Options to Improve Visual Amenity of Electrification

Phase 1 Output Report – Preliminary Review of Options

W1001K-BBR-REP-EOH-000001-A01

Balfour Beatty Rail

Contents

Introduction

Network Rail are modernising the Great Western route, which runs from London Paddington to Bristol, Cardiff and Swansea. The route is being electrified as part of this modernisation programme.

The route passes through several sections of countryside that have been designated as Areas of Outstanding Natural Beauty (AONB). This report documents the output from Phase 1 of a study that has been commissioned to review options to improve the visual amenity of the OLE through these sections of the route.

This phase was designed to capture and explore as many ideas as possible. In reviewing the options filters such as technical requirements were used to rule out ideas that were not suitable to take forward. A benefit of this approach is that more time and effort can be focused on the concepts that can developed, in the following phases.

The following phases including a LVIA will develop options further.

Executive Summary

Network Rail is installing overhead line electrification (OLE) to the existing rail route from Paddington to Bristol, Cardiff and Swansea as part of the Great Western Electrification Programme (GWEP). Balfour Beatty Rail has been commissioned to review options to improve the visual amenity of the OLE through Areas of Outstanding Natural Beauty (AONB).

Option Generation

The initial part of this review was an options generation workshop that was held on 23rd – 24th February 2016. This workshop generated 79 different potential options. These were generated against the following four categorisations:

- Modification (changes to structure spacing, size, or relative horizontal and vertical aspects);
- Stealth (changes to the shape or material used);
- Screening (hiding the structure); and
- "Blue sky" (including removal of part or all of the overhead system).

An initial high-level filter was undertaken that considered each of these options against criteria based on functional performance, safety and time to implement based criteria. This review filtered out 35 of the original 79 options as they did not provide solutions that would meet these critical requirements.

Initial Assessment

Each option passing through the filter was then the subject of an initial assessment. This considered the potential visual improvement and impact of implementing each option. The result of this assessment was the identification of 11 main options (plus further associated sub options) that it is proposed to take into Phase 2 for further assessment.

The options identified to develop further include:

- Modification and/or complete replacement of the standard OLE structures;
- Painting; and
- Use of green bridges.

In addition, a further 11 options were identified that included some form of landscape mitigation and may be suitable solutions for specific locations. It is proposed that these are considered as complementary solutions that will be reviewed once the context of the landscape has been better understood via a Landscape and Visual Impact Assessment (LVIA).

Next Steps

The next phase of work will comprise the following activities:

- Basic visualisations of the structural options are being developed.
- Engineering review of the structural options being progressed.
- LVIA of the section of route potentially affecting Chilterns & North Wessex Downs AONBs in consultation with Natural England and the conservation boards.

1. Introduction

The Great Western Electrification Programme (GWEP) currently being undertaken by Network Rail includes the installation of 25kV AC Overhead Line Electrification (OLE) through several Areas of Outstanding Natural Beauty (AONB). GWEP is using the recently developed Furrer and Frey "Series 1" electrification system. This section sets out the background to the study that has been commissioned to review the potential options to improve the visual amenity of the OLE through these AONBs.

1.1 Background

The AONBs being considered as part of this review are:

- Chilterns AONB & North Wessex Downs AONB;
- Cotswold AONB.

The specific sections of the route are:

- Four-track "Goring Gap" section from Tilehurst to Moreton Cutting (41m 27ch to 51m 77ch on MLN1)
- Two-track section from Alderton Tunnel to Chipping Sodbury Tunnel (97m 57ch to 101m 06ch on SWB)
- Two-track section from Box Tunnel to Batheaston (100m 78ch to 103m 62ch on MLN1)

The section of the route through the Chilterns AONB & North Wessex Downs AONBs (the "Goring Gap") includes the following listed structures for which specific approvals have already been sought for the proposed electrification system design:

- Gatehampton Viaduct (44m 00ch on MLN1);
- Moulsford Viaduct (47m 27ch on MLN1).

Due to the programme's critical path (associated with the testing of new trains), electrification equipment has already been designed and is being installed along the section of line through the Chilterns AONB & North Wessex Downs AONBs. This is not being considered as a constraint to the potential options being considered by the study.

1.2 Review Process

The review process to identify potential options consists of three phases:

Phase 1: Workshop, generation of potential options and initial assessment

Phase 2: Further refinement, predominantly development of visual images and technical review

Phase 3: Further development of visual images (set in context of landscape) plus assessment of Whole Life Cost of the system, delivery programme and feasibility of construction staging.

The planned LVIA will inform the phase 2 and 3 outputs. Network Rail are engaging with the AONBs through an advisory group and their comments shall influence on-going work.

Through each of these phases it is anticipated that the number of options under consideration will reduce, resulting in a small number of viable options at the end of Phase 3.

1.3 Functional Requirements

The project has a set of functional requirements. The identified options are assessed as part of each phase to ensure that the solutions that are progressed can meet these requirements. The functional requirements include compliance with:

- Standards - EU legislation Technical Specification for Interoperability (TSI) and Railway Group Standards;
- Department for Transport (DfT) rolling stock strategy (i.e. need to be able to run IEP & EMU trains on specified dates);
- 140 mph linespeed;
- Sectional running times;
- Gauging;
- Route availability; plus
- Performance and reliability.

Other factors that have been included in assessing the options are:

- Access requirements to install and maintain the equipment;
- Safety; and
- Timescale for design, development and installation.

Whole life cost and other costs were excluded from the initial assessment. This was to ensure that no options were ruled out on the grounds of cost during the Phase 1 assessment. However whole life cost will be a consideration as the potential options are developed through the later phases of the study.

.

2. Phase 1 Methodology

The following section outlines the methodology adopted for Phase 1 of the study. This was based on a two-day workshop with potential solutions being developed on the first day and an initial assessment against the predetermined criteria being undertaken on the second day.

2.1 Phase 1 Workshop Attendees

A two-day workshop was held on 23rd and 24th February. The first day was attended by twenty two people, including six from Network Rail (NR), with differing backgrounds. Nine people attended the second day of the workshop.

The list of attendees present for the first day, at which the list of potential solutions was identified, was selected to provide a mix of people with a wide range of experience. This included people with relevant experience from outside the rail environment.

The skill-sets present included:

- OLE designer;
- Railway system engineering;
- Railway infrastructure maintenance;
- Innovative thinkers;
- Architecture;
- Landscape consultants; and
- Structure masking specialists.

Network Rail's Head of Consents plus the Sponsor for the Great Western Electrification Programme were also in attendance to demonstrate Network Rail's full commitment to this process. They also assisted in providing an overview of the study.

The group in attendance for the second day of the workshop, when the potential options were assessed against the agreed criteria using a standard assessment template, was a sub-set of those in attendance during the first day. The same range of experience and skill-sets was present on the second day.

An observer from Network Rail's Midland Main Line programme was also in attendance throughout the workshop to support the process of transferring the experience being gained by GWEP to other NR electrification programmes.

2.2 Baseline

The options for improving the visual amenity were assessed relative to a baseline of the Furrer and Frey "Series 1" system design for a four-track railway, i.e. the scenario for the "Goring Gap" section of the route including portal structures.

Whilst meeting engineering efficiency objectives, a number of aspects of this system design were identified that increase its visual intrusion into the landscape:

- Fresh galvanised surfaces contribute to the long range visibility of the structures;
- 600mm deep open lattice structure of the boom and cantilever were not seen as succeeding in reducing the visual intrusion because the vertical plates are very visible and catch the eye;
- Having all the masts extending high above the position of the aerial auto-transformer feed (ATF) increases the visual intrusion for no obvious purpose (to the onlooker) and gives the impression of a succession of rugby goal posts;

- Lack of clean lines free of the "clutter" associated with the sub-assemblies to hold the contact wire in the correct design position;
- From the visual viewpoint, the evident functionality was seen to hinder rather than compensate for the appearance.

The Furrer and Frey "Series 1" system design meets the functional requirements. As the visual improvement scores are relative to this option as a baseline, it has been given a score of **0**.

2.3 Day 1: Generation of Options

The aim of the first day was to understand the brief and generate potential options to minimise the visual impact of electrification through AONBs. This was undertaken without setting constraints in order to include all potential solutions.

The slide-pack used to brief the group prior to the option generation session is included as **Appendix 1** of this report for information. The presentation includes the names of the attendees. The briefing provided a general background and set the context in terms of the equipment that has already been installed.

The attendees were split into four groups. Each group had a mix of the skill-sets. Following the briefing presentation, the day was structured around a sequence of generic categories of potential changes to the electrification system. These categories were:

- **Modification** (changes to structure spacing, weight, size, or relative horizontal and vertical aspects);
- **Stealth** (changes to the shape or material used);
- **Screening** (hiding the structure); and
- **"Blue sky"** (removing part or all of the overhead system).

The groups all considered each category individually and then reported back the options that they had generated. Further options and clarifications emerged during the reporting back sessions.

There was some commonality of ideas between groups as would be expected, but there were also some ideas unique to each particular group. In total, 79 different options were generated and captured. **Appendix 2** provides a list of the potential options that were generated.

2.4 Day 2: Assessment of Options

In advance of the workshop, a set of assessment criteria were developed that were based on the functional requirements. These are set out in the introduction above (section 1.3).

An assessment template was developed that incorporated a two-stage approach. The first stage for each option was a filter to determine if the option obviously failed to:

- Meet the overall functional requirements;
- Improve the visual amenity;
- Be safe to install or operate;
- Avoid having a major negative environmental impact during construction; or
- Provide early benefit due to the significant amount of time required to develop and/or install (thus leaving the existing structures in place).

This first stage filter was a go/no go decision. Options were dropped out of the assessment process if they failed to meet any of these critical criteria.

The second stage, which was applied to all the options that passed through this filter, applied an initial ranking. This ranking was based on an assessment of the potential visual improvement of each option and the potential impact factors of implementing each option. The ranking was measured relative to the "do nothing" option of the baseline: the Furrer and Frey "Series 1" system design. This ranking was used to prioritise the options and identify those that should be progressed further.

An assessment sheet was completed for each option. The assessment template used is provided in **Appendix 3.**

.

3. Assessment Output

The following section provides an overview of the output from the two-day workshop. It briefly describes the main options that were identified at the workshop that will be taken forward to Phase 2 of the study.

3.1 Introduction

The potential options that were developed during the workshop were based on the objective of improving the visual amenity relative to the baseline of Series 1. The option references are indicated in brackets.

It should be noted that the visual impact assessments were made with the context of being relatively close to the structures. As such the potential improvement from more distant views is likely to be overstated. The relative effect of distance and context of views will be reviewed in later stages of the study.

In assessing the visual impact of options, in general the workshop did not have drawings or visualisations to go on, just outline sketches and descriptions from the group(s) that identified the option. This meant that a degree of interpretation was required in order to assess the merits of the option. Diagrams have been drawn post-workshop to aid this report and are presented in **Appendix 5**.

The following sections briefly consider:

- Removal of the aerial ATF;
- Challenge electrical clearances;
- Classic lattice boom/cantilevers;
- Braced structure;
- Section with improved aesthetic shape;
- Classic headspan design;
- Alternative headspan designs;
- Alternative system designs
- Colour and surface finish;
- Green bridges;
- Landscape mitigation;
- Blue sky solutions.

3.2 Removal of the Aerial ATF

Removal of the aerial ATF from the masts of Series 1 to at or below the ground (and hence shortening the masts) scored **30**. The removal of the aerial ATF is also a sub-option providing further benefit that could be included with many of the other identified options.

However it was noted that shortening of the masts could also be achieved with the ATF kept at a high level. An example of this is the proposed design for the Moulsford viaduct.

The additional height of the masts along the entire length of the “Goring Gap” section may be because some masts are required to carry additional, more bulky, equipment associated with the ATF. This may require some of these particular masts to be higher and it seems that all the masts may have been made higher to standardise the design. Shortening most (or all) of the masts is a “quick win” in reducing the visual impact.

However it should be noted that the Autotransformer System is a significant development in the way that power is supplied from the National Grid via feeder substations to the line. The Traditional system requires booster transformers on the masts every 3-8 km along the line. This can be a significant intrusion in the landscape. The Autotransformer System removes the need for these boosters and reduces the number of feeder substations required. The extra voltage, using the Autotransformer System thus reduces the number of feeder stations required. For example, electricity to the Great Western Main Line will be fed from only four feeder stations. Reducing the number of feeder stations. The impact of electrification on the landscape is therefore reduced because fewer components, buildings and wires are required.

3.3 Electrical Clearances

The extensive removal of lineside vegetation in order to achieve the necessary electrical clearances is seen as one of the causes of high visual intrusion from the electrification programme.

One option identified was to review and challenge **the electrical clearances** to see if the structures and /or extent of lineside devegetation can be reduced. The removal of the aerial ATF will also reduce the extent of the devegetation required.

This will be considered further as part of the engineering review in the next phase.

3.4 Lattice Booms and Cantilevers

As open lattice structures, the Series 1 booms and cantilevers might have been expected to be less visible than they are. The workshop considered that a lattice construction could be less visible (from afar) if it employed the more traditional tracery of thin diagonal rods linking the corner members to carry shear and torsion. **Traditional Lattice Boom/Cantilever (SL1)** scored **30**.

The Series 1 lattice form has been designed for its structural purpose. There is a clear challenge in seeking less visible alternatives, with reduced depth booms, that retain the required structural strength.

3.5 Braced Structure

Reduction of boom/cantilever section size by use of **Braced Structure (N109)** was assessed. This is used to a small extent in the viaduct portal design and could have a marked benefit on a long cantilever. Bracing to reduce sections (as an incremental improvement) scored **30**.

3.6 Improved Aesthetic Shape

Beautiful Sections (AS1) were also postulated and assessed. For example, where structural sections are required to have greater strength/stiffness horizontally and torsionally than vertically (as in an anchorage or possibly “rigid headspan”), a bespoke non-circular hollow “wing” section of depth say 200mm and width say 600mm might be used which is less visible (from front or rear) and perceived as more beautiful than the equivalent circular section. Visual improvement score **60**, increasing to **70** with the aerial ATF removed **(AS2)**.

The use of **Radiused (PSC)** corners on the portals was seen as a method of “beautifying” the design and reducing the visual intrusion. This was assessed as raising the portal score to **60**.

3.7 Classic Headspan Design

In terms of low visibility, the existing **Standard Headspan (N108)** design (consisting mainly of tensioned wires) is of high merit and therefore represents an improvement visually relative to Series 1.

However, this type of design introduces significant functional reliability issues. As such, the standard headspan may not be a serious candidate for a 140mph railway with trains using multiple pantographs with a higher tension in the OLE wire than the classic UK systems.

The headspan represents an “invisibility” target which effectively calibrates the upper region of the visual score. It was assessed to have a visual improvement score of **70**. This score was no greater because this solution needs higher masts than portals or cantilevers.

3.8 Alternative Headspan Designs

Two potential non-standard headspan options were identified in an attempt to harvest the visual performance of the headspan whilst achieving the required reliability performance. The first is a **Mix of Headspans and Portals/Cantilevers (A106)** (non-anchorage) in various proportions along the track to dilute the visual impact of the portals: score **35**.

The second option is a concept that was developed during the workshop: a **Rigid Headspan (G416)**. The idea is that the system contains a hybrid of wires and rigid members to stabilise the geometry in the event of a wire break. This scored **70** with an aerial ATF, increasing to **75** with the aerial ATF removed **(G416b)**.

The rigid headspan was only a conceptual idea at the time of the workshop and there was no detail developed as to the actual design configuration. The design concepts, as identified during and immediately post-workshop, are set out below.

A standard headspan uses a set of transverse wires ranged between the masts to support the OLE: the wires are tensioned and adjusted such that the correct geometry vertically and transversely is obtained for all tracks with the system in equilibrium. If a contact wire breaks then the equilibrium is affected and the geometry of the other contact wires is disturbed. For a four-track railway, the other three lines will be affected.

The idea of the Rigid Headspan is to include some rigid sections into the arrangement to stiffen it in the event of contact wire breakage.

At least three ways have been envisaged to implement this:

1. Use a slender boom (from mast to mast) in conjunction with the tension wires to provide stiffness.
2. Incorporate slender cantilevers from the masts that are stiffened by tensioned wires. The concept is that equilibrium can be achieved without the wires or boom spanning from mast to mast: by design there is a break in the middle and the geometry of one side is unaffected by the behaviour at the other side. Higher masts are required.
3. A slender boom is carried on a robust central mast creating two cantilevers and structurally isolating one side from the other. The cantilevers are stiffened by tensioned wires from unobtrusive extensions to the mast.

3.9 Alternative System Designs

Review of the system designs proposed for use elsewhere on the route identified options that would be less visually obtrusive and may be suitable for use in the Goring Gap. Their technical suitability will need to be confirmed during phase 2 of the study.

The designs for the **Moulsford Viaduct Portal (VP)** and **Back to Back TTC (VTTC)** structures are available as assembly drawings and were assessed accordingly by the workshop. Constructed from slim tubular sections (356 mm diameter) with clean lines free of the clutter associated with ease of assembly, and lacking flat surfaces that uniformly reflect light, the workshop subjectively scored these visually better than Series 1 considering them less visible (from afar) and more beautiful.

Use of the **Moulsford TTC** structure was also considered for twin track applications **(VTTC2)**. Visual improvement scores: portal **50**, back to back TTC **60,** TTC **60**.

3.10 Colour and Surface Finishes

A number of options based on colour and surface finish were assessed.

Generally, it was considered that natural or induced ageing/darkening was beneficial, and that flat painted colour could not address all views/backgrounds. In some applications a graduated light/dark finish could help, and in the specific case of the "wing" a dark top surface and light underside could provide stealth to help hide the structure when viewed from afar.

3.12 Landscape Based Mitigation

Eleven options were identified that included some form of landscape mitigation. These may be used in isolation or as a combination of solutions. They may also be used on their own or in combination with other changes to the structures.

Until a full assessment has been undertaken on the impact on the landscapes and the locations and viewpoints of the sensitive receptors, it will not be possible to evaluate their potential use.

As such, these are to be considered as complementary solutions that will be reviewed once the context of the landscape is understood. This will be achieved by undertaking a Landscape and Visual Impact Assessment (LVIA).

3.11 Green Bridges

One specific option identified was the use of green bridges to mask the visual intrusion at specific locations. As with the other landscape based options, the potential of this as a solution will be considered once the LVIA exercise has been completed.

3.13 Blue Sky Options

A number of blue sky options were identified. These ranged from alternative track alignments through to overhead systems that "disappeared" when not in use. However, most of these failed to pass the first stage filter.

The workshop identified the possibility of a railway OLE structure that makes a statement, and hence benefits from being visible rather than invisible. While the workshop endorsed the need to include aesthetics as an essential design consideration, it did not consider that the OLE in AONBs should be a candidate for a significant visual statement.

3.14 Summary

In total, 35 of the 79 identified options failed to pass the first stage filter of the assessment. The second-stage ranking of the remaining options identified 11 prioritised options that are to be progressed through for further assessment. The options to be progressed include painting, green bridges and modification and/or complete replacement of the standard Series 1 OLE system.

In addition, a further 11 landscape based options were identified for further consideration following completion of the LVIA exercise.

A summary of the results of the workshop are tabulated in **Appendix 4**. **Appendix 5** provides a list of those options that is proposed to take forward, together with a photo or sketch depicting the concept.

An assessment sheet has been completed for each identified option. Where the options have been rejected, the summary table indicates the headline reason for rejection (**Appendix 4**). There is further description within each assessment sheet and these are provided in **Appendix 6**.

.

4. Next Steps

Phase 1 of this study has identified 79 potential options. An initial assessment of these has reduced this to a group of 11 options that will be progressed into phase 2 for further technical evaluation.

A more detailed assessment of the remaining options will be undertaken during the next phase. This assessment will focus on the technical aspects of the remaining options. In particular, the work undertaken during this phase will consider whether the solution is technically proven and available, or requires further product development work.

The Phase 2 work will also include:

- Checking compliance with legislation and standards, including the TSIs;
- Initial review of any potential reliability and/or performance issues.

Basic visualisations will be developed for each option so that comparisons can be made. It is anticipated that this phase of the assessment study will further reduce the number of structural options under consideration.

Further assessment criteria are to be developed to assess the options during Phase 2. These will take account of both the initial impact of the options as well as the longer term effects, such as operation and maintenance.

In parallel with development and review of these options, a character and sensitivity assessment of the landscape through the Chilterns & North Wessex Downs AONBs is to be undertaken in consultation with Natural England the conservation boards. This will enable an informed selection of complementary options that are suitable for the given landscape to be undertaken.

It is also anticipated that a similar assessment and engagement will be undertaken for sections passing through the Cotswolds AONB, following the progression of the work to the Chilterns & North Wessex Downs AONB areas.

A number of comments have been received from Chilterns AONB and Natural England. Some of these have led to changes to this report. They are included as an appendix for future reference.

Appendices

The following appendices are included in this report.

Appendix	Description
Appendix 1	Workshop briefing Slide Pack
Appendix 2	List of Options Generated
Appendix 3	Phase 1 Assessment Template
Appendix 4	Summary of Assessments
Appendix 5	Summary of Options to Progress (including visual concept)
Appendix 6	Individual Assessment Sheets
Appendix 7	Maps 7a Cotswolds, N Wessex Downs & Chilterns 7b N Wessex Downs & Chilterns 7c Cotswolds
Appendix 8	Log of Issues Raised by Chilterns AONB and Natural England

Andy Clayton
Head of Consultancy Services
E: andy.clayton@bbrail.com
T: +44 (0)1332 225178
M: +44 (0)7967 667562
W: balfourbeatty.com