The Institution of Railway Signal Engineers Inc

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A Review of the Thameslink Programme

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SUMMARY

The aim of this paper is to provide a project description and update to Network Rail's Thameslink Programme in London. It discusses the history behind the programme and key design considerations. The paper then goes on to look at the reasons behind the decision to implement ATO over ETCS Level 2, before explaining some of the supporting projects and work-streams. In order to successfully commission ATO, a migration strategy and comprehensive set of system proving is required; testing activities are discussed in the paper. Finally, examples of best practice and lessons learned are given, before highlighting key considerations to be made by other high capacity infrastructure projects.

1 INTRODUCTION

Opened in 1988, the Thameslink route runs along the North – South plane of London, connecting services through the heart of the city. It currently covers 68 stations and 225km of track, with the majority of services running from Bedford to Brighton via London Bridge. The route serves two airports, London Luton and London Gatwick, as well as King's Cross St Pancras where connections to Eurostar services can be made.

The success of the initial Thameslink route opening resulted in a British Rail proposal in the 1990s for its expansion, upgrading facilities and adding more stations.

Initially billed as "Thameslink 2000", the programme was delayed as a result of public funding inquiries, with funding agreement eventually confirmed in 2007. Following this agreement, the programme was divided into three stages: Key Output 0 (KO0), Key Output 1 (KO1) and Key Output 2 (KO2).

This paper sets out to describe the Thameslink Programme, looking at the technology choices made, giving a current status update and drawing upon some lessons learned to make recommendations for considerations on new high capacity infrastructure proposals.

2 NOTATION

AC: Alternating Current

ATO: Automatic Train Operation

CBTC: Communications Based Train Control

DC: Direct Current

DfT: Department for Transport

ETCS: European Train Control System

ENIF: ETCS National Integration Facility

HCI: High Capacity Infrastructure

ROC: Rail Operating Centre

SRA: Siemens Rail Automation

TMS: Traffic Management System

tph: Trains per hour

3 WHAT IS THAMESLINK?

3.1 Three Stages

KO0 was completed in March 2009 and saw the number of trains per hour (tph) through the core area increase from 8 to 15 in the peak.

KO1 was completed in December 2011, introducing 12 car trains across the whole route, along with an increased capacity to 16tph in the core area at the peak.

KO2 is set to conclude the programme in 2018 with the introduction of 24tph through the core area through the utilisation of Automatic Train Operation (ATO) over European Train Control System (ETCS) Level 2. KO2 includes the remodelling of London Bridge Station, the creation of a grade separated junction at Bermondsey, the opening of Canal Tunnels to link the railway to the East Coast Main Line, and the introduction of 115 purpose built Class 700 trains to the route.

When completed, the extended Thameslink route will serve routes to Bedford, Peterborough and Cambridge in the north, and Brighton, Sutton, Sevenoaks and Maidstone East in the south, as shown in Figure 1.

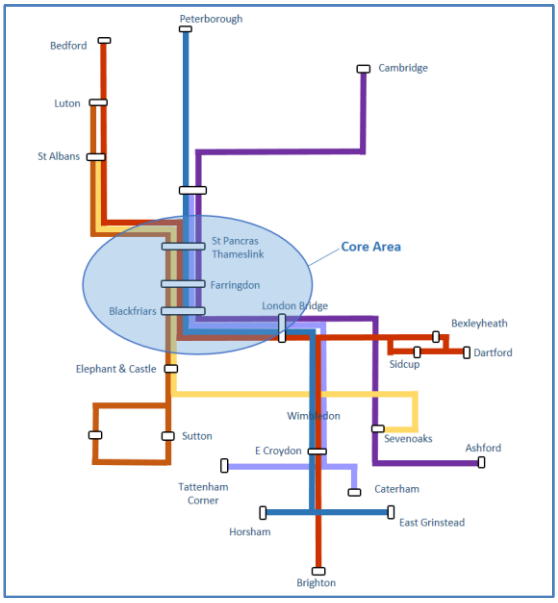

Figure 1 Final 2018 Thameslink implementation

Figure 2 shows the interaction that the Thameslink route will have with Crossrail, highlighting the interchange between the two that will take place at Farringdon station.

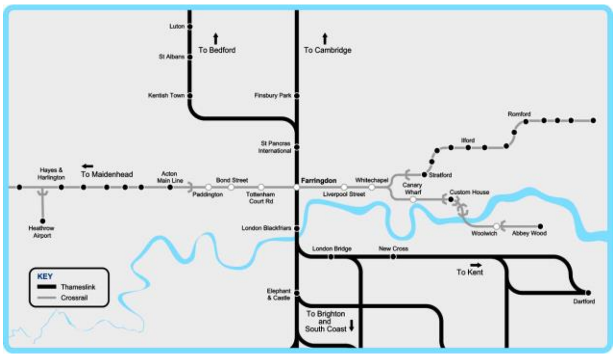

Figure 2 Thameslink and Crossrail routes and interchange

3.2 Key project Drivers

Section 1 discusses the success of the initial Thameslink route, which opened in 1988. This success resulted in the line becoming overcrowded and as a result, the need to increase the capacity of the route arose. Modelling showed that in order to meet high capacity demands, the programme would need to support trains at a frequency of 24tph through the core at peak times, with the ability to run 30tph in short bursts to support perturbation recovery. In order to introduce 24tph operation, ATO would need to be implemented.

In addition, ageing assets needed replacement; instead of renewing these like for like, the capacity upgrade was seen as a good opportunity for the introduction of an upgraded set of assets.

Lastly, the increasing demands of passenger travel in London are such that the entire network (including the tube, overground and buses) is congested and exhausted. The Thameslink Programme, with its proposed metro style operation through the core area and its interconnections with multiple travel modes, will serve to relieve other parts of the overcrowded London network when complete. This, of course, will be supported by the Crossrail project, which will run from west to east London when completed.

3.3 Schedule

The diagram below lays out the key milestones of the programme. The High Capacity Infrastructure implementation of 24tph remains on target for commissioning at the end of 2018.

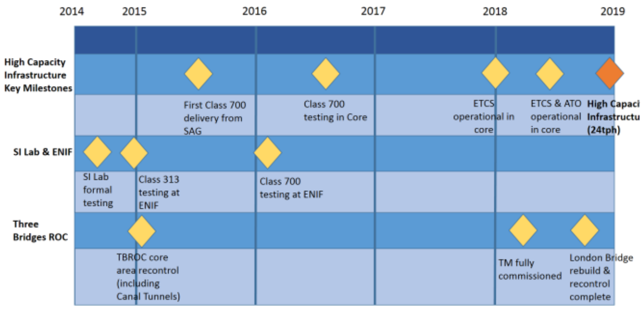

Figure 3 – Thameslink Programme Schedule

4 DESIGN AND TECHNICAL DECISIONS

4.1 Key considerations

The key considerations during the concept design stage largely centred on the restrictive nature of the infrastructure. A metro style of operation is the desired output, however, the stations through the core area are at varying distances, with some very close together.

Alongside this, the stations and platforms present a problem for passenger flow; some stations have a steep gradient on their approach, speeds are restricted to 30 miles per hour through most of the core area and rolling stock is suited to suburban/intercity journeys.

These considerations combined led to a design that would see the majority of the Thameslink route being upgraded in some way, across all asset areas. Whilst the signalling system at the heart of the solution to train capacity was designed, a host of enabling projects were also commissioned. These included a review of traction supplies, rebuilding of stations, introduction of new rolling stock, procurement of a Traffic Management System (TMS), construction of a signalling centre and considerable human factors and wayfinding work.

4.2 Technology choice considerations

As discussed earlier, in order to achieve an output of 24tph, a form of ATO is to be installed in the core area. Whilst publicly the programme is billed as supplying a metro style service through the centre of London, the technology decision was not as simple as opting for the traditional Communications Based Train Control (CBTC) approach that has often been assumed. Instead, an options selection stage was undertaken, where all available technology choices were assessed.

Many variables can affect the ability of a network to run a 24tph service, however, the key technology decision for Thameslink was influenced largely by the ability to signal trains at a high frequency, along with the ability to successfully install a working system whilst keeping the railway operational during the majority of the works.

The use of conventional signalling was ruled out early in the design stage, as it was shown that it cannot support the required capacity of 24tph. This left a choice between CBTC and ETCS, both of which have been shown to deliver the required capacity with ATO.

In order to decide between these two technologies, the main requirements and constraints of the proposed system were considered, along with the way in which the programme would be implemented. The key considerations for the decision making process were:

- Area of operation: 24tph is required through the core area only (Elephant & Castle and London Bridge to Kentish Town), leading to a requirement for services to transition to conventional signalling either side of this section of the route.
- Implementation/migration strategy: due to the nature of the Thameslink route and the sheer number of passengers it carries, closing the railway for the upgrade is not an option. Throughout the life of the programme, there are a number of opportunities to take extended possessions, however, for the most part it should be assumed that the railway will remain operational. It is therefore imperative that the

technology of choice supports a phased introduction to the network in order that there is no risk to the timetabled train service.

- Timescales: the technology of choice must be able to be implemented by the end of 2018
- Level of confidence: due to the high profile route along which the technology will be implemented, it is important that programme risk is kept to a minimum. The level of confidence will be largely gained from using a technology that has already been proven elsewhere.
- Interoperability: the Thameslink route covers a range of infrastructure, technology and rolling stock. Trains that travel through the core area will also have to travel over conventionally signalled routes, transitioning between the two without the need to stop. This means that the system installed needs to be interoperable with adjacent systems and not be limited to a single type of rolling stock; although a decision was taken to procure a single type of rolling stock (see Section 5.1), future network strategies require that the technology choice for Thameslink does not limit the railway to a single choice of rolling stock.
- Wider national (and European) strategy: following the European decision to support and promote ETCS, a view was taken by Network Rail that this would also be its technology of choice. A rollout programme for ETCS was developed by Network Rail; whilst the timescales of the Thameslink Programme required design decisions to be ahead of Network Rail's overall rollout programme, it was still crucial that these were made with whole GB network in mind.

4.3 Technology of Choice

Having considered the points detailed in Section 4.2, a decision was taken to install ATO over ETCS Level 2 through the core area of the Thameslink route. The main reason that this technology was chosen over CBTC was that, theoretically, it supports all of the key points listed; the largest risk with choosing this is that ATO over ETCS Level 2 has only been demonstrated theoretically and not on an operational railway.

ETCS is known to strongly support a staged first implementation, with migration to higher levels being relatively simple compared to other equivalent technology upgrades. In contrast, whilst CBTC has been shown to support ATO in practice, at the time of the technology decision, it did not support some of the other strategic decision points listed in the previous section. These include the ability to migrate to the upgraded system using a staged process, relative ease of supporting mixed rolling stock and interoperability between different signalling systems. At the same time, CBTC does not align with Network Rail's strategy; in fact, Crossrail have had to obtain a derogation in order to be allowed to proceed with the implementation of CBTC and will be expected to implement ETCS Level 3 at such a time it becomes more widely available.

Whilst the on-board equipment required to implement ATO over ETCS Level 2 can be retrofitted, a strategic decision was made by the industry to procure a fleet of new trains especially designed for the Thameslink route. Existing rolling stock for Thameslink is in need of renewal; this, coupled with the extra capacity required on the trains, prompted the industry to recognise the need for a new fleet. More detail of this fleet is given in Section 5.1.

The technology choice of ATO over ETCS Level 2, when implemented, will provide the ability to signal a robust 24tph service through the core area, however, a number of other factors will have to be realised in order to support this capacity. These are discussed in Section 5.

5 SUPPORTING PROJECTS AND WORKSTREAMS

5.1 Procurement of trains

115 new Class 700 trains have been procured by the DfT. Specific to the Thameslink route, these will all be dual voltage Electric Multiple Units in order that they can run across the DC and AC areas of the network. Manufactured by Siemens Germany (SAG), they will support the widely publicised introduction of the Digital Railway.

The new trains will be of fixed formation, with 55 8 car and 60 12 car units being delivered. They will be delivered to the project with ETCS Baseline 3 equipment installed, along with the capability ATO and Driver Advisory Systems (DAS).

Whilst they come equipped ready for the new signalling and traffic management upgrades, the trains have also been designed in order to best support passenger flow, high capacity and overall customer experience. Train doors are wider so that two passengers will be able to board whilst two others are alighting; smart passenger information screens give information not only of upcoming stations, but also of intermodal updates, such as any delays on the London Underground; larger luggage racks have been installed and better placed; aisles between seats have been widened to allow easier passage of customers with luggage or those walking side by side; through corridor connections between cars mean that passengers can walk from one end of the train to the other.

The delivery of the new rolling stock will be one of the first for the GB rail network where trains have been designed with the system as a whole in mind. Not only have they been built to support what would be referred to as traditional technology (signalling) upgrades, but they also look at the complete passenger experience, considering human factors and the ability of the trains to carry the number of passengers enabled by ATO over ETCS Level 2.

Figure 4 shows a photograph of the first Class 700 train that was delivered to Thameslink Programme on 31st July 2015.

Figure 4 Class 700 train

Finally, early driver consultations and cross industry collaboration resulted in a new design of driver cab, with the seat located in the centre as opposed to the more traditional left hand side. Driver representatives were invited to trial different desk layouts and seat types, with human factors engineers being engaged. As a result, the new style of driver cab should be more ergonomic than previous rolling stock and support interactions with the new Driver Machine Interface.

5.2 Train Control Systems

A centralised TMS for the programme has been contracted to Hitachi Rail Europe and is currently in detailed design phase. Due to recent national developments, the agreement of this contract is particularly significant, as the system (due to be commissioned in 2018) will be a leading example for Network Rail.

The Hitachi TMS will support ATO throughout the core area, regulating train movement and communicating via the user defined ETCS Packet 44.

In addition, DAS are being implemented across the route. Throughout the core area (and for its 20 minute sphere of influence), Connected DAS (C-DAS) will be available to the driver should ATO not be available. Further afield, outside the 20 minute sphere, Standalone DAS (S-DAS) will be used.

The link between the TMS and DAS will ensure that any service adjustments will be reflected in the timetable information stored on the DAS server, with trains being given updated information when they are able to receive it.

Much like similar systems implemented with airport stacking management at complex airports such as Heathrow, this staged complexity will ensure that as trains approach the core area, they will have already been managed and scheduled by the signaller so that they approach the most congested sections of the route in an efficient and effective formation.

5.3 Communications Systems

The Thameslink Programme will be relying upon a robust GSM-R network to support the continual operation of ETCS Level 2. If the network fails at any point, the frequency of service will be severely disrupted. In addition, through the tunnelled sections of the network, leaky feeders are being used to ensure consistent coverage.

In order to confirm the correct level of telecoms coverage at all times, the High Capacity Infrastructure team is upgrading the network to a state of dual redundancy, with two Base Stations at each location throughout the route. In addition, the coverage of the network is being measured at different stages throughout the project lifecycle in order to ensure that actual network strengths are as expected after being calculated theoretically.

5.4 Stations

In order to support the upgrades to the network, major remodelling of several London stations was required. Primarily, these upgrades support the expected increase in customer numbers, along with the more streamlined passenger flow that would be needed to compliment the increased train capacity.

Blackfriars station was rebuilt, introducing the first station with platforms spanning the Thames. During this redevelopment, existing structures were used to support the staged building works; the station was divided into two longitudinally, with one half being rebuilt and extended whilst the other remained open to traffic. The roof of the station was built following the completion of the platform level construction, with solar panels installed along its length to reduce station operating costs and lower carbon emissions.

Once the Thameslink Programme is completed, Farringdon station will serve to be the one of the busiest stations in the centre of London, providing an interchange between Thameslink, Crossrail and London Underground services. In order that the station is capable of supporting the challenging customer numbers, the station concourse and ticket hall were remodelled to best allow passenger flow.

Currently, the most significant set of works being carried out are at London Bridge, perhaps the most challenging of all the station works. As part of the project, the whole emphasis of the station is changing, as it will go from having six through and nine terminating platforms, to nine through and six terminating platforms. The works will include the construction of a new section of railway, known as Bermondsey Diver Under. When finished, the station will have a passenger capacity 35% higher than before and will host 16 Thameslink services per hour at the peak.

Figure 5 and Figure 6 show the track layouts of London Bridge station before and after the works have taken place.

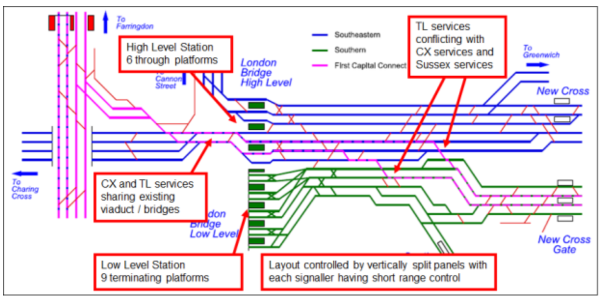

Figure 5 London Bridge starting layout (2012)

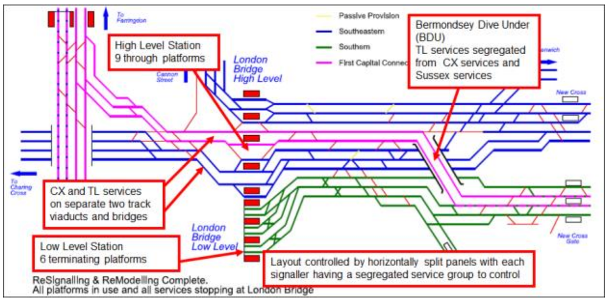

Figure 6 London Bridge finishing layout (2018)

When completed, the remodelled station will change the landscape of London's Southbank, as can be seen in the artist's impression of the station shown in Figure 7.

Figure 7 Completed London Bridge station (artist's impression)

5.5 ROC

In line with Network Rail's national programme, the Thameslink Route will be controlled from a new Rail Operating Centre (ROC) that has been built at Three Bridges.

The Three Bridges ROC is a three storey building with 6,980m^2 floor space. It not only provides space for rail operation, but also training facilities, test facilities and diagnostics.

To date, two signalling panels previously located in West Hampstead and Victoria have been successfully relocated here, along with the newly commissioned Canal Tunnels signalling control. When the programme is complete, the entire Thameslink route will be signalled from desks on one floor of the ROC.

5.6 Human Factors

Alongside technology choice options, human factors engineers have been working to ensure that proposed designs reflect the needs of all user groups, including drivers and customers. Challenging platform dwell times of 45 seconds during times of perturbation recovery are required through the core area. At the same time, they have been working to implement innovative solutions and challenge traditional approaches, such as driver cab layouts and passenger wayfinding.

In addition to the human factors considerations for the Class 700 trains (discussed in Section 5.1), examples of innovation in order to provide a higher level of customer experience include:

- Smart customer information screens that provide a range of data, including destinations and times until next trains (mirroring a metro style operation); stopping stations of most immediate services; formation and layout of the rolling stock that will arrive next, including level access location
- Level access on platforms with centre stopping in order that this will be located at the same spot for each service, regardless of train formation.
- Signage position modelling and review of core area stations, with clearer wayfinding, introduction of markers on platform tiles and better display screen spacing.

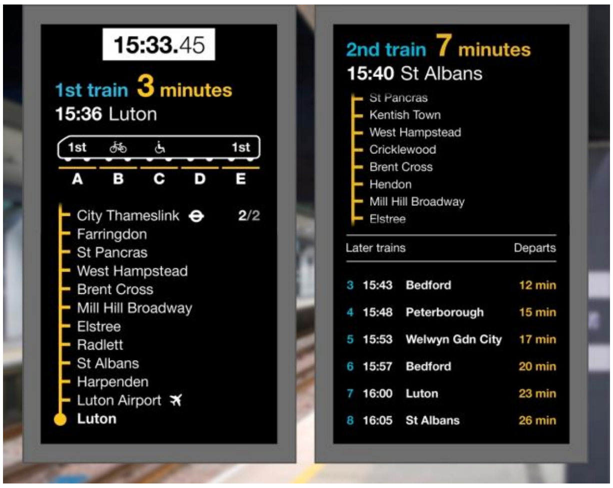

Figure 8 Proposed layout of passenger information boards

For all of the examples given above, in depth modelling and technology trials where required have either been carried out, or are planned to be in the near future.

5.7 Electrification/traction upgrades

The introduction of a more frequent service, in conjunction with a more aggressive driving style, forged the need for a review of the electrification capacity of the route.

The overall Electrification and Plant required an upgrade (due to increased loading and aging infrastructure); one of the most problematic areas was the DC supply south of London. Here, 750V DC third rail supplies traction to the railway and a concern was raised that feeder cables would not support increased loads. Rather than reinforcing the entire route, analysis showed that, due to the cable loading characteristics, only the first and last third of each electrical section needed to be upgraded.

As well as reinforcements to feeder cables, substations also had to be upgraded and in some cases, new substations had to be installed. Perhaps the flagship substation of the project is the 20 Megawatt installation at Ludgate Cellars; one of Europe's largest DC substations, which was designed, built and commissioned in under nine months.

For AC, analysis showed that the northern section of the route needed reinforcing. Here, an Autotransformer system was installed over 20km of the Midland Mainline.

At the time, it was the first installation of its kind on the GB railway.

Lastly, one of the largest logistical challenges regarding power was to tackle the issue of the changeover between DC and AC. Originally, southbound trains that failed to switch from AC to DC would be taken out of service at Farringdon and held at Moorgate to cause minimal disruption to the service. Following closure of the Moorgate branch (a separate workstream of the programme), the catenary was extended to City Thameslink. Failed trains now travel to City Thameslink before returning northbound using a newly installed crossover. Northbound train services now switch from DC to AC at City Thameslink station instead of Farringdon station, again, in order to allow for service recovery in the case of a failed changeover.

6 SYSTEM PROVING

6.1 Early Development

The testing strategy for the High Capacity Infrastructure has a comprehensive, staged approach. The programme has been able to gain lessons learned from the Cambrian early deployment scheme. Following these lessons learned, the first stage of development was to procure an Operational Simulator for use during the early development stages of the operational rules; due to its portability, this simulator was also used to showcase the proposed technology and increase stakeholder engagement.

6.2 Systems Integration laboratory

As the programme progressed, the next stage of testing was to procure a Systems Integration laboratory. Written into the contract for the Class 700 trains was a requirement to provide a set of on-board equipment for testing purposes. This was housed, alongside replica sets of trackside and telecoms equipment, in a laboratory. Siemens Rail Automation (SRA) developed a system that simulated the Thameslink route, timetable and trains, while Giaconda were contracted to produce the driver's view visual representation.

With all the equipment combined, the Thameslink Systems Integration laboratory is able to simulate an environment whereby all real pieces of equipment can be tested and their behaviour recorded as though they are trackside. In addition to testing this equipment, the facility provides a means of stakeholder engagement and driver manager consultation.

The key aim of the Systems Integration laboratory is to test the air gap between supplied systems; whilst the separate pieces of equipment supplied are individually tested by the supplier, the integrated system as a whole is not. The view of the Thameslink Programme was that it would be a major project risk to leave integration testing until equipment had been installed on site, so this intermediate stage of testing was introduced.

Figure 9 Thameslink System Integration Laboratory

Figure 10 Thameslink Systems Integration Laboratory driver's desk

6.3 ETCS National Integration Facility (ENIF)

The final stage of testing before running ETCS trains in the core area is to be carried out at ENIF. This facility was commissioned by Network Rail and consists of a five mile test track and test laboratory for ETCS. The Thameslink Programme has scheduled time to use ENIF for testing purposes with a real test train, a step up from the System Integration laboratory.

6.4 Final testing activities

Lastly, the final system proving tests will be carried out in the core area using first an adapted Class 313 test train and then Class 700 units. It is intended that, due to the robustness of the testing strategy before rolling stock is introduced to the core area, the risks associated with the project are much lower. Not only does this strategy support early testing, it has added safety benefits as there is less need to have staff trackside and has the ability to engage with stakeholders early during the operational rules development.

This ability to simulate and test the majority of scenarios that will occur on the Thameslink route means that a large proportion (estimated at 90%) of the proposed testing, validation and verification will be completed offline.

In addition to the testing simulators discussed above, the programme also procured a Line of Route simulator early on. This simulator mimics the signaller panels for the West Hampstead, Victoria and London Bridge workstations and also served as an early engagement tool for those across the industry. With the ability to load proposed timetables and activate Automatic Route Setting, the Line of Route simulator can practically demonstrate the behaviour of timetabled trains early on, years before the timetable is implemented on the operational railway.

7 FOCUS: AREAS OF BEST PRACTICE AND LESSONS LEARNED

7.1 Migration Strategy

One of the key themes running through the entirety of the Thameslink Programme – its design, technology choice, planning, verification, validation and implementation – is the need to deliver a higher capacity service whilst allowing the operational to remain operational throughout the majority of the works.

In order to ensure the service is maintained and that risk is reduced wherever possible, the programme was developed around the ability to apply a staged migration to the final design. As discussed earlier in Section 4.3, the technology of choice, ETCS, was selected as it allows staged implementation, whilst leaving the option for an upgrade at a later date. With ETCS on Thameslink, trackside equipment can be installed without interfering with the operational railway; to date, the majority of Eurobalises have been installed.

In addition, due to the defined nature of ETCS, the ability to use early deployment schemes (the Cambrian line) and test runs on test tracks (ENIF) as an integral part of the overall system proving activities means that a lesser amount of testing in the actual core area itself needs to be carried out than perhaps would with traditional signalling installations.

7.2 Working as a collaborative team

It is acknowledged that the system being introduced on Thameslink is innovative, complex and different from any other type of project Network Rail is undertaking.

At the start of the High Capacity Infrastructure programme, a decision was taken that Network Rail and SRA would work as a collaborative team, supporting each other with their respective areas of expertise. This collaboration promoted open and honest working, helping to de-risk its delivery.

The collaborative approach between Network Rail and SRA has now developed, with many other contractors working alongside one another in the project office. These additional contractors include employees of Siemens Germany, Hitachi and Lloyds Register. This integrated team approach has been developed in order to present the programme with the best possible support in delivering a High Capacity Infrastructure on time in 2018.

7.3 Early Operational rules development

One of the initial areas of development for the programme was to begin the process of writing and agreeing the operational rules. Traditionally in Network Rail, this is a time consuming task, not only because of the development work that has to be done, but also because peer review and board approval can take a long time.

As soon as work with ETCS and ATO commenced, a team of Operations specialists began consultations with various stakeholders, before designing the operational scenarios. This process was started as early as possible in order that any delays in approval would be minimised.

Due to the early start of this development and the team's regular communications with stakeholders, the operational rules are due to be signed off by the end of 2015. This will end a four year process which consisted of 18 months for the team to write the draft operational scenarios, 12 months for an operational rules specialist to formalise these and 18 months for their approval following their submission to the Network Rail board. Had this process not started as early in the programme as it did, there would have been a much greater risk to the project.

7.4 Early Stakeholder engagement

From an early stage, the Thameslink Programme recognised the need to consult stakeholders and user groups. The function of this approach was multifaceted, in that it not only served to obtain stakeholder buy-in, but it also helped with early development of the operational concept and rules. Additionally, by sharing the proposed implementation with groups across the industry, the programme was able to gain a peer review type approval of the design, again de-risking the implementation by giving the opportunity for feedback.

As discussed in Section 6, some of the obvious tools for engagement are the Operational Simulator and the Systems Integration Laboratory. The Operational Simulator is portable and was taken to various industry expositions, whilst the list of visitors to the Systems Integration Laboratory stretches wide amongst Network Rail, contractors and visitors from overseas. For the Train Operating Companies, some driver representatives were nominated early on in the project and frequently visit the laboratory.

Network Rail has a dedicated presentation area on the ENIF test train. When a visit is made to ENIF, passengers board the Class 313 test train at Kings Cross station and travel to Hertford. During this journey, briefings and presentations are given in a dedicated carriage of the train. This tool has been utilised by the Thameslink Programme in order to educate stakeholders, who are also able to view a project of the Driver Machine Interface whilst the train is in ETCS.

Finally, another key stakeholder group that has been engaged throughout the project is customers at stations. As mentioned in Section 5.4, a number of the major stations in London have been remodelled as part of the Thameslink Programme. A large focus has been given throughout the life of the project to educating passengers and providing warning of any reduced services. This communication has included making suggestions of alternative routes when areas are expected to be busier than usual, providing extra station staff presence following the introduction of new station layouts and distributing information leaflets ahead of any major network closures. Network Rail has not only made use of spare advertising space at stations (e.g. temporary hoardings) to alert customers, but it has also used different forms of media, such as promoting the works using videos published on the Thameslink YouTube channel.

8 CONSIDERATIONS FOR OTHER HIGH CAPACITY RAILWAYS

When upgrading a railway to high capacity (or installing a new build), it is key that the requirements of the upgrade are identified and defined before any concept decisions are made. It is crucial that the motivations behind installing a new signalling system are clear. Generally speaking, the main drivers for a system will be one or more of capacity, safety, running costs, asset condition, operational expenditure savings or high speed (thus introducing the need for in cab signalling).

Once the business need of the system has been clearly identified, the high level design and technology choice can be agreed. Without the project drivers being clear, there is a risk that the wrong technology choice will be made due to a lack of understanding of its implementation need.

For Thameslink, ATO over ETCS Level 2 was selected for a number of reasons, as detailed in Section 4.3. When considering which signalling system is to be implemented, the following should be taken into account:

- Geographical location: for which areas/lines is the upgrade required, and should the upgrade be limited to this area alone?
- Migration plan: will the technology be installed at a greenfield site or a brownfield site; if the latter, will this be required to remain operational during the works?
- Interoperability: what are the interfaces of the system?
- National/state implementation strategies: is there wider plan to implement a certain type of technology and is one system better supported than another?
- Frequency of service: will the technology support the number of trains per hour required
- Complexity of layout and variability of service:
- Maintenance requirements:
- Timescales: how quickly will the technology need to be implemented?
- Level of confidence: has the technology been implemented elsewhere?
- Surrounding infrastructure: aside from the signalling system, will the rest of the railway infrastructure support the upgrade to this technology?
- Rolling stock: how many types of rolling stock (including freight) will the technology be required to support?
- Cost: what are the operational and capital expenditures associated with the technology?

Once the technology of choice has been agreed, it should then be a priority to commence activities such as operational scenario development, stakeholder engagement and maintenance concept definition. The highest risk areas for the project should be identified and mitigation for these progressed as early as possible. In the case of a brownfield installation, it is imperative that a migration strategy for the project is developed, considering each stage of the programme as individual milestones are reached.

9 CONCLUSION

The Thameslink Programme is set to deliver a High Capacity Infrastructure of 24 tph through the core area on London. So far, the programme is on target for completion in 2018 as planned.

Incorporating the use of newly developed technology, pioneering implementation techniques and a robust migration strategy, the programme provides multiple learning opportunities for other high capacity infrastructure installations.

Whilst ATO and ETCS Level 2 sit at the centre of the developments, a number of projects were required in order to enable the increased capacity. These include station upgrades (notably Blackfriars, Farringdon and London Bridge), procurement of a new train fleet, and electrification and telecoms upgrades.

In order to de-risk the implementation of the new system, a comprehensive system proving programme will be completed; testing has already commenced in Systems Integration laboratory and at ENIF. This staged approach to testing supports the need for a robust migration strategy, allowing the railway to remain operational for the majority of the works.

This paper discusses the developments, challenges and experiences so far with the Thameslink Programme, and draws on lessons learned to make recommendations for other high capacity infrastructure projects. It is hoped that the examples of best practice and lessons learned detailed in this paper will serve to support other such challenging and complex installations.

10 References and Acknowledgements

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Georgina Hartwell

An experienced ERTMS engineer, Georgina joined Network Rail Consulting after developing ETCS and ATO as part of the Thameslink Programme in the UK, where she was also involved in some post-implementation development activities on the UK's Cambrian Line ERTMS installation.

During her time with Thameslink, as part of the High Capacity Infrastructure (HCI) team, Georgina developed her ERTMS expertise as Project Engineer for the Thameslink System Integration Laboratory. This facility is a world first in that it combines actual on-board equipment, simulated trackside equipment and Network Rail's GSM-R reference network to simulate the 'real-life' railway system in its entirety.

Georgina has extensive knowledge of the ETCS System Requirements Specifications published by the European Railway Agency, and has managed the engineering installation of equipment from Siemens Germany (SAG), Siemens Rail Automation (formerly Invensys) and Network Rail Telecoms (NRT).

Since moving to Sydney in October 2014, Georgina has been supporting the System Integration activities for TfNSW's Advanced Train Control Systems (ATCS) Program.