-Included	NetworkDefault	0.50
3	**1**	Default	35	80	0.00	0	0	NetworkDefault	Not-Included	NetworkDefault	0.50

5	**1**	Default	35	80	0.00	0	0	NetworkDefault	Not-Included	NetworkDefault	0.50
7	**1**	Default	35	80	0.00	0	0	NetworkDefault	Not-Included	NetworkDefault	0.50
x1	**1**	Default	35	80	0.00	0	0	NetworkDefault	Not-Included	NetworkDefault	0.50
x2	**1**	Default	35	80	0.00	0	0	NetworkDefault	Not-Included	NetworkDefault	0.50
x3	**1**	Default	35	80	0.00	0	0	NetworkDefault	Not-Included	NetworkDefault	0.50
x4	**1**	Default	35	80	0.00	0	0	NetworkDefault	Not-Included	NetworkDefault	0.50

Flows

Arm	Traffic Stream	Total Flow (PCU/hr)	Normal Flow (PCU/hr)	Bus Flow (PCU/hr)	Tram Flow (PCU/hr)	Cruise Sensitivity Multiplier (%)	Calculated Cruise Speed (kph)
1	**1**	1200	1200	0	0	100	1.00
3	**1**	1200	1200	0	0	100	1.00
5	**1**	1200	1200	0	0	100	1.00
7	**1**	1200	1200	0	0	100	1.00
x1	**1**	1200	1200	0	0	100	1.00
x2	**1**	1200	1200	0	0	100	1.00
x3	**1**	1200	1200	0	0	100	1.00
x4	**1**	1200	1200	0	0	100	1.00

Normal - Modelling

Arm	Traffic Stream	Stop Weighting (%)	Delay Weighting (%)
1	**1**	100	100
3	**1**	100	100
5	**1**	100	100
7	**1**	100	100
x1	**1**	100	100
x2	**1**	100	100
x3	**1**	100	100
x4	**1**	100	100

Sources - default sources for entries

Arm	Traffic Stream	Normal Cruise Time (seconds)	Normal Cruise Speed (kph)	Bus Free Running Speed (kph)	Tram Free Running Speed (kph)
1	**1**	12.00	30.00	Buses Not Permittted	Trams Not Permitted
3	**1**	12.00	30.00	Buses Not Permittted	Trams Not Permitted
5	**1**	12.00	30.00	Buses Not Permittted	Trams Not Permitted
7	**1**	12.00	30.00	Buses Not Permittted	Trams Not Permitted

Sources - sources for internals

Arm	Traffic Stream	Source	Source Type	Source Link	Source Traffic Stream	Source Total Flow (PCU/hr)	Source Normal Flow (PCU/hr)	Source Bus Flow (PCU/hr)	Source Tram Flow (PCU/hr)	Normal Cruise Time (seconds)	Normal Cruise Speed (kph)	Bus Free Running Speed (kph)	Tram Free Running Speed (kph)
x1	**1**	**1**	TrafficStream	N/A	5/1	600	600	0	0	12.00	30.00	Buses Not Permittted	Trams Not Permitted
x1	**1**	**2**	TrafficStream	N/A	7/1	300	300	0	0	12.00	30.00	Buses Not	Trams

												Permittted	Not Permitted
x1	**1**	**3**	TrafficStream	N/A	3/1	300	300	0	0	12.00	30.00	Buses Not Permittted	Trams Not Permitted
x2	**1**	**1**	TrafficStream	N/A	1/1	300	300	0	0	12.00	30.00	Buses Not Permittted	Trams Not Permitted
x2	**1**	**2**	TrafficStream	N/A	5/1	300	300	0	0	12.00	30.00	Buses Not Permittted	Trams Not Permitted
x2	**1**	**3**	TrafficStream	N/A	7/1	600	600	0	0	12.00	30.00	Buses Not Permittted	Trams Not Permitted
x3	**1**	**1**	TrafficStream	N/A	1/1	600	600	0	0	12.00	30.00	Buses Not Permittted	Trams Not Permitted
x3	**1**	**2**	TrafficStream	N/A	3/1	300	300	0	0	12.00	30.00	Buses Not Permittted	Trams Not Permitted
x3	**1**	**3**	TrafficStream	N/A	7/1	300	300	0	0	12.00	30.00	Buses Not Permittted	Trams Not Permitted
x4	**1**	**1**	TrafficStream	N/A	3/1	600	600	0	0	12.00	30.00	Buses Not Permittted	Trams Not Permitted
x4	**1**	**2**	TrafficStream	N/A	5/1	300	300	0	0	12.00	30.00	Buses Not Permittted	Trams Not Permitted
x4	**1**	**3**	TrafficStream	N/A	1/1	300	300	0	0	12.00	30.00	Buses Not Permittted	Trams Not Permitted

Flow Allocation Tool Tables - OD Matrix: OD1

Normal Input Flows (PCU/hr)

		To			
		1	**2**	**3**	**4**
From	**1**	0	300	600	300
	2	300	0	300	600
	3	600	300	0	300
	4	300	600	300	0

Bus Input Flows not shown as they are blank.

Tram Input Flows not shown as they are blank.

Locations

ODMatrix	Location	ID	Name	Entries	Exits	Total Flow In (PCU/hr)	Normal Flow In (PCU/hr)	Bus Flow In (PCU/hr)	Tram Flow In (PCU/hr)	Total Flow Out (PCU/hr)	Normal Flow Out (PCU/hr)	Bus Flow Out (PCU/hr)	Tram Flow Out (PCU/hr)
OD1	**1**	1	(untitled)	1/1	x1/1	1200	1200	0	0	1200	1200	0	0
OD1	**2**	2	(untitled)	3/1	x2/1	1200	1200	0	0	1200	1200	0	0

OD1	**3**	3	(untitled)	5/1	x3/1	1200	1200	0	0	1200	1200	0	0
OD1	**4**	4	(untitled)	7/1	x4/1	1200	1200	0	0	1200	1200	0	0

Signal Timings

90s cycle time; 90 steps

Controller Stream

Controller Stream	ID	Name	Description	Gaining Delay Type	Signals Manipulation Mode	Multiple Cycling	Offset Relative To	Offset Valid	Offset Positive (s)	Offset Negative (s)	Auto Redistribute	Optimisation Level	Use Sequence
1	1	(untitled)		Absolute	StageBased	Single	1	True	0	0	True	Offsets And Green Splits	1

Phases

Controller Stream	Phase	ID	Name	Minimum Green (s)	Maximum Green (s)	Relative Start Displacement (s)	Relative End Displacement (s)	Dummy
1	**A**	A	(untitled)	7	300	0	0	False
1	**B**	B	(untitled)	7	300	0	0	False
1	**C**	C	(untitled)	7	300	0	0	False
1	**D**	D	(untitled)	7	300	0	0	False

Library Stages

Controller Stream	Library Stage	ID	Phases In Stage	User Stage Minimum (s)
1	**1**	1	A	1
1	**2**	2	B	1
1	**3**	3	C	1
1	**4**	4	D	1

Stage Sequences

Controller Stream	Stage Sequence	ID	Name	Stage IDs	Stage Ends	Multiple Cycling Stage IDs	Multiple Cycling Stage Ends
1	**1**	1	(untitled)	1,3,2,4	32,54,76,8		
1	**2**	2	(untitled)	1,2,3,4	0,22,44,66		
1	**3**	3	(untitled)	1,3,4,2	0,22,44,66		
1	**4**	4	(untitled)	1,2,4,3	0,22,44,66		
1	**5**	5	(untitled)	1,4,2,3	0,22,44,66		
1	**6**	6	(untitled)	1,4,3,2	0,22,44,66		

Resultant Stages

Controller Stream	Stage	Is Base Stage	Library Stage ID	Phases In This Stage	Stage Start (s)	Stage End (s)	Stage Duration (s)	User Stage Minimum (s)	Stage Minimum (s)
1	**1**	True	1	A	13	32	19	1	7
1	**2**	True	3	C	37	54	17	1	7
1	**3**	True	2	B	59	76	17	1	7
1	**4**	True	4	D	81	8	17	1	7

Resultant Phase Green Periods

Controller Stream	Phase	Green Period	Is Base Green Period	Start Time (s)	End Time (s)	Duration (s)
1	A	1	True	13	32	19
1	B	1	True	59	76	17
1	C	1	True	37	54	17
1	D	1	True	81	8	17

Intergreen Matrix for Controller Stream 1

		To			
		A	B	C	D
From	A	-	5	5	5
	B	5	-	5	5
	C	5	5	-	5
	D	5	5	5	-

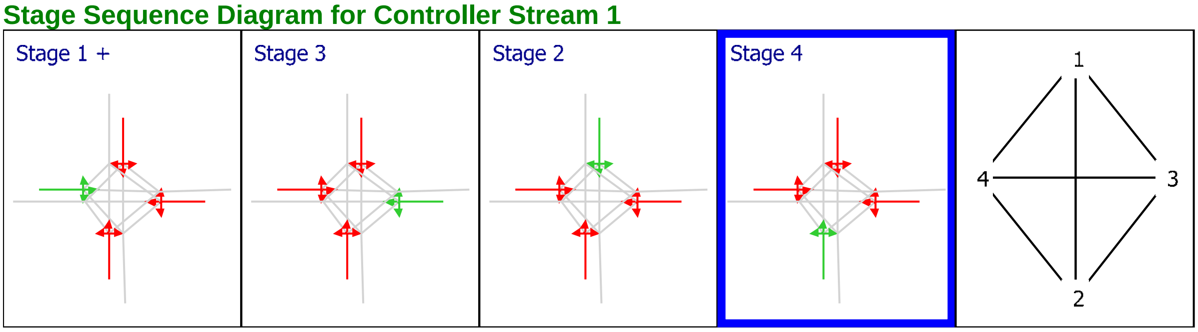
Interstage Matrix for Controller Stream 1

		To			
		1	2	3	4
From	1	-	5	5	5
	2	5	-	5	5
	3	5	5	-	5
	4	5	5	5	-

Banned Stage transitions for Controller Stream 1

		To			
		1	2	3	4
From	1	-	False	False	False
	2	False	-	False	False
	3	False	False	-	False
	4	False	False	False	-

Stage Sequence Diagram for Controller Stream 1



TRANSYT 14

Version: 14.0.4.241 [21/03/11]

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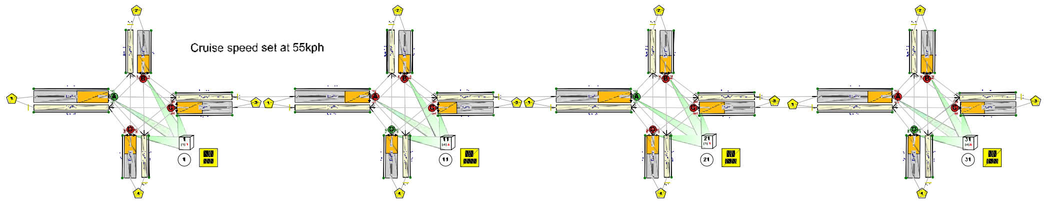
The users of this computer program for the solution of an engineering problem are in no way relieved of their responsibility for the correctness of the solution

Network Diagram



MMQ Queues Enabled
Node Signals Cones Enabled
Node Traffic Cones Enabled
Stopline Signals States Enabled

(untitled)
Cycletime 0s / 90s , Timesteps 0 / 90
Diagram produced using TRANSYT 14.0.4.241 Network Construction Editor

Network Options

Network Timings

Network Cycle Time (s)	Resolution	Number Of Steps	Time Segment Length (min)	Number Of Time Segments	Modelled Time Period (min)
90	1	90	60	1	60

Signals Options

Equal Length Multiple Cycling	Start Displacement (s)	End Displacement (s)	Phase Minimum Broken Penalty (£)	Phase Maximum Broken Penalty (£)	Intergreen Broken Penalty (£)
True	2	3	10000.00	10000.00	10000.00

Traffic Options

Traffic Model	DOS Threshold (%)	Flow Scaling Factor (%)	Cruise Scaling Factor (%)	Cruise Times Or Speeds	Use Link Stop Weightings	Use Link Delay Weightings	Exclude Pedestrian Links	Random Delay Mode	Type of Vehicle-in-Service	Type Of Random Parameter	PCU Length (m)
Quick PDM	90	50	100	Cruise Speeds	True	True	False	Complex	Uniform (TRANSYT)	Uniform (TRANSYT)	5.75

Optimisation Options

Auto Redistribute	Optimisation Type	Optimisation Level	Hill Climb Increments	Shotgun Number Of Runs	SAStart Temperature	SACooling Factor	Random Seed	Use Enhanced Optimisation	Optimisation Order	Locked Green Splits
True	HillClimb	Offsets And Green Splits	15,40,-1,15,40,1,-1,1	N/A	N/A	N/A	N/A	True	1,11,21,31	

Traffic Streams

Arm	Traffic Stream	ID	Name	Description	Length (m)	Traffic Model	Has Restricted Flow	Saturation Flow Source	Saturation Flow (PCU/hr)	Cell Saturation Flow (PCU/hr)	Is Signal Controlled	Controller Stream	Phase	Phase2 Enabled	Phase2	Is Give Way	Traffic Type
1	**1**	1	Traffic		100.00	([QuickPDM])	True	DirectlyEntered	4058	(N/A)	True	1	A	False	(N/A)	False	Normal
11	**1**	1	Traffic		100.00	([QuickPDM])	True	DirectlyEntered	4058	(N/A)	True	11	A	False	(N/A)	False	Normal
13	**1**	1	Traffic		100.00	([QuickPDM])	True	DirectlyEntered	4058	(N/A)	True	11	B	False	(N/A)	False	Normal
15	**1**	1	Traffic		100.00	([QuickPDM])	True	DirectlyEntered	4058	(N/A)	True	11	C	False	(N/A)	False	Normal
17	**1**	1	Traffic		100.00	([QuickPDM])	True	DirectlyEntered	4058	(N/A)	True	11	D	False	(N/A)	False	Normal
1x1	**1**	1	Traffic		100.00	([QuickPDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
1x2	**1**	1	Traffic		100.00	([QuickPDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
1x3	**1**	1	Traffic		100.00	([QuickPDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
1x4	**1**	1	Traffic		100.00	([QuickPDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
21	**1**	1	Traffic		100.00	([QuickPDM])	True	DirectlyEntered	4058	(N/A)	True	21	A	False	(N/A)	False	Normal
23	**1**	1	Traffic		100.00	([QuickPDM])	True	DirectlyEntered	4058	(N/A)	True	21	B	False	(N/A)	False	Normal
25	**1**	1	Traffic		100.00	([QuickPDM])	True	DirectlyEntered	4058	(N/A)	True	21	C	False	(N/A)	False	Normal
27	**1**	1	Traffic		100.00	([QuickPDM])	True	DirectlyEntered	4058	(N/A)	True	21	D	False	(N/A)	False	Normal
2x1	**1**	1	Traffic		100.00	([QuickPDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
2x2	**1**	1	Traffic		100.00	([QuickPDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal

2x3	**1**	1	Traffic		100.00	([QuickPDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
2x4	**1**	1	Traffic		100.00	([QuickPDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
3	**1**	1	Traffic		100.00	([QuickPDM])	True	DirectlyEntered	4058	(N/A)	True	1	B	False	(N/A)	False	Normal
31	**1**	1	Traffic		100.00	([QuickPDM])	True	DirectlyEntered	4058	(N/A)	True	31	A	False	(N/A)	False	Normal
33	**1**	1	Traffic		100.00	([QuickPDM])	True	DirectlyEntered	4058	(N/A)	True	31	B	False	(N/A)	False	Normal
35	**1**	1	Traffic		100.00	([QuickPDM])	True	DirectlyEntered	4058	(N/A)	True	31	C	False	(N/A)	False	Normal
37	**1**	1	Traffic		100.00	([QuickPDM])	True	DirectlyEntered	4058	(N/A)	True	31	D	False	(N/A)	False	Normal
3x1	**1**	1	Traffic		100.00	([QuickPDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
3x2	**1**	1	Traffic		100.00	([QuickPDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
3x3	**1**	1	Traffic		100.00	([QuickPDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
3x4	**1**	1	Traffic		100.00	([QuickPDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
5	**1**	1	Traffic		100.00	([QuickPDM])	True	DirectlyEntered	4058	(N/A)	True	1	C	False	(N/A)	False	Normal
7	**1**	1	Traffic		100.00	([QuickPDM])	True	DirectlyEntered	4058	(N/A)	True	1	D	False	(N/A)	False	Normal
x1	**1**	1	Traffic		100.00	([QuickPDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
x2	**1**	1	Traffic		100.00	([QuickPDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
x3	**1**	1	Traffic		100.00	([QuickPDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal
x4	**1**	1	Traffic		100.00	([QuickPDM])	False	(N/A)	(N/A)	(N/A)	False	(N/A)	(N/A)	(N/A)	(N/A)	False	Normal

Flows

Arm	Traffic Stream	Total Flow (PCU/hr)	Normal Flow (PCU/hr)	Bus Flow (PCU/hr)	Tram Flow (PCU/hr)	Cruise Sensitivity Multiplier (%)	Calculated Cruise Speed (kph)
1	1	1200	1200	0	0	100	1.00
11	1	1200	1200	0	0	100	1.00
13	1	1200	1200	0	0	100	1.00
15	1	1200	1200	0	0	100	1.00
17	1	1200	1200	0	0	100	1.00
1x1	1	1200	1200	0	0	100	1.00
1x2	1	1200	1200	0	0	100	1.00
1x3	1	1200	1200	0	0	100	1.00
1x4	1	1200	1200	0	0	100	1.00
21	1	1200	1200	0	0	100	1.00
23	1	1200	1200	0	0	100	1.00
25	1	1200	1200	0	0	100	1.00
27	1	1200	1200	0	0	100	1.00
2x1	1	1200	1200	0	0	100	1.00
2x2	1	1200	1200	0	0	100	1.00
2x3	1	1200	1200	0	0	100	1.00
2x4	1	1200	1200	0	0	100	1.00
3	1	1200	1200	0	0	100	1.00
31	1	1200	1200	0	0	100	1.00
33	1	1200	1200	0	0	100	1.00
35	1	1200	1200	0	0	100	1.00
37	1	1200	1200	0	0	100	1.00
3x1	1	1200	1200	0	0	100	1.00
3x2	1	1200	1200	0	0	100	1.00
3x3	1	1200	1200	0	0	100	1.00
3x4	1	1200	1200	0	0	100	1.00
5	1	1200	1200	0	0	100	1.00
7	1	1200	1200	0	0	100	1.00
x1	1	1200	1200	0	0	100	1.00
x2	1	1200	1200	0	0	100	1.00
x3	1	1200	1200	0	0	100	1.00
x4	1	1200	1200	0	0	100	1.00

Sources - default sources for entries

Arm	Traffic Stream	Normal Cruise Time (seconds)	Normal Cruise Speed (kph)	Bus Free Running Speed (kph)	Tram Free Running Speed (kph)
1	1	6.55	55.00	Buses Not Permittted	Trams Not Permitted
3	1	6.55	55.00	Buses Not Permittted	Trams Not Permitted
7	1	6.55	55.00	Buses Not Permittted	Trams Not Permitted
13	1	6.55	55.00	Buses Not Permittted	Trams Not Permitted
17	1	6.55	55.00	Buses Not Permittted	Trams Not Permitted
23	1	6.55	55.00	Buses Not Permittted	Trams Not Permitted
27	1	6.55	55.00	Buses Not Permittted	Trams Not Permitted
33	1	6.55	55.00	Buses Not Permittted	Trams Not Permitted
35	1	6.55	55.00	Buses Not Permittted	Trams Not Permitted
37	1	6.55	55.00	Buses Not Permittted	Trams Not Permitted

Sources - sources for internals

Arm	Traffic Stream	Source	Source Type	Source Link	Source Traffic Stream	Source Total Flow (PCU/hr)	Source Normal Flow (PCU/hr)	Source Bus Flow (PCU/hr)	Source Tram Flow (PCU/hr)	Normal Cruise Time (seconds)	Normal Cruise Speed (kph)	Bus Free Running Speed (kph)	Tram Free Running Speed (kph)
11	1	1	TrafficStream	N/A	x3/1	0	0	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
15	1	1	TrafficStream	N/A	2x1/1	0	0	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
1x1	1	1	TrafficStream	N/A	15/1	600	600	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
1x1	1	2	TrafficStream	N/A	17/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
1x1	1	3	TrafficStream	N/A	13/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
1x2	1	1	TrafficStream	N/A	11/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
1x2	1	2	TrafficStream	N/A	15/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
1x2	1	3	TrafficStream	N/A	17/1	600	600	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
1x3	1	1	TrafficStream	N/A	11/1	600	600	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
1x3	1	2	TrafficStream	N/A	13/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
1x3	1	3	TrafficStream	N/A	17/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not

													Permitted
1x4	**1**	**1**	TrafficStream	N/A	13/1	600	600	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
1x4	**1**	**2**	TrafficStream	N/A	15/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
1x4	**1**	**3**	TrafficStream	N/A	11/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
21	**1**	**1**	TrafficStream	N/A	1x3/1	0	0	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
25	**1**	**1**	TrafficStream	N/A	3x1/1	0	0	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
2x1	**1**	**1**	TrafficStream	N/A	25/1	600	600	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
2x1	**1**	**2**	TrafficStream	N/A	27/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
2x1	**1**	**3**	TrafficStream	N/A	23/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
2x2	**1**	**1**	TrafficStream	N/A	21/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
2x2	**1**	**2**	TrafficStream	N/A	25/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
2x2	**1**	**3**	TrafficStream	N/A	27/1	600	600	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
2x3	**1**	**1**	TrafficStream	N/A	21/1	600	600	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
2x3	**1**	**2**	TrafficStream	N/A	23/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
2x3	**1**	**3**	TrafficStream	N/A	27/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
2x4	**1**	**1**	TrafficStream	N/A	23/1	600	600	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
2x4	**1**	**2**	TrafficStream	N/A	25/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
2x4	**1**	**3**	TrafficStream	N/A	21/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
31	**1**	**1**	TrafficStream	N/A	2x3/1	0	0	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
3x1	**1**	**1**	TrafficStream	N/A	35/1	600	600	0	0	6.55	55.00	Buses Not	Trams

												Permittted	Not Permitted
3x1	**1**	**2**	TrafficStream	N/A	37/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
3x1	**1**	**3**	TrafficStream	N/A	33/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
3x2	**1**	**1**	TrafficStream	N/A	31/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
3x2	**1**	**2**	TrafficStream	N/A	35/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
3x2	**1**	**3**	TrafficStream	N/A	37/1	600	600	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
3x3	**1**	**1**	TrafficStream	N/A	31/1	600	600	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
3x3	**1**	**2**	TrafficStream	N/A	33/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
3x3	**1**	**3**	TrafficStream	N/A	37/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
3x4	**1**	**1**	TrafficStream	N/A	33/1	600	600	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
3x4	**1**	**2**	TrafficStream	N/A	35/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
3x4	**1**	**3**	TrafficStream	N/A	31/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
5	**1**	**1**	TrafficStream	N/A	1x1/1	0	0	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
x1	**1**	**1**	TrafficStream	N/A	5/1	600	600	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
x1	**1**	**2**	TrafficStream	N/A	7/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
x1	**1**	**3**	TrafficStream	N/A	3/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
x2	**1**	**1**	TrafficStream	N/A	1/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
x2	**1**	**2**	TrafficStream	N/A	5/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
x2	**1**	**3**	TrafficStream	N/A	7/1	600	600	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted

x3	**1**	**1**	TrafficStream	N/A	1/1	600	600	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
x3	**1**	**2**	TrafficStream	N/A	3/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
x3	**1**	**3**	TrafficStream	N/A	7/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
x4	**1**	**1**	TrafficStream	N/A	3/1	600	600	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
x4	**1**	**2**	TrafficStream	N/A	5/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted
x4	**1**	**3**	TrafficStream	N/A	1/1	300	300	0	0	6.55	55.00	Buses Not Permittted	Trams Not Permitted

Signal Timings

90s cycle time; 90 steps

Controller Stream

Controller Stream	ID	Name	Description	Gaining Delay Type	Signals Manipulation Mode	Multiple Cycling	Offset Relative To	Offset Valid	Offset Positive (s)	Offset Negative (s)	Auto Redistribute	Optimisation Level	Use Sequence
1	1	(untitled)		Absolute	StageBased	Single	1	True	0	0	True	Offsets And Green Splits	1
11	11	(untitled)		Absolute	StageBased	Single	1	True	11	-79	True	Offsets And Green Splits	1
21	21	(untitled)		Absolute	StageBased	Single	1	True	89	-1	True	Offsets And Green Splits	1
31	31	(untitled)		Absolute	StageBased	Single	1	True	11	-79	True	Offsets And Green Splits	1

Phases

Controller Stream	Phase	ID	Name	Minimum Green (s)	Maximum Green (s)	Relative Start Displacement (s)	Relative End Displacement (s)	Dummy
1	**A**	A	(untitled)	7	300	0	0	False
1	**B**	B	(untitled)	7	300	0	0	False
1	**C**	C	(untitled)	7	300	0	0	False
1	**D**	D	(untitled)	7	300	0	0	False
11	**A**	A	(untitled)	7	300	0	0	False
11	**B**	B	(untitled)	7	300	0	0	False

11	**C**	C	(untitled)	7	300	0	0	False
11	**D**	D	(untitled)	7	300	0	0	False
21	**A**	A	(untitled)	7	300	0	0	False
21	**B**	B	(untitled)	7	300	0	0	False
21	**C**	C	(untitled)	7	300	0	0	False
21	**D**	D	(untitled)	7	300	0	0	False
31	**A**	A	(untitled)	7	300	0	0	False
31	**B**	B	(untitled)	7	300	0	0	False
31	**C**	C	(untitled)	7	300	0	0	False
31	**D**	D	(untitled)	7	300	0	0	False

Resultant Stages

Controller Stream	Stage	Is Base Stage	Library Stage ID	Phases In This Stage	Stage Start (s)	Stage End (s)	Stage Duration (s)	User Stage Minimum (s)	Stage Minimum (s)
1	**1**	True	1	A	88	16	18	1	7
1	**2**	True	3	C	21	38	17	1	7
1	**3**	True	2	B	43	61	18	1	7
1	**4**	True	4	D	66	83	17	1	7
11	**1**	True	1	A	9	27	18	1	7
11	**2**	True	3	C	32	49	17	1	7
11	**3**	True	2	B	54	71	17	1	7
11	**4**	True	4	D	76	4	18	1	7
21	**1**	True	1	A	87	13	16	1	7
21	**2**	True	3	C	18	36	18	1	7
21	**3**	True	2	B	41	60	19	1	7
21	**4**	True	4	D	65	82	17	1	7
31	**1**	True	1	A	9	27	18	1	7
31	**2**	True	3	C	32	49	17	1	7
31	**3**	True	2	B	54	72	18	1	7
31	**4**	True	4	D	77	4	17	1	7

Resultant Phase Green Periods

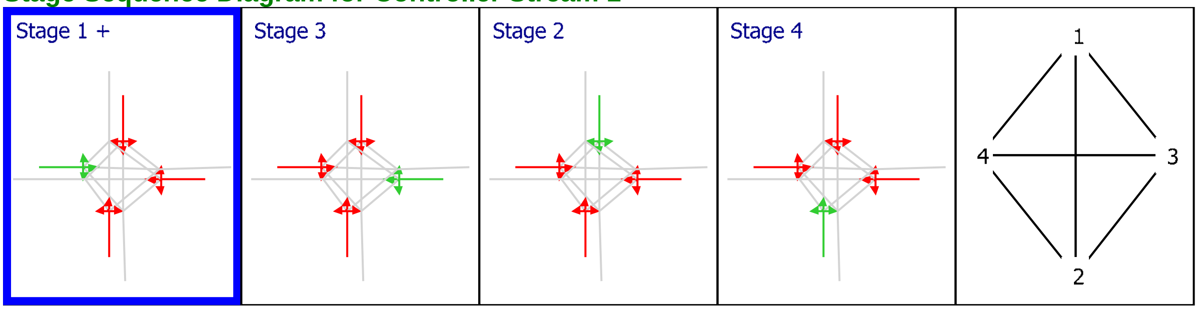
Controller Stream	Phase	Green Period	Is Base Green Period	Start Time (s)	End Time (s)	Duration (s)
1	**A**	**1**	True	88	16	18
1	**B**	**1**	True	43	61	18
1	**C**	**1**	True	21	38	17
1	**D**	**1**	True	66	83	17
11	**A**	**1**	True	9	27	18
11	**B**	**1**	True	54	71	17
11	**C**	**1**	True	32	49	17
11	**D**	**1**	True	76	4	18
21	**A**	**1**	True	87	13	16
21	**B**	**1**	True	41	60	19
21	**C**	**1**	True	18	36	18

21	**D**	**1**	True	65	82	17
31	**A**	**1**	True	9	27	18
31	**B**	**1**	True	54	72	18
31	**C**	**1**	True	32	49	17
31	**D**	**1**	True	77	4	17

Intergreen Matrix for Controller Stream 1

	To				
		A	B	C	D
From	A	-	5	5	5
	B	5	-	5	5
	C	5	5	-	5
	D	5	5	5	-

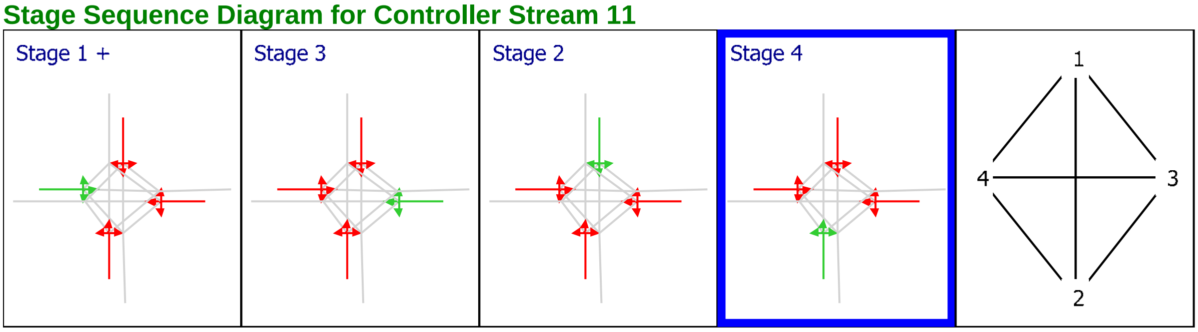
Stage Sequence Diagram for Controller Stream 1



Intergreen Matrix for Controller Stream 11

	To				
		A	B	C	D
From	A	-	5	5	5
	B	5	-	5	5
	C	5	5	-	5
	D	5	5	5	-

Stage Sequence Diagram for Controller Stream 11

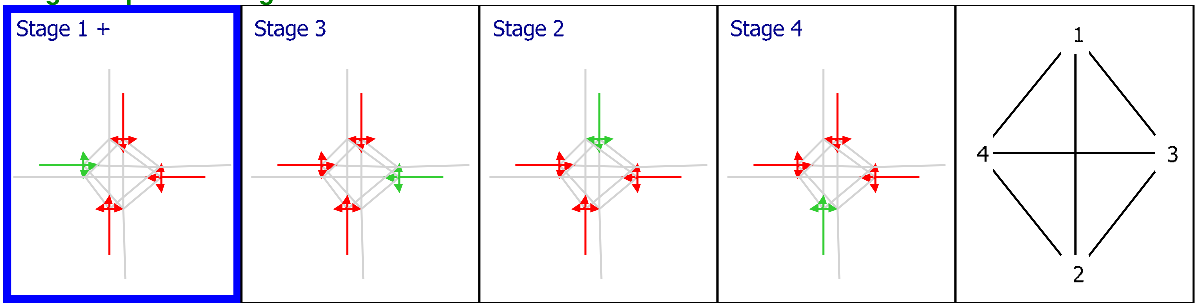


Intergreen Matrix for Controller Stream 21

	To				
From		A	B	C	D
	A	-	5	5	5
	B	5	-	5	5
	C	5	5	-	5

	D	5	5	5	-

Stage Sequence Diagram for Controller Stream 21



Intergreen Matrix for Controller Stream 31

		To			
		A	**B**	**C**	**D**
From	**A**	-	5	5	5
	B	5	-	5	5
	C	5	5	-	5
	D	5	5	5	-

Phase Timings Diagram for Controller Stream 31